# 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**

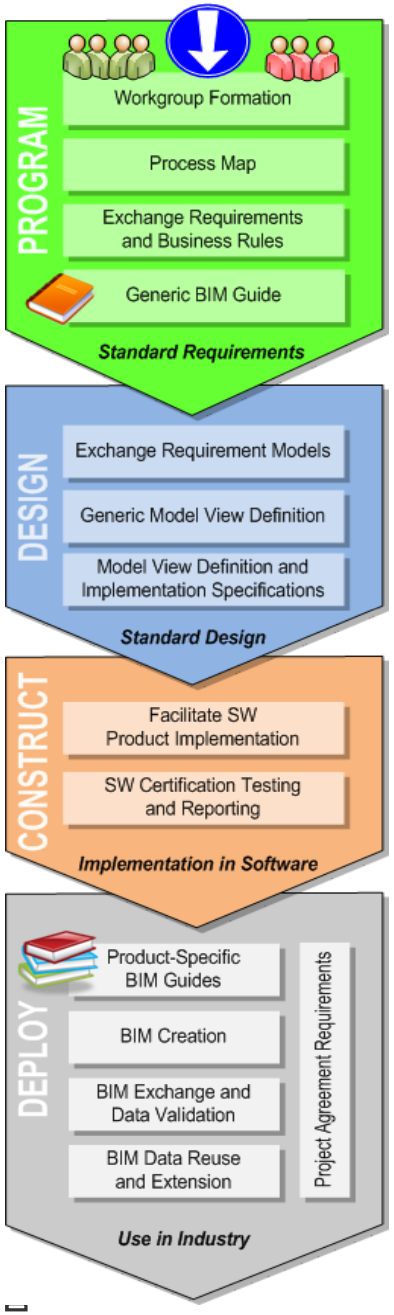
*Industry Collaboration, Process Modelling, Detailing Exchange Requirements*

- **MVD Development**

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

- **Conclusions**

*Where are we? What can be learned for other domains?*




## *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

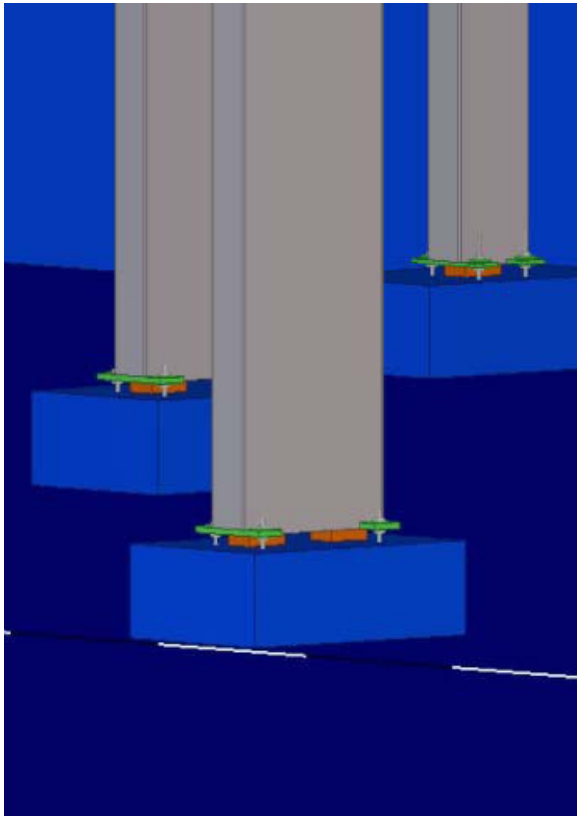
2006 Charles Pankow Foundation project to assess interoperability in architectural precast

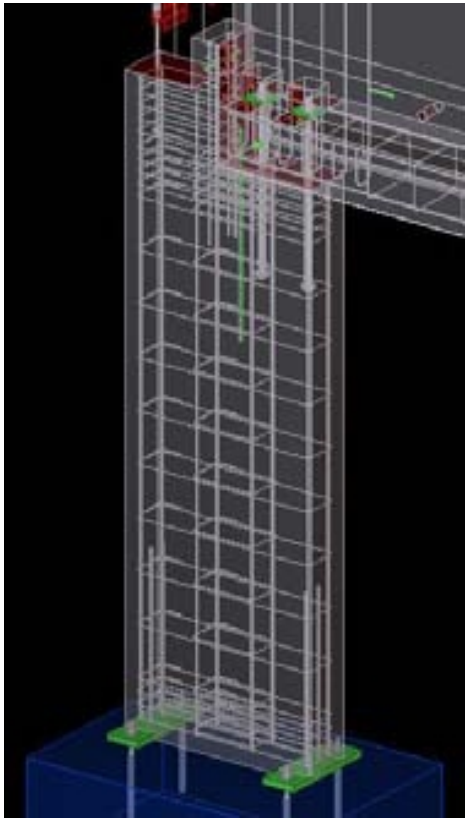
2008 Charles Pankow Foundation funds GA Tech/Technion to develop BIM standard for all precast; PCI BIM advisory committee established

