National BIM Exchange Standards for Precast Concrete

National BIM Exchange Standards for Precast Concrete

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• Introduction

National BIM Exchange Standards

• History

Development of Precast Modeling Software and Interoperability, Benchmark and Rosewood Experiments, Early IDM Development

• IDM Development

Industry Collaboration, Process Modelling, Detailing Exchange Requirements

• MVD Development

Concepts, Constructs, IFC Mappings, Missing IFC Entities and Relationships

• Conclusions

Where are we? What can be learned for other domains?
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**Scope of Process Phases**

**Program:**
What is the requirement?
*standard requirements definition
process model of exchanges*

**Design:**
How to solve the requirements?
*standard design documents: functional specification of each exchange*

**Construct:**
How to build it?
*verifiable implementation in software;
development of model views for each exchange*

**Deployment:**
Use in Industry
*verifiable BIM data exchange*
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History

2001 Precast Concrete Software Consortium (PCSC) founded
2002 Developed spec for BIM precast fabrication software
2003 PCSC selected Tekla for software product development
2003 Structureworks also undertakes product development
2005 Tekla completed implementation; PCSC disbanded
2006 Charles Pankow Foundation project to assess interoperability in architectural precast
2008 Charles Pankow Foundation funds GA Tech/Technion to develop BIM standard for all precast; PCI BIM advisory committee established

2009 Publication of Precast Concrete National BIM Standard ??
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PCSC 2001-2005

Precast Concrete Functionality in Building Information Modeling Tools
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Rosewood Experiment

Full scale exchange and modeling experiment of architectural precast facades

• Found serious limitations with IFC exchanges

• Found 57% productivity gain for precast fabrication detailing
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Benchmark Experiment

Benchmark model exchange – steel, CIP concrete and precast

- Found serious limitations with IFC exchanges
- Underlined the need for BIM standards
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Precast/Prestressed Concrete Institute (PCI)

BIM Advisory Committee

Chair: Michael W. LaNier, ABAM Engineers

Lee Bailey, Precision Development
Greg Black, Skockey Precast
Edward Davis Chauviere – HKS
Jason Patrick Davis – Gate Precast
Jim Davis – Stresscon
Allen R. Finfrock, Finfrock Industries, Inc.
Aaron W. Fink, Oldcastle Precast Building Systems
David W. Foley, High Concrete Group
Lynn Foster, Mid-States Concrete Industries
Jennifer Huber, EnCon United
Wayne Kassian, Kassian Dyck & Associates
Mark Kraft, The Consulting Engineers Group, Inc.
Karen A. Laptas, Blue Ridge Design, Inc.
Jason P. Lien, EnCon United
Eric Lillie, Unistress Corporation
Dieter W. Maucher, Tindall Corporation

Bob McGee, Coreslab Structures (TEXAS) Inc.
Wayne Norris, Metromont Corporation
David W. Orndorff, The Shockey Precast Group
Monty L. Overstreet
Charles Pool, Tekla, Inc.
Mark Potter, Finfrock Industries, Inc.
Mike Putich, Hanson Structural Precast – Irwindale
A.J. Scarfato, Metromont Corporation
Michael Slobojan, StructureWorks LLC
Michael J. Sloter, IPC, Inc.
Daniel VanWieren, Concrete Vision
Steven Walker, Knife River Corporation
Dr. John Wang, Mid-State Precast, L.P.
Skip Wolodkewitsch, The Shockey Precast Group
Richard Woodhall, Coreslab Structures (Texas) Inc.
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Four precast workflow teams:

- Architectural precast
- Precast lead contractor
- Precast sub-contractor
- Precast fabrication & erection
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Process Model - Architectural

<table>
<thead>
<tr>
<th>Schematic Design</th>
<th>Design Development</th>
<th>Fabrication Level Design</th>
<th>Fabrication</th>
<th>Erection</th>
</tr>
</thead>
</table>

