Developing Coverage Analysis for IFC Files

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http://www.nist.gov/el/msid/infotest/ifc-file-analyzer.cfm

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Introduction

- Conformance and interoperability testing
  - Necessary for reliable software implementations and to meet user's expectations for interoperability
- Either type of testing requires IFC test files
- IFC schema contains "a lot" of information concepts
  - 653 entities, 317 property sets, 164 enumerations
  - Multiple domains, attributes, materials, geometry, representations, "a lot" of combinations
- Infeasible to generate a comprehensive set of test files for the entire schema
- More feasible for subsets of the schema

Testing Projects

- IFC Certification process from 2007
  - 717 "Step 1" files (391 in building elements category)
  - 38 "Step 2" files of complete buildings
- Other IFC file exchange projects characterized by a common model with varying test criteria
  - Danish IAI IFC Exchange Test (simple building)
  - Precast Concrete Data Interoperability Benchmark Test
  - ATC-75 Project: Development of IFC for Structural Components (section of a stadium)
  - Re-Export Test (furnished house)
- Upcoming IFC Certification
- Testing of STEP application protocols

Coverage Analysis

- For effective testing, need methods and metrics to measure the coverage of information concepts in IFC test files

- "Improving Conformance and Interoperability Testing", Kindrick, Sauter, Matthews, in StandardView, March 1996

- Coverage Analysis for STEP files defined as:
  - Coverage of a test data set against a specification
  - Degree of coverage or completeness of a test suite against the test purposes
  - Percentage of all possible test purposes that are satisfied by the input data provides a measure of test-suite coverage over the stated testing objectives