*2009 Publication of Precast Concrete National BIM Standard ??*

PCSC 2001-2005

*Precast Concrete Functionality in Building Information Modeling Tools*

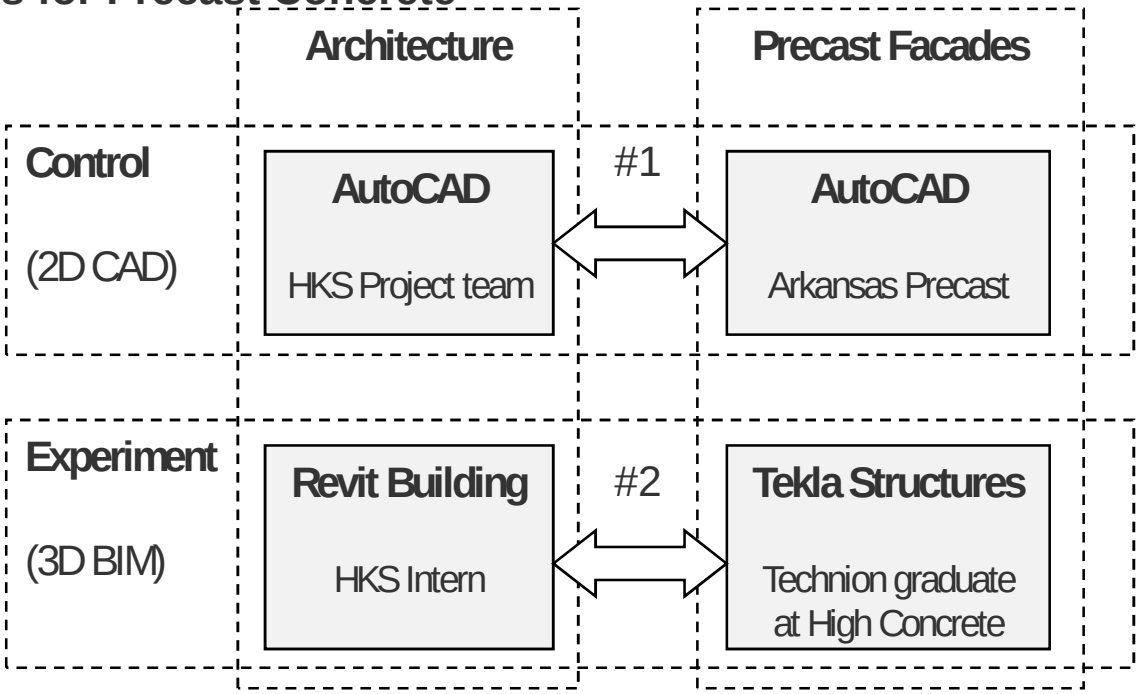


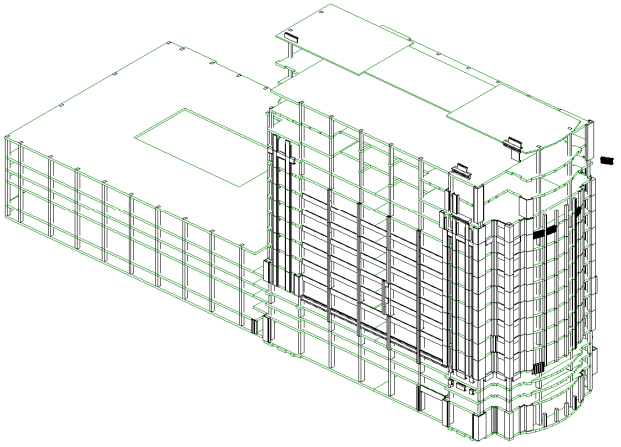


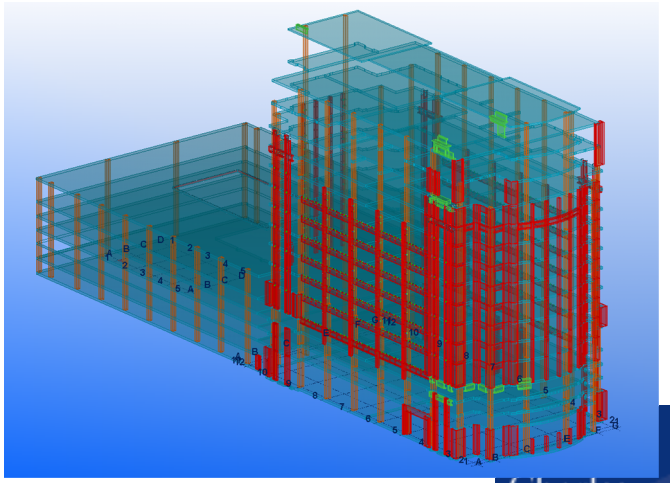
## Rosewood Experiment

Full scale exchange and modeling experiment of architectural precast facades

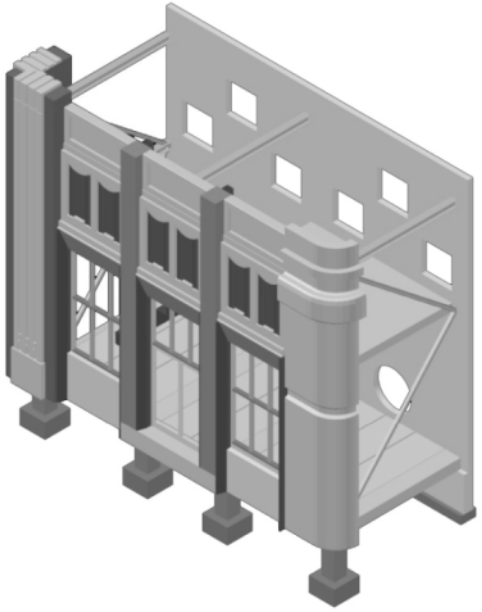
- Found serious limitations with IFC exchanges
- Found 57% productivity gain for precast fabrication detailing

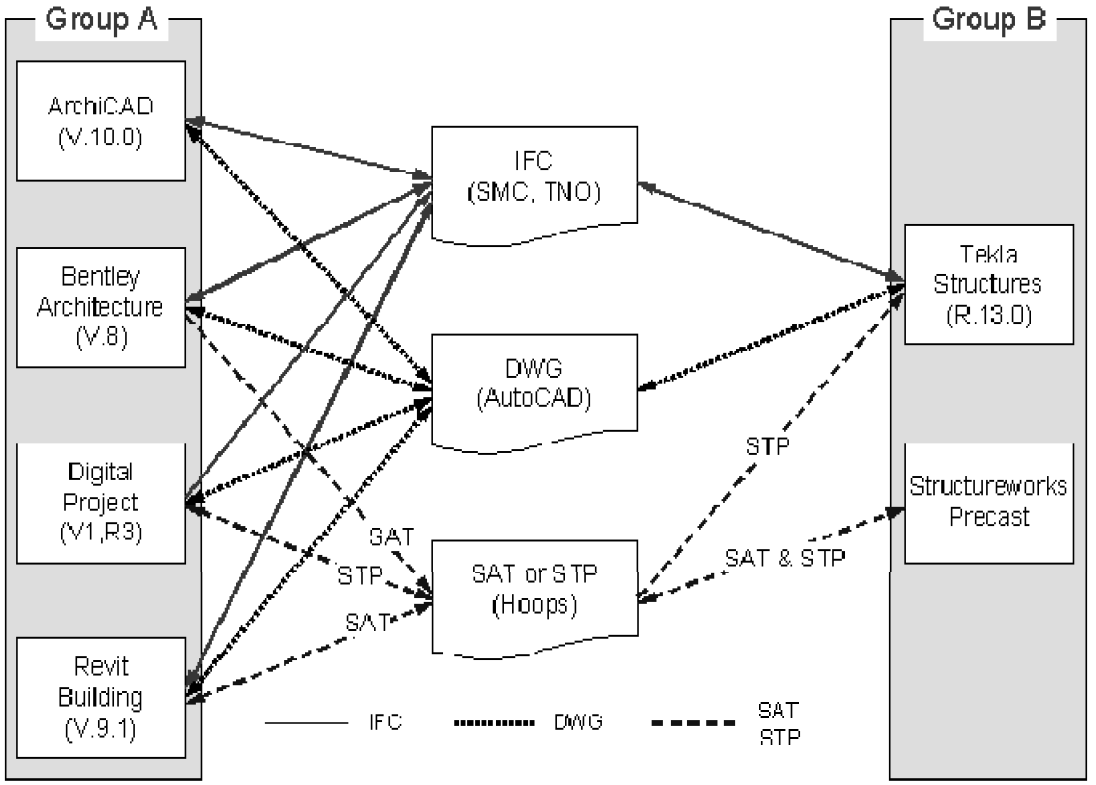




## Benchmark Experiment






Benchmark model exchange – steel, CIP concrete and precast

- Found serious limitations with IFC exchanges
- Underlined the need for BIM standards

# National BIM Exchange Standards for Precast Concrete


## 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
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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
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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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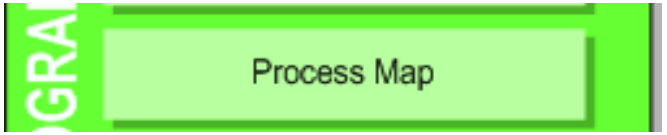
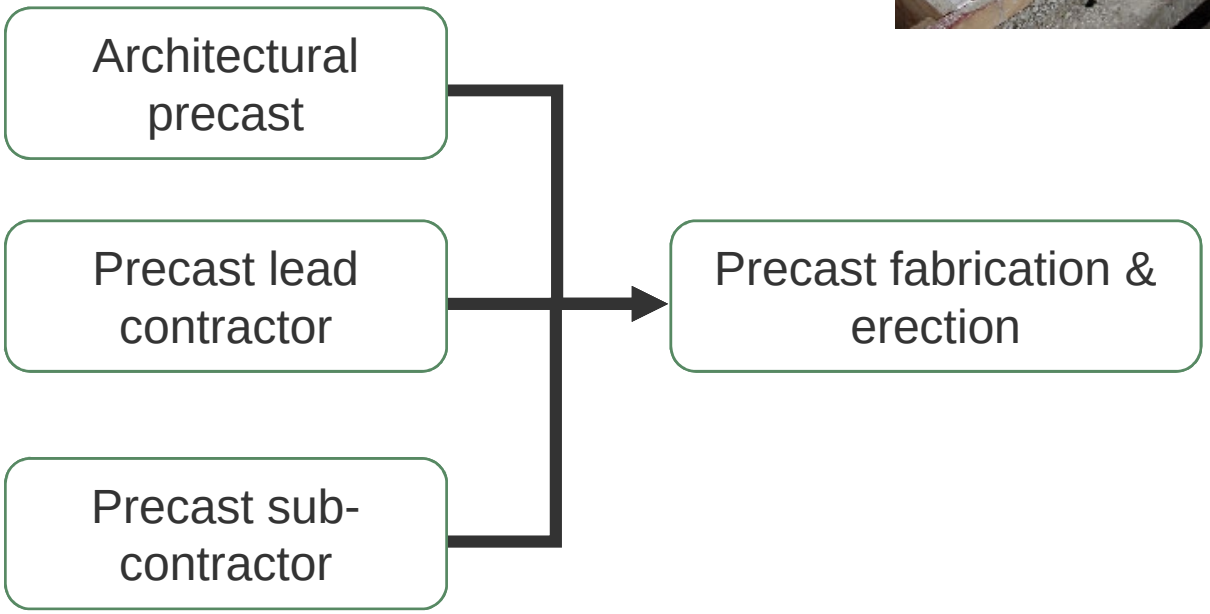
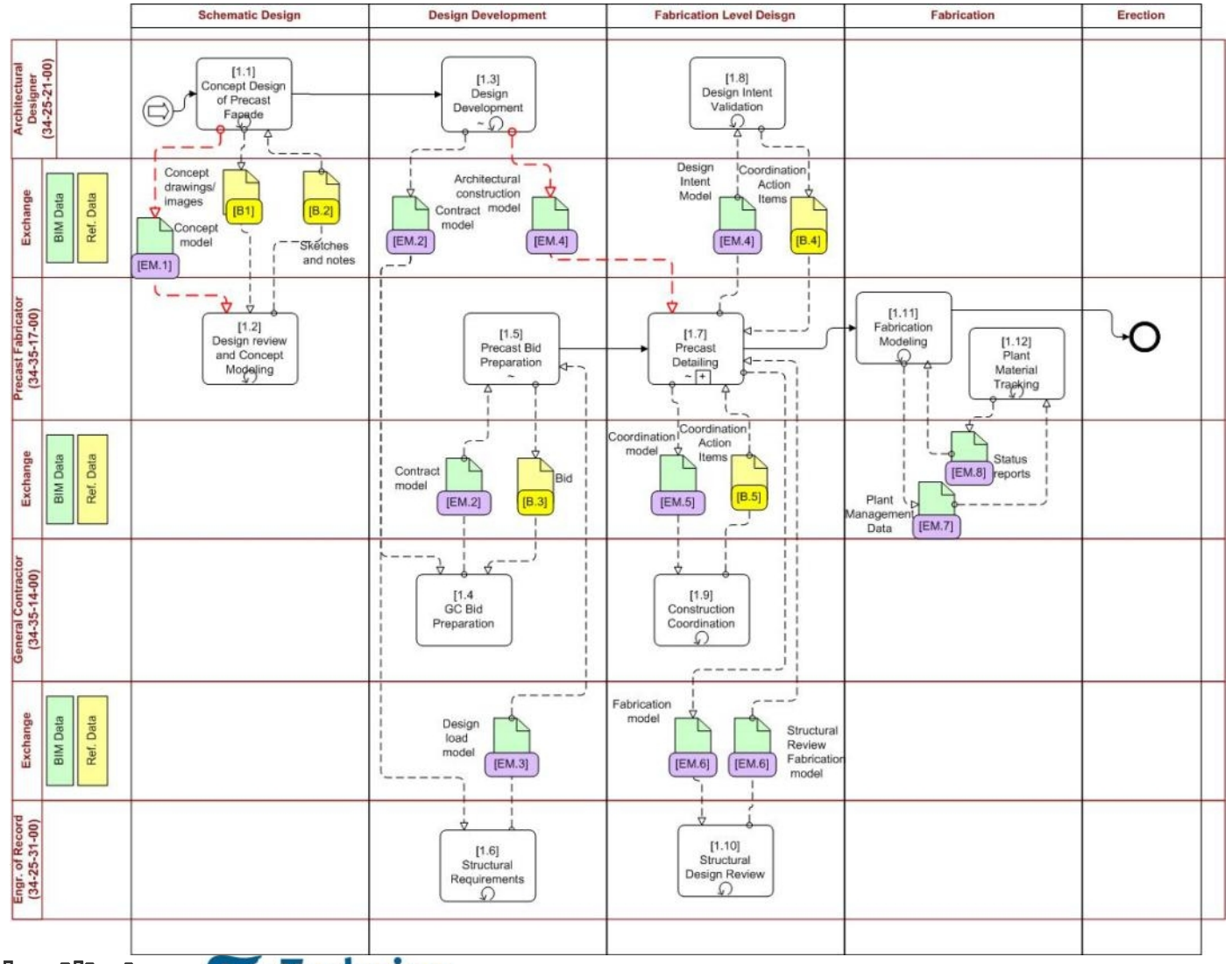