1. Concept Design of Precast Fragile
   - Concept drawings
   - Sketches and notes

2. Design review and Concept Modeling
   - Contract model
   - BIM

3. Precaution Bid Preparation
   - Coordination draw model

4. Precaution
   - Coordinationdraw model
   - Status report
   - Plant management data

5. Construction Coordination
   - Structural review fabrication model

6. Structural Design Review
   - Fabrication model
   - Coordination draw model

7. Design load model
   - Fabrication model

8. Design Intent Validation
   - Coordination action items

9. Design Intent Model
   - Coordination action items

10. Design Intent Plane Layout
   - Coordination action items

11. Fabrication Modeling
   - Coordination action items

12. Plant Material Tracking
   - Coordination action items

13. Construction Coordination
   - Coordination action items

14. Fabrication Coordination
   - Coordination action items

---

[Logos: Georgia Institute of Technology, Technion, and Charles Pankow Foundation]
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Process Model – Precast as lead

[Diagram of process model with nodes and edges representing different stages and activities such as Preliminary Project Description, Design Development, Construction Documentation, Procurement, Product Development, Fabrication, and Erection Phase.]
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Process Model – Sub-contractor

[Diagram showing the process model with various stages and tasks, including
1. Concept Design of Precast Features
2. Design Development
3. Construction Document
4. Procurement
5. Product Development
6. Fabrication
7. Erection Phase
8. Preliminary Project Description
9. Design Development
10. Construction Documentation
11. Procurement
12. Product Development
13. Fabrication
14. Erection Phase]

[Logos and affiliations at the bottom of the page]
### [1.51] Structural Analysis and Design

<table>
<thead>
<tr>
<th>Type</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Structural Analysis and Design</td>
</tr>
<tr>
<td>OmniClass Code</td>
<td>31-40-30-17 Product Evaluation Phase</td>
</tr>
<tr>
<td>Documentation</td>
<td>Structural engineer reviews the composition of piece definitions and sizing with regard to adequacy to carry loads, sizing, spans bearing conditions and live and dead loads and lateral forces, for efficacy of the precast piece definition. Reviews issues of erection sequencing and temporary erection loads and supports.</td>
</tr>
</tbody>
</table>

### [1.52] Precast Piece Layout

<table>
<thead>
<tr>
<th>Type</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Precast Piece Layout</td>
</tr>
<tr>
<td>OmniClass Code</td>
<td>31-40-30-11 Product Prototyping Phase</td>
</tr>
<tr>
<td>Documentation</td>
<td>The precast designer/engineer develops the final definition of precast assemblies and pieces that make up the project, dealing with architectural panel layout and joints, structural elements and their spanning and load carrying requirements, and large assemblies such as stairways and service cores.</td>
</tr>
</tbody>
</table>

### [1.53] Construction Coordination

<table>
<thead>
<tr>
<th>Type</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Construction Coordination</td>
</tr>
<tr>
<td>OmniClass Code</td>
<td>31-40-40-11 Construction Start-up Phase</td>
</tr>
<tr>
<td>Documentation</td>
<td>The General contractor coordinates with all subcontractors regarding the sequence of construction and there for delivery and erection sequences. Initially these are at a high level. The models are used to review complex conditions needed special attention.</td>
</tr>
</tbody>
</table>
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Exchange model definition

Information groups are compiled and their functional options are detailed

<table>
<thead>
<tr>
<th>Information groups</th>
<th>Exchange model</th>
</tr>
</thead>
<tbody>
<tr>
<td>piece families, reinforcing, analysis model, loads, connections, finishes</td>
<td></td>
</tr>
<tr>
<td>Information items within category: Grade Beam, Pier Cap, Spread footing, Slab on Grade, Stem Wall, Retaining wall, Drilled Pier, Cassion, Pile, Pile Cap</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute sets relevant for category</th>
<th>Required?</th>
<th>Type?</th>
<th>Features?</th>
</tr>
</thead>
<tbody>
<tr>
<td>attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural loads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GOAL:

- to define information requirements in adequate detail to drive implementation
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Exchange model definitions

The information content of exchanges are defined and their functional requirements determined