Coverage Analysis
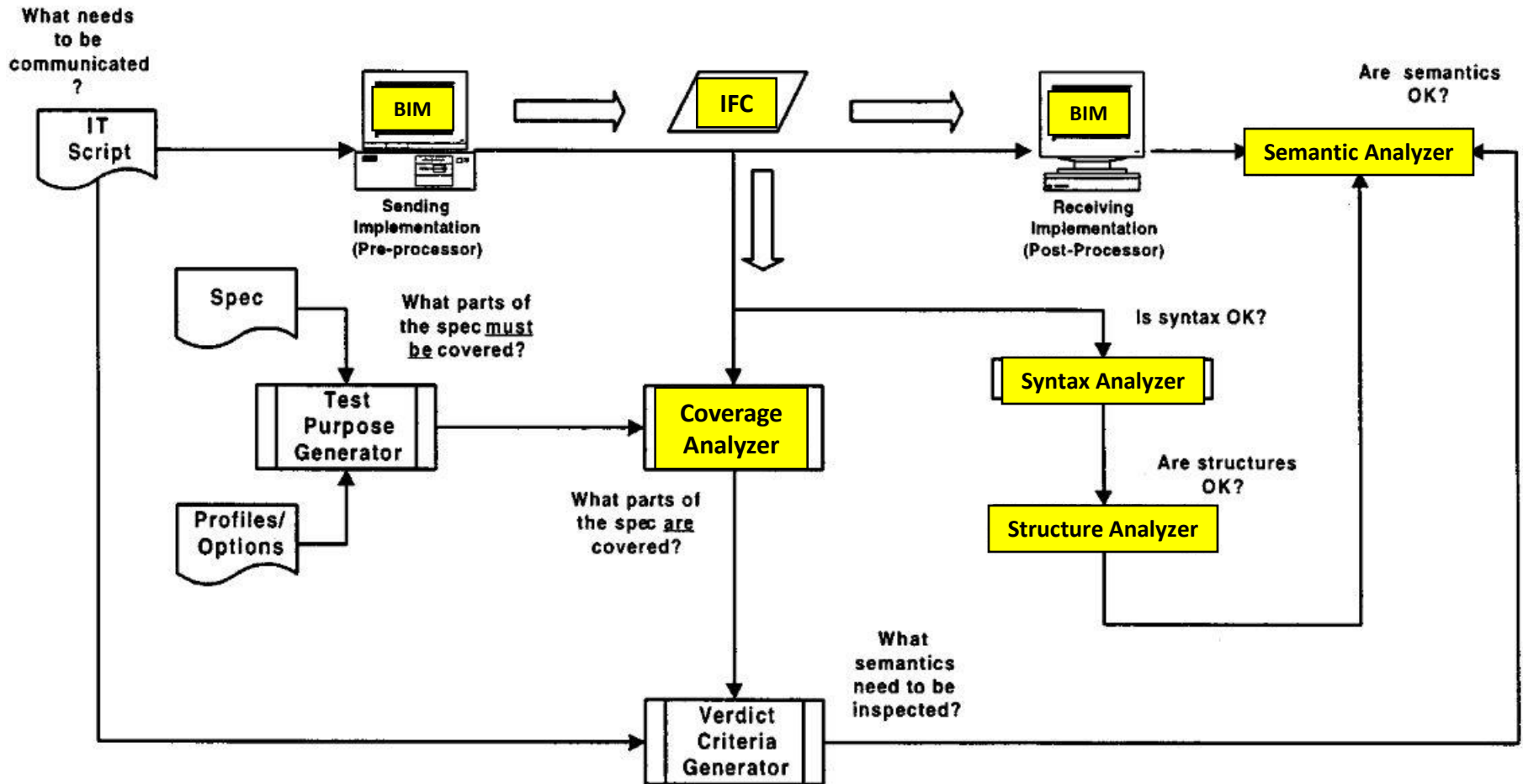
Coverage Analysis

- Borrowing from Kindrick and software industry code coverage analysis

- Principles of IFC coverage analysis:

  1. Finding which parts of the IFC schema or specific subset is covered by a set of test files and conversely which parts are not

  2. Help guide the generation of IFC test files to ensure a required level of coverage

  3. Identifying redundant test files that do not increase coverage

IFC File Analyzer

- Software application for Coverage Analysis of IFC files

- Reads single or multiple IFC files
  - Compare similar models from different IFC applications

- Generates an Excel spreadsheet
  - View all attributes at once rather than drilling down to values for an individual entity

- Uses IFCsvr to read and parse IFC files

- Live demo, Friday morning at the BIM workshop

IFC File Analyzer
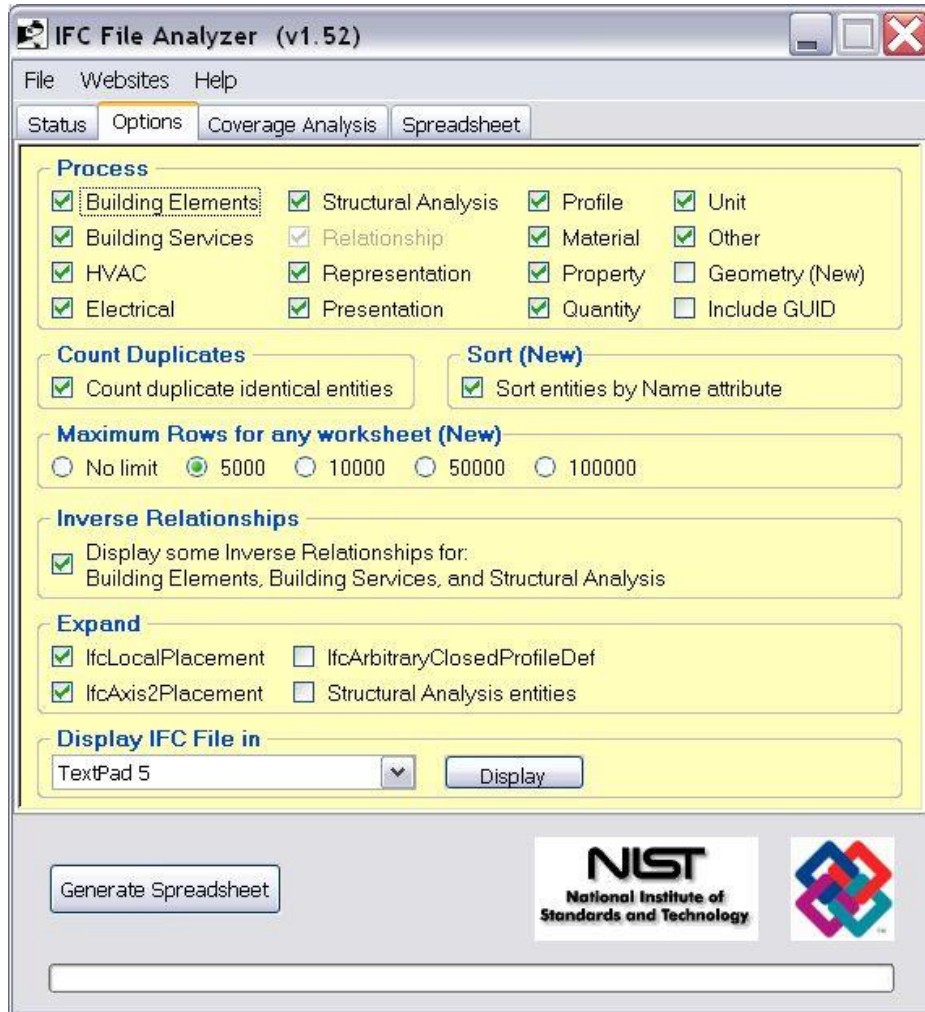
- Selectively process entity types