Four precast workflow teams:



## National BIM Exchange Standards for Precast Concrete

### Process Model - Architectural



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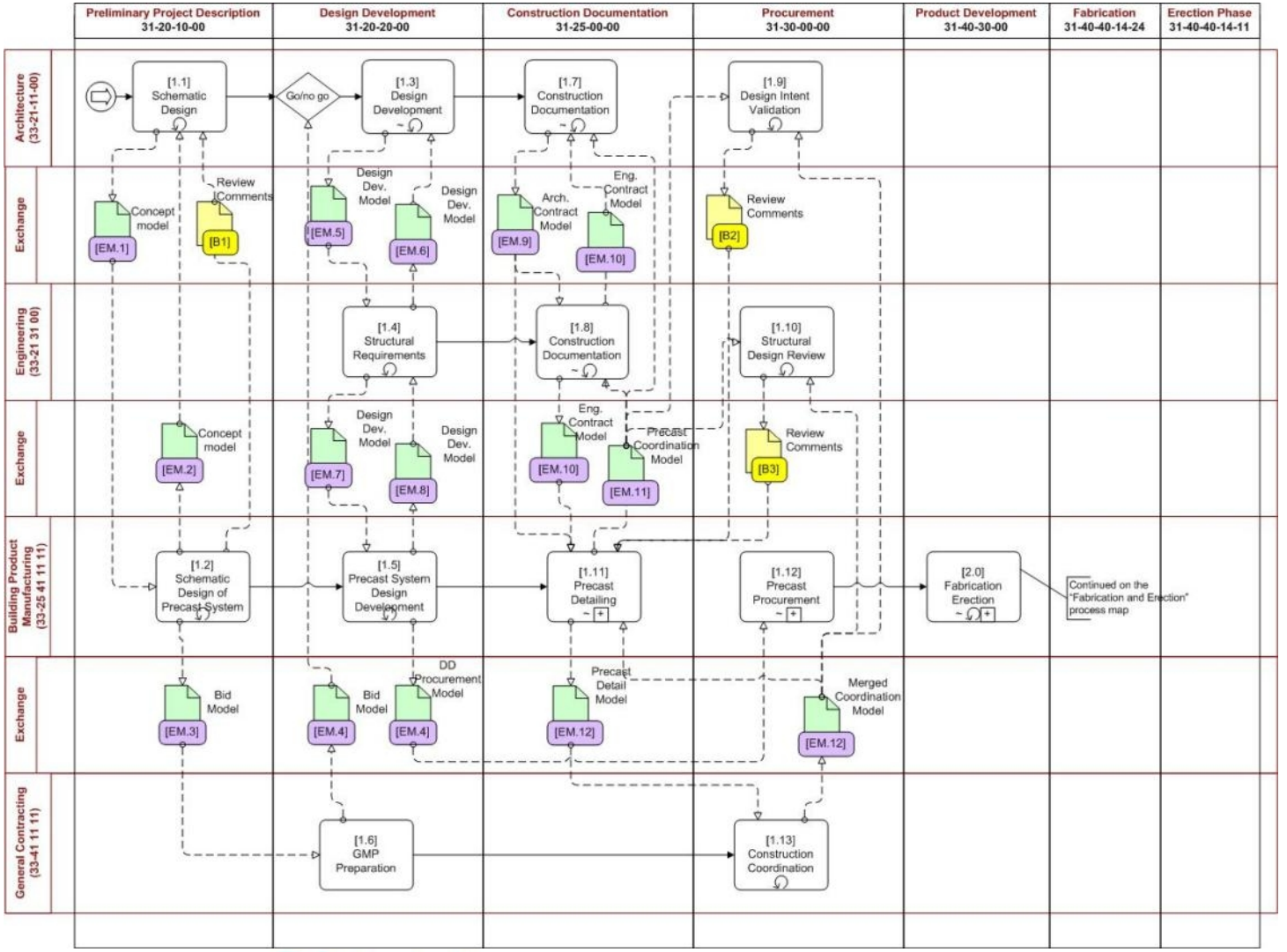
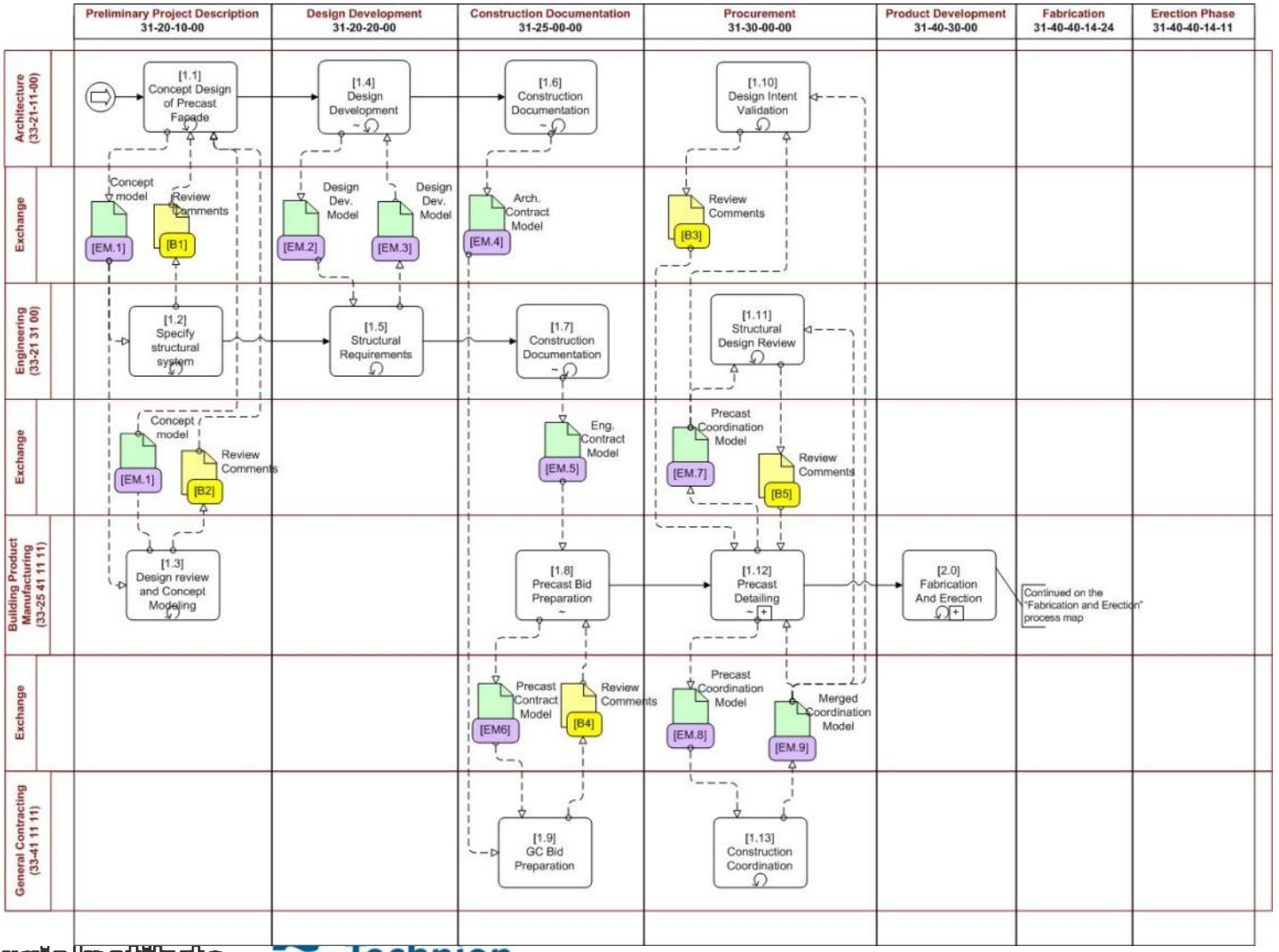
### Process Model – Precast as lead