<table>
<thead>
<tr>
<th>Information Group</th>
<th>Information Items</th>
<th>Attribute Set</th>
<th>Attributes</th>
<th>EM.1</th>
<th>EM.2</th>
<th>EM.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast: Load-bearing pieces</td>
<td>BEAMS (Rectangular, Inverted Tees, L Beams, T Beams)</td>
<td>Geometry</td>
<td>Required?</td>
<td>R</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deformations?</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accuracy?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WALLS (Core, Lite-, Shear, K-Frames, Pilasters, Insulated)</td>
<td>Gross/Net Area</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gross/Net Volume</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Openings/Voids geometry</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dimensional Tolerance Info</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Piece Mark</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control Number</td>
<td>Required?</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deformed Geometry?</td>
<td>A = As cast or fabricated; D = Deformed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Geometry Function</td>
<td>V = viewable only; F = reference geometry; E = editable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Geometry Accuracy Required</td>
<td>P = planar/mesh sufficient; C = curved surfaces required</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Exchange model definitions

All exchanges from four processes are compared and rationalized
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### Attribute Set | Attributes | Architectural Concept | Structural Concept | Precast Concept | Arch. Design Development
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Identity</td>
<td>Name, Function</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Contact Info</td>
<td>Addresses</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Phones, email, etc.</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Perimeter</td>
<td>Geometry</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Function?</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Accuracy?</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Location</td>
<td>Longitude, Latitude, Orientation</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Topography</td>
<td>Digital terrain model (contours)</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Assembly relations</td>
<td>Contains buildings...</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Author, Version, Date</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Approval Status, Date</td>
<td>Required?</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

Note: The table indicates the required status (R) and the presence of values (V) for each attribute across different concepts and development stages.
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INFORMATION DELIVERY MANUAL

(IDM)

FOR ARCHITECTURAL PRECAST CONCRETE

Version 1.0

July 14th, 2008

PROF. CHARLES EASTMAN
ASSOC PROF. RAFAEL SACKS
DR. IVAN PANUSHEV
Model View Definition

‘Constructs’ and ‘Concepts’

A ‘construct’ is an object representation of a well-defined information item for use in model. A construct is defined by a set of concepts.

A ‘concept’ is a component of a ‘construct’ definition that has a direct schema binding.
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Model View Definition

‘Constructs’ and ‘Concepts’

Constructs and Concepts can be re-used in multiple exchange models.

Concepts are validated once for all uses.

Conformance testing can be done at Construct and Concept Level.

Information Delivery Manual

Exchange Definitions

Model View Definitions

IFC Model View Concept

1:1 mapping

Object relations

IFC Expression

Generic Model View Definition

Model View Definition and Implementation Specifications

Standard Design

The Charles Pankow Foundation
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MVD Process

Precast concrete mapped piece, replicating a reference piece in a new location, allowing minor modifications.

RELATIONS:
- IsDecomposedBy: these are optional embeds; reinforcing, pretensioning, different from original.
- HasAssociations: Precast piece being mapped
- ConnectedTo: Building Elements that this piece is connected to
- HasStructuralMember: associated structural element
- HasCovering: Relation to finish specification
- ProductRepresentation: the object’s shape
- ObjectPlacement: location and reference object

PROPERTIES:
- GlobalId: machine assigned guid
- OwnerHistory: history of object
- ObjectType: "precast" identifies this as a precast piece

Legend:
- Required
- Optional Relation
- Optional Properties
- Assigned Properties
- Required Relations
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Concept Composition for a Double-Tee beam

DT template

CONCEPT: custom profile
CONCEPT: extruded geometry
CONCEPT: local origin
CONCEPT: precast piece type
CONCEPT: lateral tie embeds
CONCEPT: pre-tension tendons
CONCEPT: tendon pattern

PropertySet
HasPropertySets
HasAssociations
References

DT Mapped Instance

CONCEPT: placement
CONCEPT: physical Connection
CONCEPT: structural connection
CONCEPT: precast piece instance (mapped)
CONCEPT: shape trims
CONCEPT: topping
CONCEPT: structural loads
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Missing IFC Entities and Relationships for Precast Concrete