- Count duplicate entities

- Sort entities by Name attribute

- Limit maximum number of rows

- Display Inverse relationships

- Expand Placement entities

IFC File Analyzer

8	Entity	Count	Name	Description	ObjectType	Tag	ProfileName
9	IfcBeam	75	75	75	75	0	
10	IfcColumn	45	45	45	45	0	
11	IfcSlab	3	3	3	3	0	
12	IfcWall	5	5	5	5	0	
13	IfcArbitraryClosedProfileDef	8					8
14	IfcArbitraryProfileDefWithVoids	2					2
15	IfcExtrudedAreaSolid	124					
16	IfcGeneralProfileProperties	128					128
17	IfcIShapeProfileDef	93					0
18	IfcRectangleProfileDef	2					0
19	IfcPropertySet	128	128	0			
20	IfcPropertySingleValue	512	512	512			
21	IfcRelDefinesByProperties	128	128	128			
22	IfcMaterial	12	12				
23	IfcMaterialLayer	8					
24	IfcMaterialLayerSet	8					
25	IfcMaterialLayerSetUsage	8					
26	IfcRelAssociatesMaterial	12	0	0			
27	IfcGeometricRepresentationContext	2					
28	IfcProductDefinitionShape	128	0	0			
29	IfcShapeRepresentation	254					
30	IfcRelAggregates	3	0	0			
31	IfcRelContainedInSpatialStructure	1	0	0			
32	IfcPresentationLayerAssignment	4	4	0			
33	IfcSIUnit	9	9				
34	IfcUnitAssignment	1					
35	IfcApplication	1					
36	IfcBuilding	1	1	0	0		
37	IfcBuildingStorey	1	1	0	0		
38	IfcOrganization	1	1	0			
39	IfcOwnerHistory	1					
40	IfcPerson	1					
41	IfcPersonAndOrganization	1					
42	IfcProject	1	1	1	1		
43	IfcSite	1	1	0	0		

- Summary worksheet

- Entities grouped and colored

- Count for each entity

- Simple coverage analysis of the use of Name, Description, ObjectType, Tag, ProfileName attributes