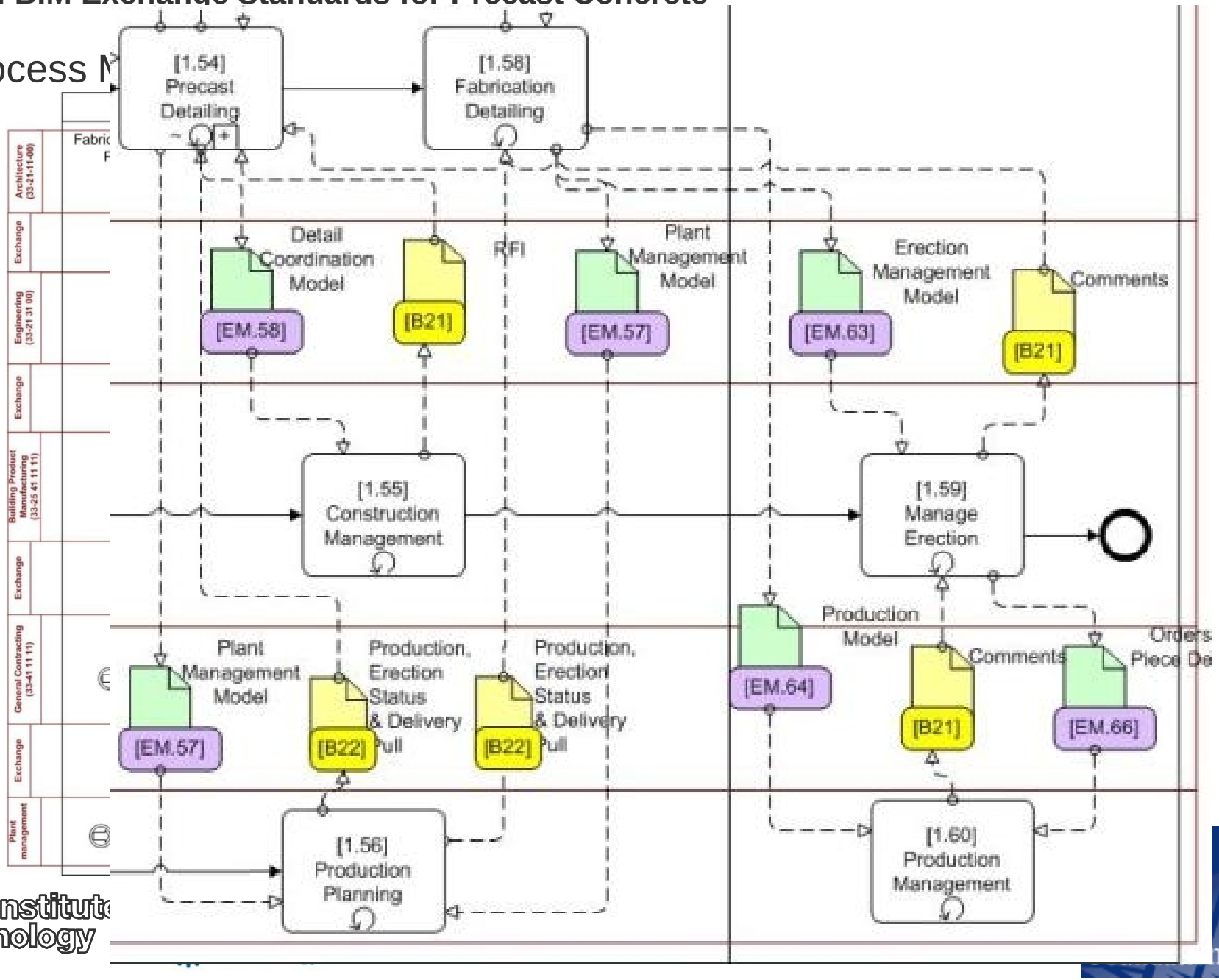


# Process Model – Sub-contractor



# National BIM Exchange Standards for Precast Concrete

Process M

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# Process Descriptions

**[1.51] Structural Analysis and Design**

| Type | Task |
|---|---|
| Name | Structural Analysis and Design |
| Omniclass Code | 31-40-30-17 Product Evaluation Phase |
| Documentation | 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. |

**[1.52] Precast Piece Layout**

| Type | Task |
|---|---|
| Name | Precast Piece Layout |
| Omniclass Code | 31-40-30-11 Product Prototyping Phase |
| Documentation | 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. |

**[1.53] Construction Coordination**

| Type | Task |
|---|---|
| Name | Construction Coordination |
| Omniclass Code | 31-40-40-11 Construction Start-up Phase |
| Documentation | 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. |

## National BIM Exchange Standards for Precast Concrete

PRO Exchange Requirements and Business Rules

Exchange model definition

Information groups are compiled and their functional options are detailed

| **Information groups** piece families, reinforcing. analysis model, loads, connections, finishes | Information items within category within category: Grade Beam, Pier Cap, Spread footing, Slab on Grade, Stem Wall, Retaining wall, Drilled Pier, Cassion, Pile, Pile Cap | Attribute sets relevant for category | attributes | Required? | **Exchange model** |
|---|---|---|---|---|---|
| | | | attributes | Type? | |
| | | | attributes | Features? | |
| | | Geometry | attributes | | |
| | | | attributes | | |
| | | Structural loads | | | |
| | | Material | | | |
| | | Relations | | | |

**GOAL:**

**- to define information requirements in adequate detail to drive implementation**

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**National BIM Exchange Standards for Precast Concrete**

# Exchange model definitions

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

| Information Group | Information Items | Attribute Set | Attributes | | EM.1 | EM.2 | EM.3 |
|---|---|---|---|---|---|---|---|
| Precast: **Load-bearing pieces** | | | | | | | |
| | **BEAMS** (Rectangular, Inverted Tees, L Beams, | | Geometry | Required? | R | | |
| | | | | Deformations? | A | D | |
| | | | | Function? | V | F | E |
| | | | | Accuracy? | P | | |
| | | | Gross/Net Area | Required? | R | | |
| | | | Gross/Net Volume | Required? | R | | |
| | | | Openings/Voids geometry | Required? | R | | |
| | | | Dimensional Tolerance Info | Required? | R | | |
| | | | Piece Mark | Required? | R | | |
| | **WALLS** (Core, Lite-, Shear, K-Frames, Pilasters, Insulated) | | Control Number | Required? | R | | |