Beam Enumeration Values

Slabs
IfcSlabWithElements
IfcSlabWithElementsType
Pset_PrecastSlab

Modules
IfcModule
IfcModuleType

Parametric Profiles
IfcDoubleTeeShapeProfileDef
IfcHollowCoreShapeProfileDef

Facades
IfcFacadeElement
IfcFacadeElementType

Discrete Accessory Values
Pset_DiscreteAccessoryProductionRequirements
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Missing IFC Entities and Relationships for Precast Concrete

**Slab with Elements – New IFC Entity**

**IfcSlabWithElements**

**IfcSlabWithElementsType**
Subtype of **IfcSlab**

**Pset_PrecastSlab**

Property Definitions:

<table>
<thead>
<tr>
<th>Name</th>
<th>Property Type</th>
<th>Data Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TypeDesignator</td>
<td>IfcPropertySingleValue</td>
<td>IfcLabel</td>
<td>Type designator for the precast concrete slab, expressing mainly the component type. Possible values are “Hollow-core”, “Double-tee”, “Flat plank”, etc.</td>
</tr>
<tr>
<td>ToppingType</td>
<td>IfcPropertySingleValue</td>
<td>IfcLabel</td>
<td>Defines if a topping is applied and what kind. Values are “Full topping”, “”, “None”</td>
</tr>
<tr>
<td>EdgeDistanceToFirstAxis</td>
<td>IfcPropertySingleValue</td>
<td>IfcPositiveLengthMeasure / LENGTHUNIT</td>
<td>The distance from the left (‘West’) edge of the slab (in the direction of span of the components) to the axis of the first component.</td>
</tr>
<tr>
<td>DistanceBetweenComponentAxes</td>
<td>IfcPropertySingleValue</td>
<td>IfcPositiveLengthMeasure / LENGTHUNIT</td>
<td>The distance between the axes of the components, measured along the ‘South’ edge of the slab.</td>
</tr>
<tr>
<td>AngleToFirstAxis</td>
<td>IfcPropertySingleValue</td>
<td>IfcPlaneAngleMeasure</td>
<td>The angle of rotation of the axis of the first component relative to the ‘West’ edge of the slab.</td>
</tr>
<tr>
<td>AngleBetweenComponentAxes</td>
<td>IfcPropertySingleValue</td>
<td>IfcPlaneAngleMeasure</td>
<td>The angle between the axes of each pair of components.</td>
</tr>
<tr>
<td>NominalThickness</td>
<td>IfcPropertySingleValue</td>
<td>IfcPositiveLengthMeasure / LENGTHUNIT</td>
<td>The nominal overall thickness of the slab.</td>
</tr>
<tr>
<td>NominalToppingThickness</td>
<td>IfcPropertySingleValue</td>
<td>IfcPositiveLengthMeasure / LENGTHUNIT</td>
<td>The nominal thickness of the topping.</td>
</tr>
</tbody>
</table>
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Missing IFC Entities and Relationships for Precast Concrete

*Slab with Elements – New IFC Entity*

IfcModule

IfcModuleType

```plaintext
ENTITY IfcModule
  SUBTYPE OF (IfcBuildingElement);
END_ENTITY;

ENTITY IfcModuleType
  SUBTYPE OF (IfcBuildingElementType);
END_ENTITY;
```
**National BIM Exchange Standards for Precast Concrete**

**Missing IFC Entities and Relationships for Precast Concrete**

**Double Tee Parametric Profile Definition**

**ENTITY** `IfcDoubleTeeShapeProfileDef`;

**ENTITY** `IfcProfileDef`;

Profile Type: `IfcProfileTypeEnum`;
Profile Name: `OPTIONAL IfcLabel`;

**INVERSE**

Has Properties: `SET OF IfcProfileProperties`;

**ENTITY** `IfcParameterizedProfileDef`;

Position: `OPTIONAL IfcAxis2Placement2D`;