IFC File Analyzer

	A	B	C	D	E
1	ID	Name	Description	ObjectType	ObjectPlacement
2	456	Concrete-Rectangular Beam:16 x 32:16 x 32:201801		Concrete-Rectangular Beam:16 x 32:201805	IfcLocalPlacement 443
3	600	Concrete-Rectangular Beam:12 x 24:12 x 24:201823		Concrete-Rectangular Beam:12 x 24:201844	IfcLocalPlacement 590
4	717	#W Shape:W18x35:W18x35:202828		#W Shape:W18x35:202831	IfcLocalPlacement 639
5	851	#W Shape:W18x35:W18x35:202845		#W Shape:W18x35:202848	IfcLocalPlacement 773
6	984	#W Shape:W14x22:W14x22:202868		#W Shape:W14x22:204327	IfcLocalPlacement 906
7	1184	#W Shape:W14x22:W14x22:203280		#W Shape:W14x22:204515	IfcLocalPlacement 1106
8	1315	#W Shape:W14x22:W14x22:204486		#W Shape:W14x22:204488	IfcLocalPlacement 1237
9	1378	Concrete-Rectangular Beam:12 x 24:12 x 24:204496		Concrete-Rectangular Beam:12 x 24:204516	IfcLocalPlacement 1368
10	1503	#Rectangular HSS:HSS6x4x3/8:HSS6x4x3/8:206088		#Rectangular HSS:HSS6x4x3/8:206118	IfcLocalPlacement 1417
11	1645	#Rectangular HSS:HSS6x4x3/8:HSS6x4x3/8:206194		#Rectangular HSS:HSS6x4x3/8:206226	IfcLocalPlacement 1562

F	G	H	I
Representation	Tag	INV-HasAssociations	INV-IsDefinedBy
IfcProductDefinitionShape 455	201801	(1) IfcMaterial 457	(8) IfcPropertySet 540 572 574 576 578 580 582 583
IfcProductDefinitionShape 599	201823	(1) IfcMaterial 457	(8) IfcPropertySet 604 621 623 625 627 629 631 632
IfcProductDefinitionShape 716	202828	(1) IfcMaterial 264	(11) IfcPropertySet 721 750 752 754 756 758 760 762 764 765 766
IfcProductDefinitionShape 850	202845	(1) IfcMaterial 264	(11) IfcPropertySet 855 883 885 887 889 891 893 895 897 898 899
IfcProductDefinitionShape 983	202868	(1) IfcMaterial 264	(11) IfcPropertySet 988 1014 1016 1018 1020 1022 1024 1026 1028 1029 1030
IfcProductDefinitionShape 1183	203280	(1) IfcMaterial 264	(11) IfcPropertySet 1188 1214 1216 1218 1220 1222 1224 1226 1228 1229 1230
IfcProductDefinitionShape 1314	204486	(1) IfcMaterial 264	(11) IfcPropertySet 1319 1345 1347 1349 1351 1353 1355 1357 1359 1360 1361
IfcProductDefinitionShape 1377	204496	(1) IfcMaterial 457	(8) IfcPropertySet 1382 1399 1401 1403 1405 1407 1409 1410
IfcProductDefinitionShape 1502	206088	(1) IfcMaterial 1504	(11) IfcPropertySet 1512 1539 1541 1543 1545 1547 1549 1551 1553 1554 1555
IfcProductDefinitionShape 1644	206194	(1) IfcMaterial 1504	(11) IfcPropertySet 1649 1676 1678 1680 1682 1684 1686 1688 1690 1691 1692

- IfcBeam worksheet, each row an entity, each column an attribute
- All attributes for all entities (except GUID, OwnerHistory)
- Inverse relationships