R

**Exchange Requirement**
R = required
O = optional
Blank = Not required

A D

**Deformed Geometry?**
A = As cast or fabricated;
D = Deformed

V F

**Geometry Function**
V = viewable only;
F = reference geometry;
E = editable

P

**Geometry Accuracy Required**
P = planar/mesh sufficient
C = curved surfaces required

## National BIM Exchange Standards for Precast Concrete

# Exchange model definitions

All exchanges from four processes are compared and rationalized

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Information Group** | **Information Items** | **Attribute Set** | **Attributes** | | EM.1 | EM.2 | **EM.3** | **EM.3** | EM.5 | EM.6 | EM.7 | EM.8 | EM.9 | EM.10 | EM.11 | EM.12 |
| 38 | **Spaces** | | | | | | | | | | | | | | | | |
| 39 | | Building Stories, Elevator and Core Shafts, Atriums | Geometry | Outline, Heights, Voids, Elevations | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 40 | | | | | Function? | V | V | F | F | F | F | E | F | F | F | F | E |
| 41 | | | | | Accuracy? | P | P | P | P | C | C | P | P | P | C | P | C |
| 42 | | | | Net and gross area | Required? | R | R | O | O | R | R | | | R | R | R | R |
| 43 | | | | Net and gross volume | Required? | R | R | O | O | R | R | | | R | R | R | R |
| 44 | | | Position | Above, below grade, % open | Required? | R | R | | | R | R | R | R | R | R | R | R |
| 45 | | | Design constraints | Classification | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 46 | | | | Use Occupancy | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 47 | | | | Fire Rating | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 48 | | | Assembly relations | Located in building... | Required? | | | O | O | R | R | | | R | R | R | R |
| 49 | | | | Contains building systems... | Required? | | | O | O | R | R | | | R | R | R | R |
| 50 | | | Meta Data | Author, Version, Date | Required? | | | O | O | R | R | O | O | R | R | R | R |
| 51 | | | | Approval Status, Date | Required? | | | O | O | R | R | O | O | R | R | R | R |
| 52 | Primary CIP or Steel Super Structure - **Assemblies** | | | | | | | | | | | | | | | | |
| 53 | | Slab Systems, Building Cores | Layout | Geometry | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 54 | | | | | Function? | V | V | F | F | F | F | E | F | F | F | F | E |
| 55 | | | | | Accuracy? | P | P | P | P | C | C | P | P | P | C | P | C |
| 56 | | | Material | Material type | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 57 | | | | Quantity | Required? | | | R | R | O | O | | | | | | |
| 58 | | | Finishes | Geometry | Required? | R | R | R | R | R | R | R | R | R | R | R | R |
| 59 | | | | | Function? | V | V | V | V | V | V | E | E | F | F | F | F |
| 60 | | | | | Accuracy? | P | P | P | P | P | P | P | P | P | C | P | C |
| 61 | | | | Surface treatments | Required? | R | R | R | R | O | O | O | O | R | R | R | R |
| 62 | | | Assembly relations | Part of building | Required? | | | O | O | R | R | | | R | R | R | R |
| 63 | | | Association | Implements structrual object.. | Required? | | | O | O | R | R | | | R | R | R | R |
| 64 | | | Nested relations | Contains components | Required? | | | O | O | R | R | | | R | R | R | R |
| 65 | | | Connection relations | .. to Precast | Required? | | | O | O | O | R | R | R | R | R | R | R |
| 66 | | | | .. to CIP | Required? | | | O | O | O | R | O | R | R | R | R | R |
| 67 | | | | .. to Steel | Required? | | | O | O | O | R | O | R | R | R | R | R |
| 68 | | | Meta Data | Author, Version, Date | Required? | | | O | O | R | R | O | O | R | R | R | R |
| 69 | | | | Approval Status, Date | Required? | | | O | O | R | R | O | O | R | R | R | R |

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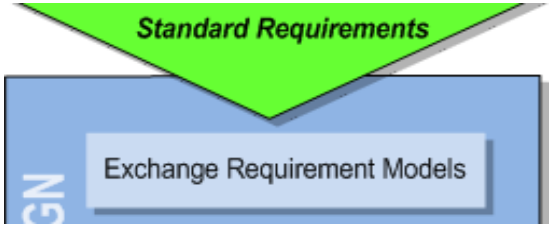
# National BIM Exchange Standards for Precast Concrete

| Attribute Set | Attributes | | Architectural Concept | | | Structural Concept | | | Precast Concept | Arch. Design Development | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A_EM.1 | P_EM.1 | S_EM.1 | A_EM.2 | P_EM.2 | S_EM.2 | A_EM.3 | A_EM.6 | P_EM.5 | S_EM.5 |
| Identity | Name, Function | Required? | R | R | | R | R | | R | R | R | |
| Contact Info | Addresses | Required? | R | R | | R | R | | R | R | R | |
| | Phones, email, etc. | Required? | R | R | | R | R | | R | R | R | |
| Perimeter | Geometry | Required? | R | R | | R | R | | R | R | R | |
| | | Function? | V | V | | V | V | | V | V | V | |
| | | Accuracy? | P | P | | P | P | | P | C | P | |
| Location | Longitude, Latitude, Orientation | Required? | R | R | | R | R | | R | R | R | |
| Topography | Digital terrain model (contours) | Required? | R | R | | R | R | | R | R | R | |
| | | Function? | V | V | | V | V | | F | F | V | |
| Assembly relations | Contains buildings… | Required? | R | R | | R | R | | R | R | R | |
| Meta Data | Author, Version, Date | Required? | R | R | | R | R | | R | R | R | |
| | Approval Status, Date | Required? | R | R | | R | R | | R | R | R | |

# National BIM Exchange Standards for Precast Concrete

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GEORGIA INSTITUTE OF TECHNOLOGY

TECHNION, ISRAEL INSTITUTE OF TECHNOLOGY

## INFORMATION DELIVERY MANUAL

## (IDM)

## FOR ARCHITECTURAL PRECAST CONCRETE

Version 1.0

July 14th, 2008

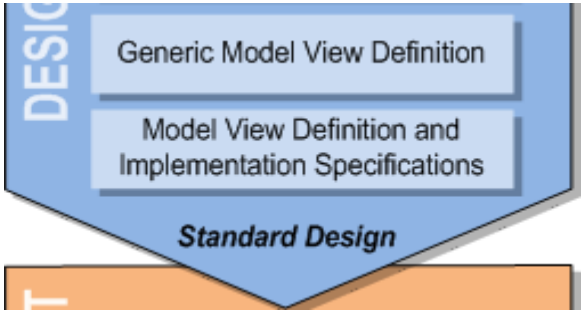
PROF. CHARLES EASTMAN

ASSOC PROF. RAFAEL SACKS

DR. IVAN PANUSHEV

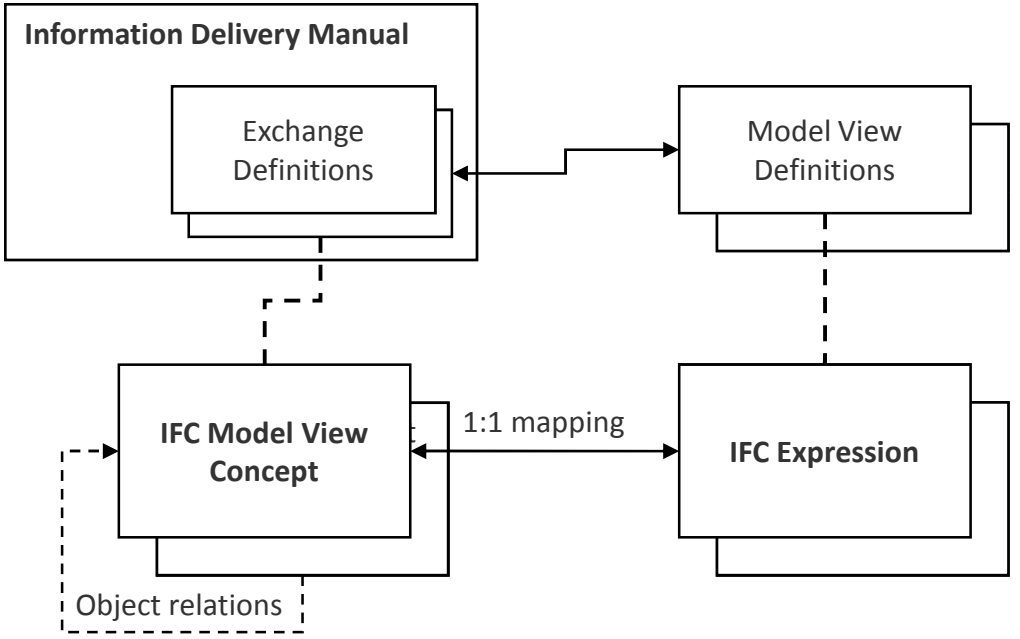
# Model View Definition

## ‘Constructs’ and ‘Concepts’



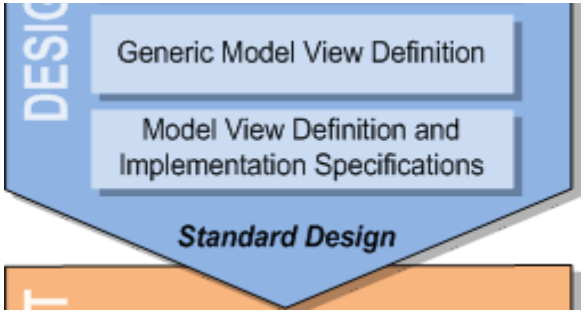

A ‘construct’ is an object representation of a well-defined information item for use in model. A construct is defined by a set of concepts

A ‘concept’ is a component of a ‘construct’ definition that has a direct schema binding