**ENTITY** `IfcHollowCoreShapeProfileDef`;

Overall Width: `IfcPositiveLengthMeasure`;
Left Flange Width: `IfcPositiveLengthMeasure`;
Right Flange Width: `IfcPositiveLengthMeasure`;
Overall Depth: `IfcPositiveLengthMeasure`;
Flange Depth: `IfcPositiveLengthMeasure`;
Flange Draft: `OPTIONAL IfcPositiveLengthMeasure`;
Flange Chamfer: `OPTIONAL IfcPositiveLengthMeasure`;
Flange Base Fillet: `OPTIONAL IfcPositiveLengthMeasure`;
Flange Top Fillet: `OPTIONAL IfcPositiveLengthMeasure`;
Stem Base Width: `IfcPositiveLengthMeasure`;
Stem Top Width: `IfcPositiveLengthMeasure`;
Stem Base Chamfer: `OPTIONAL IfcPositiveLengthMeasure`;
Stem Top Chamfer: `OPTIONAL IfcPositiveLengthMeasure`;
Stem Base Fillet: `OPTIONAL IfcPositiveLengthMeasure`;
Stem Top Fillet: `OPTIONAL IfcPositiveLengthMeasure`;

**END_ENTITY;**
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Missing IFC Entities and Relationships for Precast Concrete

**Hollow Core Parametric Profile Definition**

`IfcHollowCoreShapeProfileDef`

- **ENTITY** IfcHollowCoreShapeProfileDef;
- **ENTITY** IfcProfileDef;
- **ProfileType** : IfcProfileTypeEnum;
- **ProfileName** : OPTIONAL IfcLabel;
- **INVERSE** HasProperties : SET OF IfcProfileProperties FOR ProfileDefinition;
- **ENTITY** IfcParameterizedProfileDef
  - **Position** : OPTIONAL IfcAxis2Placement2D;
- **ENTITY** IfcHollowCoreShapeProfileDef
  - **OverallWidth** : IfcPositiveLengthMeasure;
  - **OverallDepth** : IfcPositiveLengthMeasure;
  - **EdgeDraft** : IfcPositiveLengthMeasure;
  - **DraftBaseOffset** : OPTIONAL IfcPositiveLengthMeasure;
  - **DraftSideOffset** : OPTIONAL IfcPositiveLengthMeasure;
  - **BaseChamfer** : IfcPositiveLengthMeasure;
  - **KeyDepth** : IfcPositiveLengthMeasure;
  - **KeyHeight** : IfcPositiveLengthMeasure;
  - **KeyOffset** : IfcPositiveLengthMeasure;
  - **BottomCover** : IfcPositiveLengthMeasure;
  - **CoreSpacing** : IfcPositiveLengthMeasure;
  - **CoreBaseHeight** : IfcPositiveLengthMeasure;
  - **CoreMiddleHeight** : IfcPositiveLengthMeasure;
  - **CoreTopHeight** : IfcPositiveLengthMeasure;
  - **CoreBaseWidth** : IfcPositiveLengthMeasure;
  - **CoreTopWidth** : IfcPositiveLengthMeasure;
  - **CenterCoreSpacing** : OPTIONAL IfcPositiveLengthMeasure;
  - **CenterCoreBaseHeight** : OPTIONAL IfcPositiveLengthMeasure;
  - **CenterCoreMiddleHeight** : OPTIONAL IfcPositiveLengthMeasure;
  - **CenterCoreTopHeight** : OPTIONAL IfcPositiveLengthMeasure;
  - **CenterCoreBaseWidth** : OPTIONAL IfcPositiveLengthMeasure;
  - **CenterCoreTopWidth** : OPTIONAL IfcPositiveLengthMeasure;
  - **NumberOfCores** : IfcCountMeasure;

END_ENTITY;
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Scope of Process Phases

Validation of the MVD against functional specification

Development of full test cases for each concept

Development of construct testing of each high-level unit

Deployment: Use in Industry

verifiable BIM data exchange
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Field testing
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Lessons Learned

• Information modeling is influenced by the fabrication practice. For example, profiles are defined as part of types, whereas local blockouts are parts of instances.

• Generating multiple exchange models involves a high level of replication at the schema level: a modular approach is needed to make the development and future conformance testing tractable.

• The development of the Constructs, Concepts and the bindings addresses this problem. Many of those developed have wide use.

• Additional IFC entities were needed for precast concrete, but some address generic needs – such as Slabs with Elements, Embedded Components. As more domains complete the exchange standard process, fewer will be needed.
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Thanks for your attention. Questions?

Selected Publications