IFC File Analyzer

|	A	B	C	D	E	F	G
1	Entity	ArchiCAD	Bentley	Digital Project	Revit Building	Total Entities	Total Files
2	IfcBeam	16	9	34	18	77	4
3	IfcBuildingElementPart	3				3	1
4	IfcBuildingElementProxy	19	26		82	127	3
5	IfcColumn	31	4	15	5	55	4
6	IfcColumnType				2	2	1
7	IfcCurtainWall		42		4	46	2
8	IfcDoor	1	1		2	4	3
9	IfcFooting		15			15	1
10	IfcOpeningElement	12	90		8	110	3
11	IfcSlab	7	9	1	10	27	4
12	IfcStair	1	1		1	3	3
13	IfcStairFlight				1	1	1
14	IfcWall	4	3	3	5	15	4
15	IfcWallStandardCase	14			4	18	2
16	IfcWindow	4				4	1
17	IfcArbitraryClosedProfileDef	43	43		16	102	3
18	IfcArbitraryProfileDefWithVoids		7		1	8	2
19	IfcCircleProfileDef		2		2	4	2
20	IfcExtrudedAreaSolid	74	164		33	271	3
21	IfcRectangleProfileDef	31	112		14	157	3
22	IfcComplexProperty	98			60	158	2
23	IfcDoorLiningProperties	1			2	3	2
24	IfcDoorPanelProperties	2			2	4	2
25	IfcDoorStyle	1	1		2	4	3
26	IfcMechanicalConcreteMaterialProperties			1		1	1
27	IfcMechanicalSteelMaterialProperties			1		1	1
28	IfcPropertySet	98	8		362	468	3
29	IfcPropertySingleValue	392	67		1516	1975	3
30	IfcRelDefinesByProperties	98	8		362	468	3
31	IfcWindowLiningProperties	4				4	1
32	IfcWindowPanelProperties	4				4	1
33	IfcWindowStyle	4				4	1
34	IfcMaterial	3	26	2	3	34	4
35	IfcMaterialLayer	22			5	27	2
36	IfcMaterialLayerSet	22			5	27	2
37	IfcMaterialLayerSetUsage	22			6	28	2
38	IfcMaterialList	1				1	1
39	IfcRelAssociatesMaterial	96	26		9	131	3

- Summary for multiple IFC files

- Entity counts per IFC file

- Total entity counts over all files

- Entity coverage by different apps for the same structure

- Entities used by some apps that are not used by others

Coverage Analysis Examples

- Entity and attribute coverage

- Parametric profile offset

- Precast Concrete Model View Definition (MVD) concepts

Parametric Profile Offset

- Parametric profile (I-beam, channel, angle) offset important for modeling structural steel
- **IfcParameterizedProfileDef.Position** > **IfcAxis2Placement2D.Location** > **IfcCartesianPoint**
- Test file with all parametric profiles and non-zero offsets (IfcCartesianPoint)
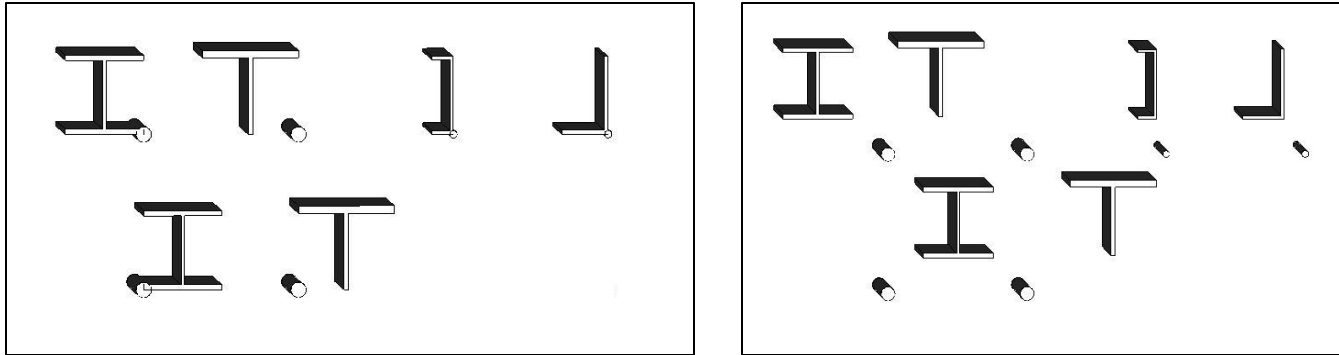
- Most IFC apps and viewers got it wrong (right side)
- 98 "Step 1" IFC files with parametric profiles for IfcColumn, IfcBeam, and IfcRailing
- Coverage Analysis showed only three files had profiles with a profile offset
- Without Coverage Analysis there would be no way to know that the concept was tested in those three files
- Shows the need to generate IFC test files to test specific concepts