# Model View Definition

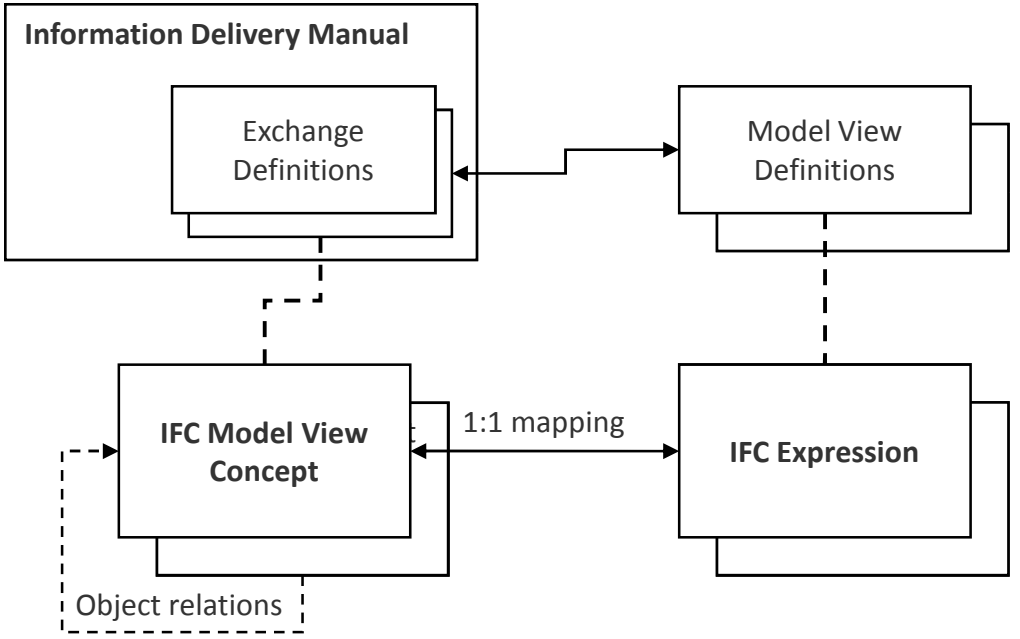
## ‘Constructs’ and ‘Concepts’




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



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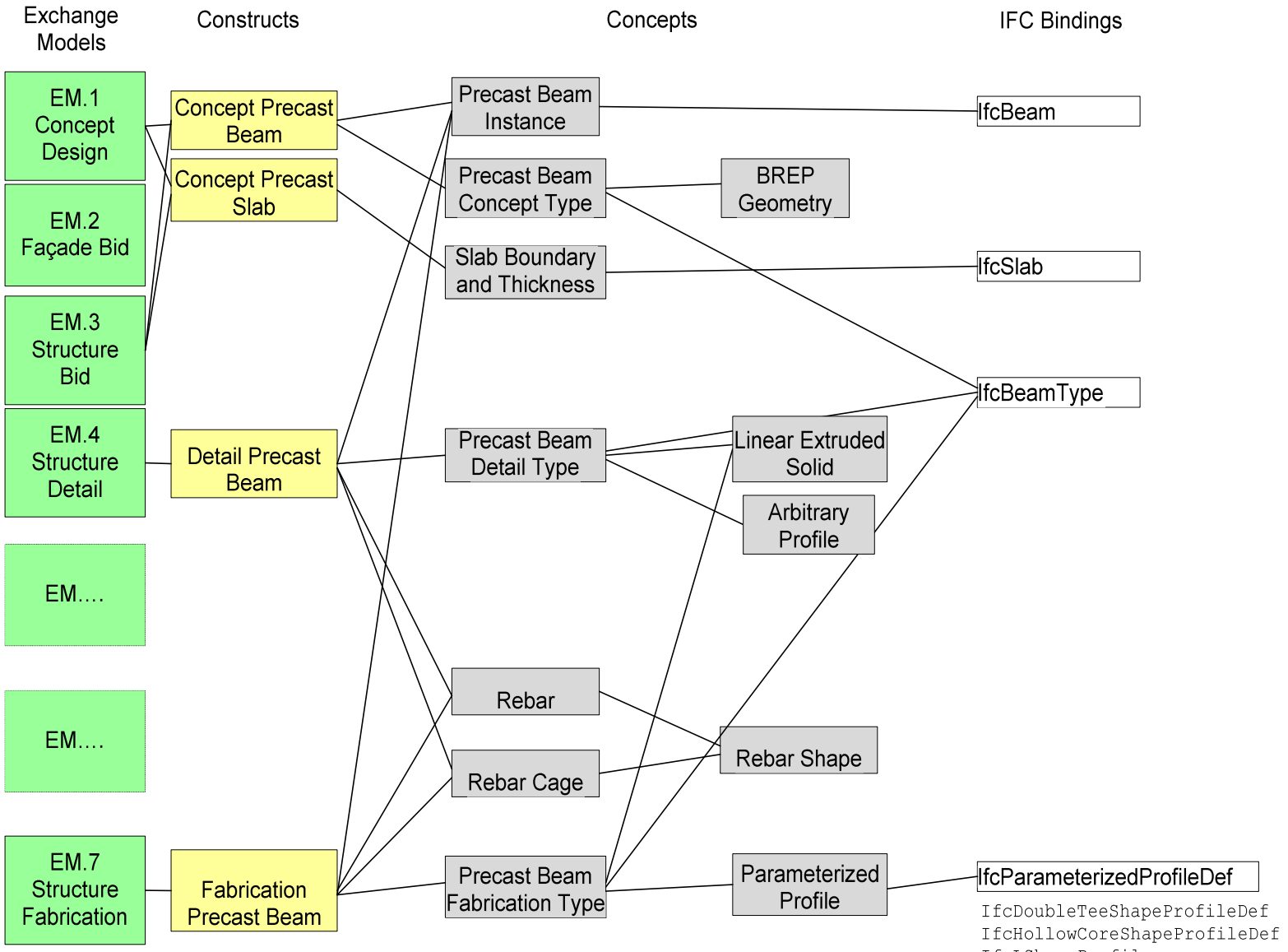
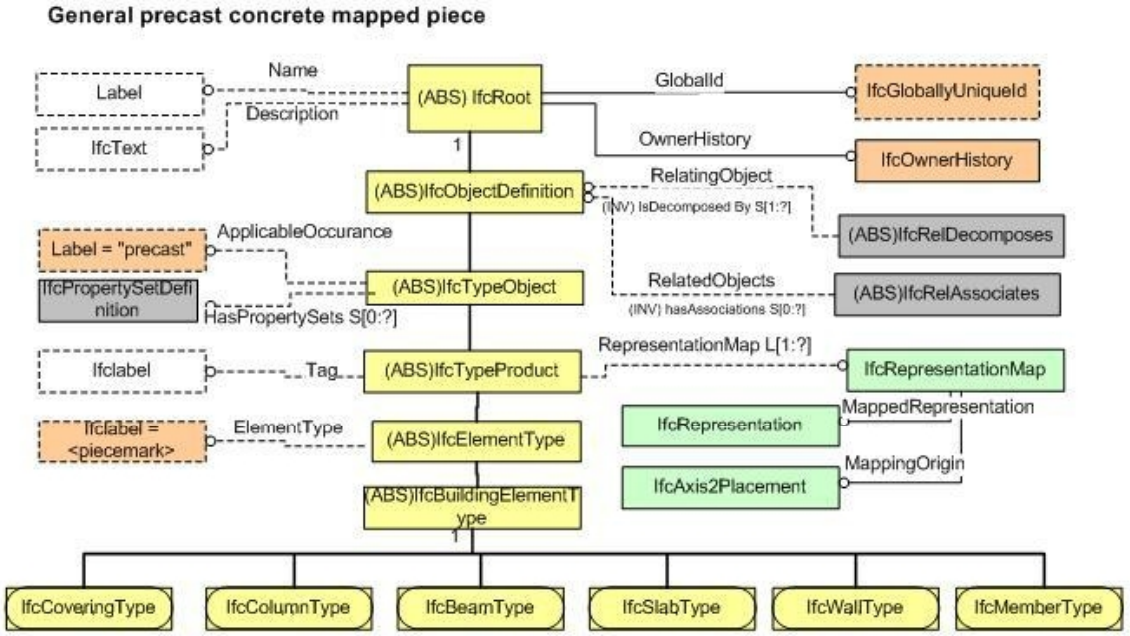


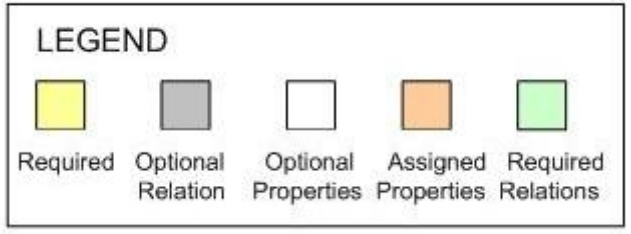
# MVD Process

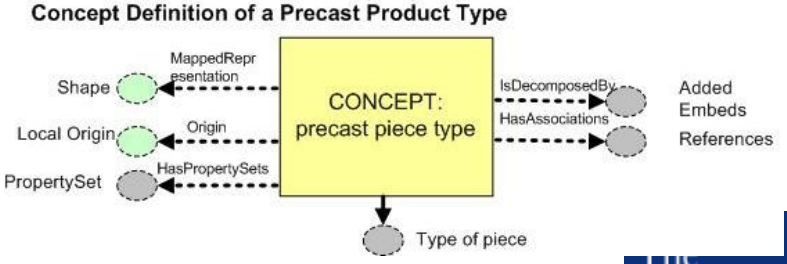



Precast concrete mapped piece, replicating a reference piece in a new location, allowing minor modifications.