MVD Concepts

- Model View Definition (MVD) defines the IFC implementation of information exchange requirements in an Information Delivery Manual (IDM)

- MVDs for many domains
  - Precast Concrete
  - Quantity Takeoff
  - Handover for FM
  - Energy Performance Analysis

- Precast Concrete has over 110 MVD Concepts such as:
  - Site Contained in Project
  - Element Type Assignment
  - Precast Blockout Assignment
  - Precast Concrete Wythe Aggregation
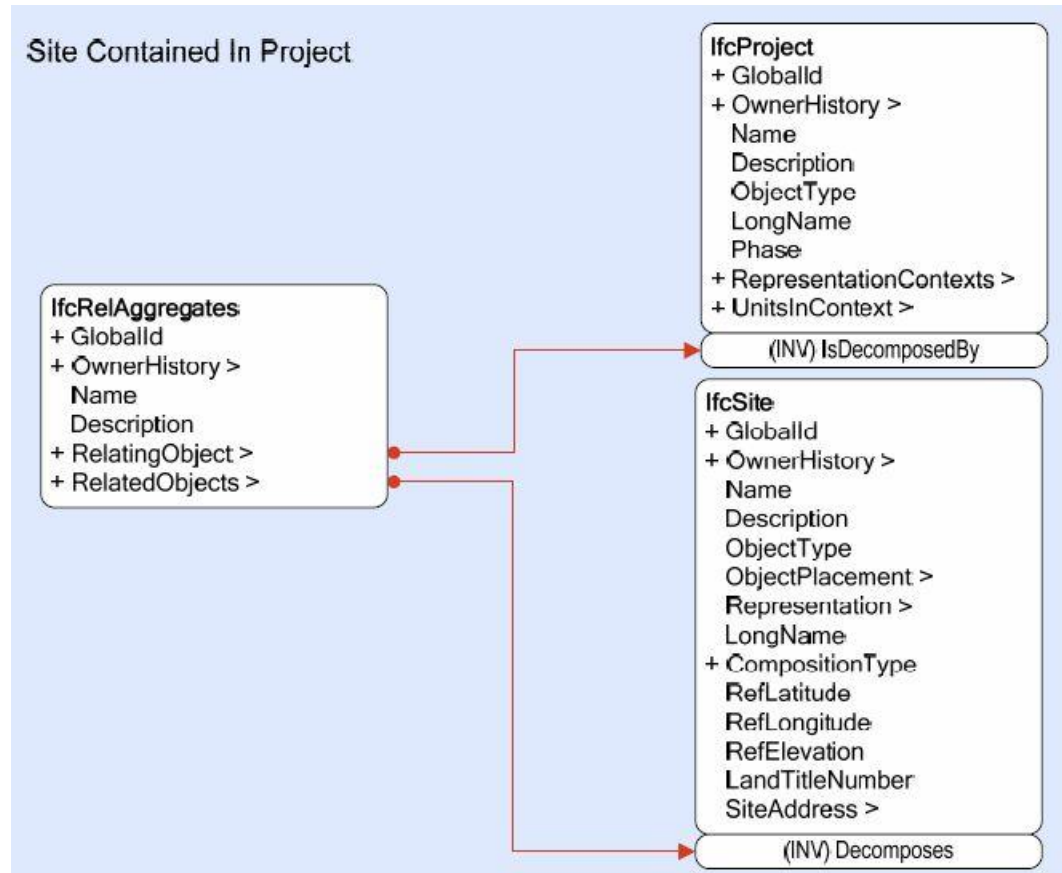
MVD Concepts

- Initial classification of MVD Concepts
  1. Relationship – association of two types of entities through IfcRelationship
     - IfcRelAggregates relates IfcSite to IfcProject
  2. Attribute – entity attribute must exist
     - IfcProject.Name must have any name
  3. Attribute Value – entity attribute must have a specific value
     - IfcSite.Name must be named "Giza"