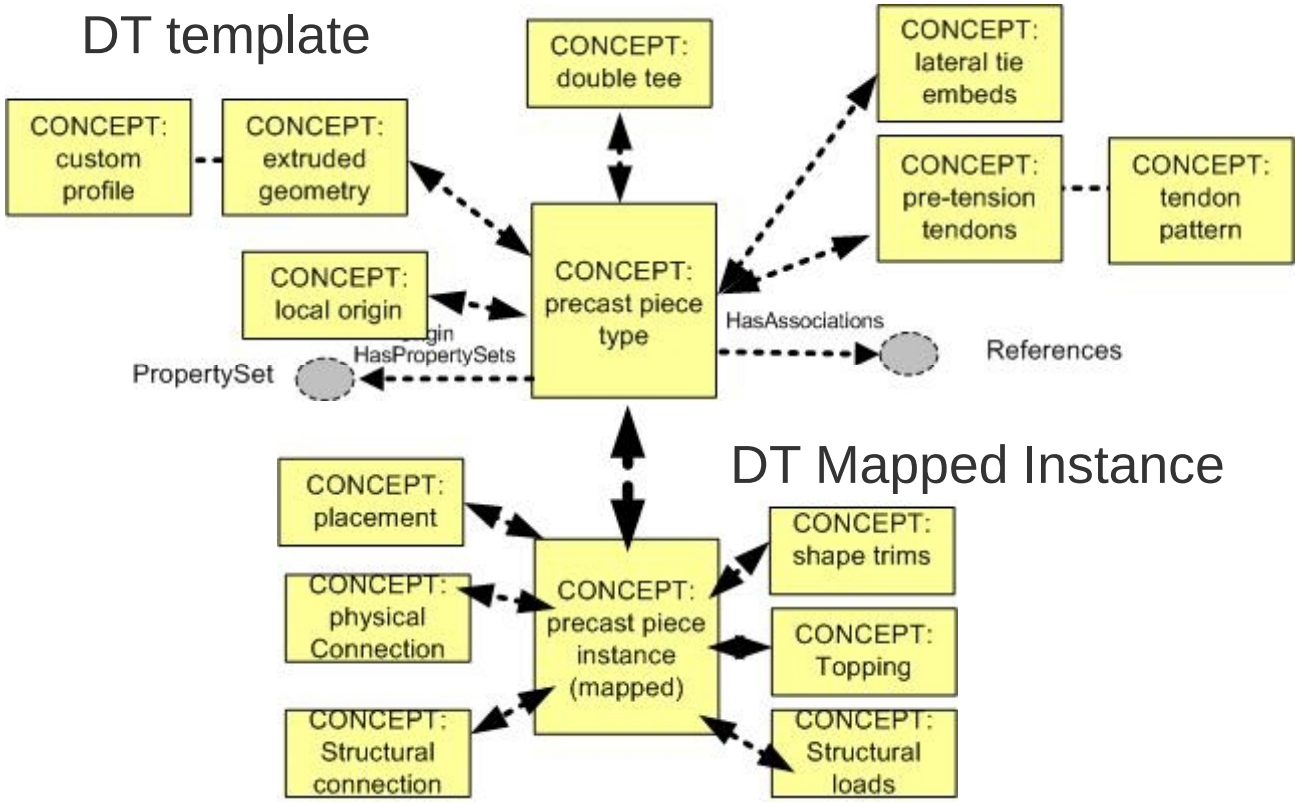
RELATIONS:
*IsDecomposedBy*: these are optional embeds: reinforcing, pretensioning, different from original.
*HasAssociations:* Precast piece being mapped
*ConnectedTo:* Building Elements that this piece is connected to
*HasStructuralMember:* associated structural element
*HasCovering:* Relation to finish 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



# Concept Composition for a Double-Tee beam




# 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_DiscreteAccessoryProduc
tionRequirements

# Missing IFC Entities and Relationships for Precast Concrete

## *Slab with Elements – New IFC Entity*

`IfcSlabWithElements`

`IfcSlabWithElementsType`

`Subtype of IfcSlab`

| | |
|---|---|
| **PropertySet Name** | Pset_PrecastSlab |
| **Applicable Entities** | `IfcSlabWithElements , IfcSlabWithElementsType` |
| **Definition** | Definition from PCI BIM advisory committee: layout and component information defining how prestressed slab components are laid out in a precast slab assembly. The values are global defaults for the slab as a whole, but can be overridden by local placements of the individual components of the slab. |

`Pset_PrecastSlab`

Property Definitions:

| Name | Property Type | Data Type | Definition |
|---|---|---|---|
| TypeDesignator | IfcPropertySingleValue | IfcLabel | Type designator for the precast concrete slab, expressing mainly the component type. Possible values are “Hollow-core”, “Double-tee”, “Flat plank”, etc. |
| ToppingType | IfcPropertySingleValue | IfcLabel | Defines if a topping is applied and what kind. Values are “Full topping”, “ ”, “None” |
| EdgeDistanceToFirstAxis | IfcPropertySingleValue | IfcPositiveLengthMeasure / LENGTHUNIT | 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. |
| DistanceBetweenComponentAxes | IfcPropertySingleValue | IfcPositiveLengthMeasure / LENGTHUNIT | The distance between the axes of the components, measured along the ‘South’ edge of the slab. |
| AngleToFirstAxis | IfcPropertySingleValue | IfcPlaneAngleMeasure | The angle of rotation of the axis of the first component relative to the ‘West’ edge of the slab. |
| AngleBetweenComponentAxes | IfcPropertySingleValue | IfcPlaneAngleMeasure | The angle between the axes of each pair of components. |
| NominalThickness | IfcPropertySingleValue | IfcPositiveLengthMeasure / LENGTHUNIT | The nominal overall thickness of the slab. |
| NominalToppingThickness | IfcPropertySingleValue | IfcPositiveLengthMeasure / LENGTHUNIT | The nominal thickness of the topping. |

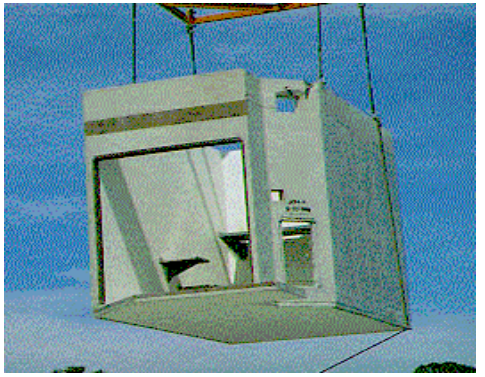
**National BIM Exchange Standards for Precast Concrete**

Missing IFC Entities and Relationships for Precast Concrete

***Slab with Elements – New IFC Entity***

IfcModule

IfcModuleType



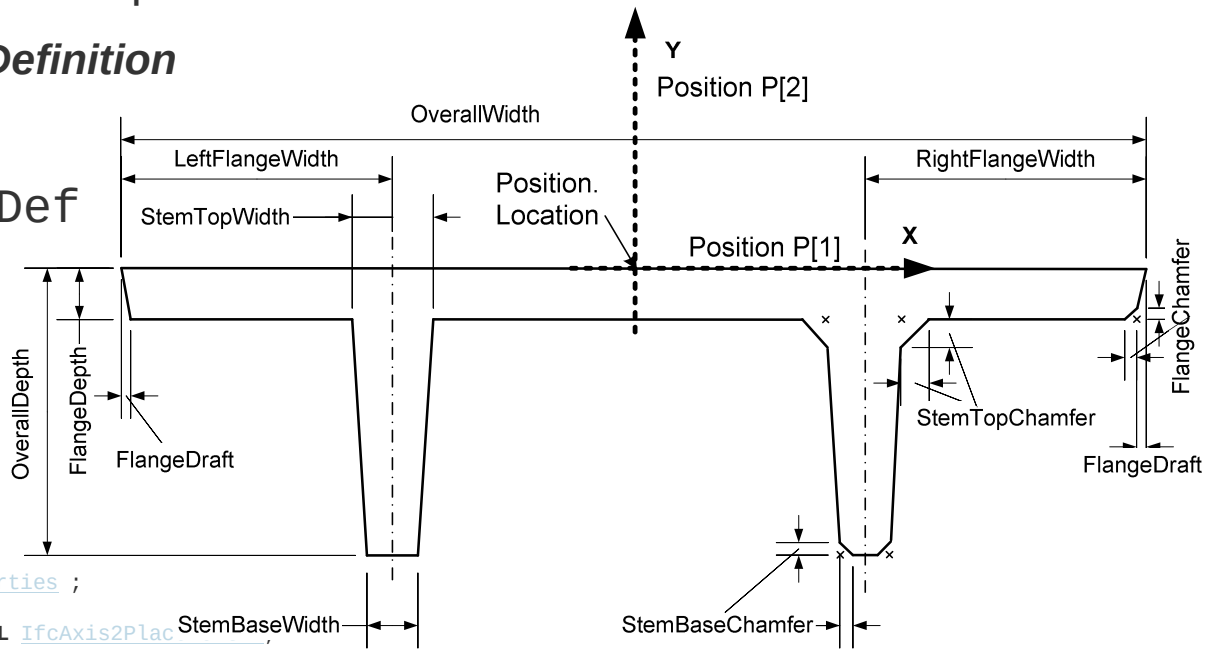
```
ENTITY IfcModule
SUBTYPE OF (IfcBuildingElement);
END_ENTITY;

ENTITY IfcModuleType
SUBTYPE OF (IfcBuildingElementType);
END_ENTITY;
```

# Missing IFC Entities and Relationships for Precast Concrete

## *Double Tee Parametric Profile Definition*

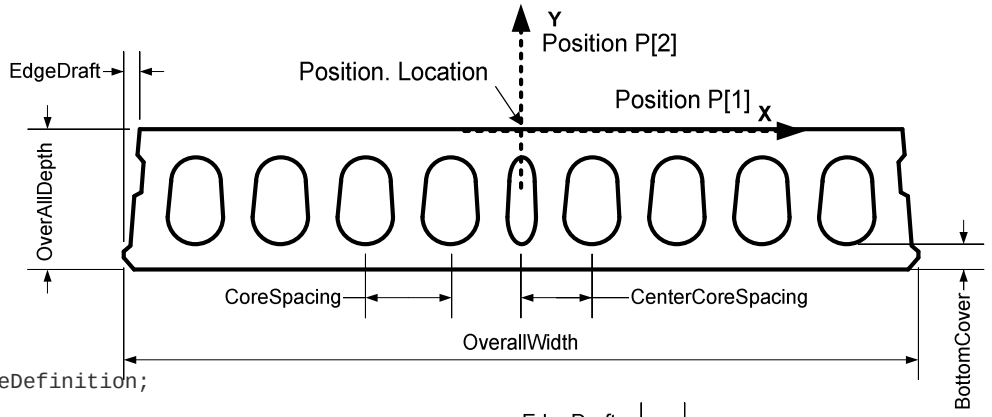
`IfcDoubleTeeShapeProfileDef`




```
ENTITY IfcDoubleTeeShapeProfileDef;
ENTITY IfcProfileDef;
ProfileType             : IfcProfileTypeEnum;
ProfileName             : OPTIONAL IfcLabel;
INVERSE
HasProperties           : SET OF IfcProfileProperties ;
ENTITY IfcParameterizedProfileDef
Position                          : OPTIONAL IfcAxis2Plac
ENTITY IfcHollowCoreShapeProfileDef;
   OverallWidth         :              IfcPositiveLengthMeasure;
   LeftFlangeWidth      :              IfcPositiveLengthMeasure;
   RightFlangeWidth:   IfcPositiveLengthMeasure;
   OverallDepth         :              IfcPositiveLengthMeasure;
   FlangeDepth          :              IfcPositiveLengthMeasure;
   FlangeDraft          :              OPTIONAL IfcPositiveLengthMeasure;
   FlangeChamfer        :              OPTIONAL IfcPositiveLengthMeasure;
   FlangeBaseFillet:   OPTIONAL IfcPositiveLengthMeasure;
   FlangeTopFillet      :              OPTIONAL IfcPositiveLengthMeasure;
   StemBaseWidth        :              IfcPositiveLengthMeasure;
   StemTopWidth         :              IfcPositiveLengthMeasure;
   StemBaseChamfer      :              OPTIONAL IfcPositiveLengthMeasure;
   StemTopChamfer       :              OPTIONAL IfcPositiveLengthMeasure;
   StemBaseFillet       :              OPTIONAL IfcPositiveLengthMeasure;
   StemTopFillet        :              OPTIONAL IfcPositiveLengthMeasure;
END_ENTITY;
```

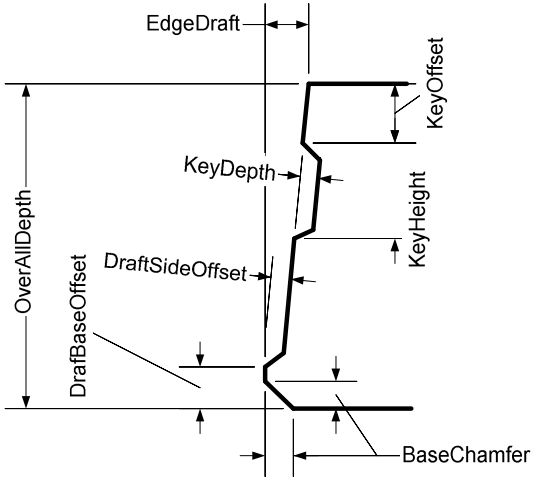
# Missing IFC Entities and Relationships for Precast Concrete

## *Hollow Core Parametric Profile Definition*



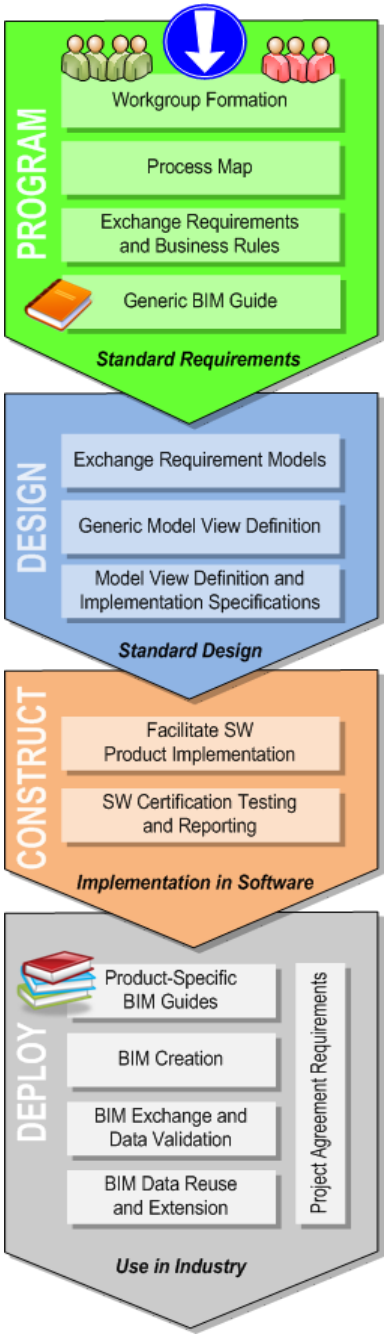

## IfcHollowCoreShapeProfileDef

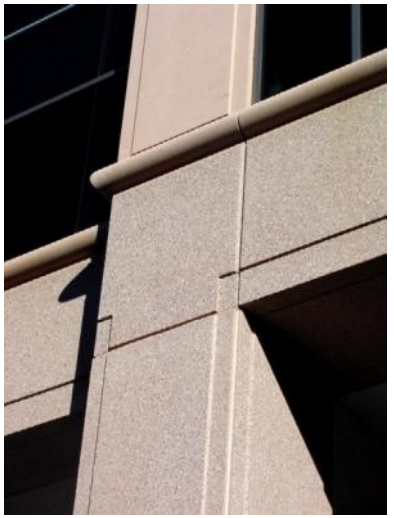
```
ENTITY IfcHollowCoreShapeProfileDef;
ENTITY IfcProfileDef;
ProfileType            : IfcProfileTypeEnum;
ProfileName            : OPTIONAL IfcLabel;
INVERSE
HasProperties          : SET OF IfcProfileProperties FOR ProfileDefinition;
ENTITY IfcParameterizedProfileDef
Position                              : 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;
```



## National BIM Exchange Standards for Precast Concrete

### *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*

Technion Israel Institute of Technology



The Charles Pankow Foundation

# Field testing

## 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.

Thanks for your attention. Questions ?

## Selected Publications

Eastman C, Sacks R and Lee G (2003) **Development and implementation of advanced IT in the North American precast concrete industry**, ITcon Vol. 8, pg. 247-262, http://www.itcon.org/2003/18

Kaner I, Sacks R, Kassian W, Quitt T (2008) **Case studies of BIM adoption for precast concrete design by mid-sized structural engineering firms**, ITcon Vol. 13, Special Issue Case studies of BIM use , pg. 303-323, http://www.itcon.org/2008/21

Jeong, Y.-S., Eastman, C.M., Sacks, R., Kaner, I., (2008). '**Benchmark Tests for BIM Data Exchanges of Precast Concrete**', Automation in Construction

Sacks, R., Kaner, I**.,** Eastman, C.M., and Jeong, Y-S., (2008). '**The Rosewood Experiment – Building Information Modeling and Interoperability for Architectural Precast Facades**', Automation in Construction

Eastman, C.M., Sacks, R., Kaner, I., Jeong, Y.-S., (2008). '**Exchange Model and Exchange Object Concepts for Implementation of National BIM Standards**', ASCE Journal of Computing in Civil Engineering