- Combinations of the above
- Concepts related to geometry and placement

- 60 of the Precast Concrete MVD Concepts use one of the three classifications

MVD Concepts

- IFC File Analyzer checks for the three classes of MVD Concepts
- Reports results per entity, file, or set of files

	Entity	Count	Name	Description	ObjectType	Tag	MVD-PCI
2	IfcColumn	1	1	1	1	1	PCI-067
3	IfcPropertySet	2	2	2			PCI-056 PCI-057
4	IfcPropertySingleValue	8	8	8			PCI-056 PCI-057
5	IfcRelDefinesByProperties	3	3	3			PCI-055 PCI-155
6	IfcQuantityArea	1	1	0			PCI-155
7	IfcQuantityLength	1	1	0			PCI-155
8	IfcQuantityVolume	1	1	0			PCI-155
9	IfcQuantityWeight	1	1	0			PCI-155
10	IfcRelAssociatesMaterial	1	0	0			PCI-061
11	IfcRelAggregates	3	3	0			PCI-042 PCI-043 PCI-044
12	IfcRelAssignsToActor	1	1	1			PCI-060
13	IfcRelAssociatesApproval	1	1	1			PCI-059
14	IfcRelContainedInSpatialStructure	2	0	0			PCI-049 PCI-062
15	IfcRelDefinesByType	1	0	0			PCI-054

- At least one entity satisfies its requirement in an MVD Concept

MVD Concepts

#	MVD-PCI	PCI IFC test file 02	PCI IFC test file 03	PCI IFC test file 04	PCI IFC test file 05	PCI IFC test file 06	PCI IFC test file 07	PCI IFC test file 08	PCI IFC test file 09	PCI IFC test file 14	PCI IFC test file 15
3	MVD-PCI										
4	040 Precast Slab Aggregation				X						
5	042 Site Contained in Project	X	X	X	X	X	X	X	X	X	X
6	043 Building Contained in Site	X	X	X	X	X	X	X	X	X	X
7	044 Building Storey Contained in Building	X	X	X	X	X	X	X	X	X	X
8	045 Space Contained in Building										
9	046 Space Contained in Building Storey										
10	047 Grid Name	X									
11	048 Grid Representation										
12	049 Grid Spatial Structure Containment	X									
13	050 Grid Axis Assignment										
14	052 Placement Relative to Grid										
15	053 Element Attributes										
16	054 Element Type Assignment	X	X	X	X	X	X	X	X		X
17	055 Precast Property Set Assignment	X	X			X	X	X			X
18	056 Precast General Attributes	X									
19	057 Precast Fabrication Attributes	X									
20	058 System Piece Aggregation										
21	059 Approval Assignment	X		X	X				X		
22	060 Actor Assignment	X		X	X				X		
23	061 Precast Piece Material Association	X	X	X	X		X		X		X
24	062 Precast Piece Containment	X	X	X	X		X	X	X		X
25	063 Relative Placement										
26	064 Absolute Placement										
27	066 Generic Brep Shape Geometry										
28	067 Precast Piece Mark	X	X	X	X	X	X	X	X	X	X
29	068 Extruded Geometry										
30	069 Arbitrary Precast Profile										
31	070 Arbitrary Precast Profile with Voids										

- Results per file, i.e. which file has at least one instance of that MVD Concept

- Currently no differentiation between concrete and other materials

- 1000 of MVD Concepts over many IDMs

- How to specify MVD Concepts in a computer processable form?

Conclusions

- Definition of Coverage Analysis

- IFC File Analyzer – Analysis of single or multiple IFC files

- Coverage of MVD Concepts

- Objective vs. Subjective Coverage Analysis

- Coverage Analysis as part of a testing methodology that includes:
  - Well-defined models (dimensions, materials, relationships, etc.)
  - Description of the attributes that the models test
  - Reference IFC file of the model
  - Test criteria to measure the characteristics of the IFC and results of importing to BIM software
  - Testing tools and how they are used to measure the test criteria