

openBIM standards for geotechnic information exchange

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ABSTRACT

The Industry Foundation Classes (IFC) is an ISO standard published for information exchange in the built environment. The standard has recently been enhanced to better support geotechnic objects and relationships, particularly in the context of infrastructure projects. This paper will explain the purpose of openBIM, the collaboration that it can facilitate, and the benefits derived from openBIM exchange. The paper also offers a description of IFC improvements to facilitate geotechnic collaboration, such as recording site investigation and interpretation. Relevant existing concepts in IFC include classification, geometric description, spatial containment, property sets and quantity take offs.

Keywords: openBIM, IFC, BIM, Interoperability, Standards, Software

1 INTRODUCTION

Project actors (designers, surveyors, builders, and technologist) are increasingly authoring digital models of the built environment. Commonly referred to as Building Information Models (BIM), they are typically stored in specialist, bespoke databases or data models unique to the preferred software of the actor.

Digital collaboration is constrained when not facilitated by openBIM data exchange, as the recipient would require the same specialist software to access the model information.

This paper outlines the latest improvements to the openBIM data model "Industry Foundation Classes" (IFC).

2 BACKGROUND

2.1 Interoperability

Interoperability is the ability to exchange data between applications or process and make use of the information. Without interoperability, users must manually transcribe information from one application to utilize in another application. In the construction industry, exchanging data has always had high importance due to the complexity of projects with specialist actors working in tandem to achieve complex outcomes. Data can be exchanged using Application Programming Interfaces (API), proprietary data formats of software vendors, or neutral formats or standards (Eastman et al., 2011).

Open data standards have an important role in the construction industry because they facilitate innovation and competition within the software market, and protect the market from vendor lock-in (Borrmann et al., 2018). Open data standards reduce risk of loss of project data over the long term when a vendor might be lost to industry for any number of reasons.

Created and maintained by buildingSMART International, the Industry Foundation Classes are the pre-eminent standard for exchanging information for the construction industry.

The Industry Foundation Classes IFC specification is registered as ISO 16739.

To date, the Industry Foundation Classes data model has specifically targeted building projects, but the latest version (IFC4.3) has been enhanced to better support infrastructure projects, in particular the domains of Roads, Rail and Ports/Waterways.

This paper will identify enhancements of the standard that relate to the field of geotechnic information exchange.

A compelling explanation on the importance of interoperability is found a promotional video (Bourke J., 1994)

2.2 Compatibility

The Industry Foundation Classes support multiple domains of the built environment, to support information exchange across these domains. Domain focused data models are typically more detailed and efficient at exchanging more specialist data within the domain.

Alternative standards such as AGS Format (including interpreted ground models) will likely remain a superior choice for information exchanges within geotechnical participants, and IFC more typically used for exchanges outside the geotechnical domain.

Reuse of common concepts across multiple domains can constrain most efficient modelling practise specific to an individual domain.

It is expected that industry bodies, including AGS, OGC and buildingSMART will endeavour to ensure high compatibility between these data model alternatives.

3 INDUSTRY FOUNDATION CLASSES

3.1 Object Oriented Classes

IFC is a data model using an object-oriented approach, with single inheritance. Each concept has attributes and relationships. Geometric representation and semantic description in the built environment can be nominated using these attributes and relationships.

3.2 Serialization

There are two official text serializations of IFC data sets for saving content to text, "Standard for the Exchange of Product model data" (STEP) and Extensible Markup Language (XML). Other technologies have been utilized, such as JavaScript Object Notation (JSON) or Structured Query Language (SQL) but are not yet published as official technologies.

STEP physical files is the typical and dominant serialization, utilizing a ".ifc" file extension. It is an efficient text serialization using line number references for relationships to other concepts (Figure 1).

XML is a more modern serialization which is more easily understood by humans due to attribute name identification and nesting (Figure 2). The file size suffers from the additional attribute name identification and the use has been constrained due to the file resultant file size.

Text file serialization offers long term data security as it is least likely to become a lost technology. Any human user can open a STEP or XML file in notepad or a text editor, however, a human may have difficulties in interpreting it correctly. Text serialization is less efficient than binary encoding. Resultant file sizes can be unacceptable, but the ifc file can be compressed into a zip file and saved with a file extension "ifczip". Zipping an IFC file can achieve file size reductions in the order of 20% to 50%.

```
#22=IFCCARTESIANPOINT((0.,0.,0.));
#23=IFCAXIS2PLACEMENT3D(#22,#21,#20);
#24=IFCLOCALPLACEMENT($,#23);
#25=IFCSITE('02FkWai_532fIiNwUn3e40',#9,'Site_1',$,$,#24,$,$,.ELEMENT.$,$,$,$,#2);
#26=IFCPROJECT('2Z5iVSY21A5BDQap9aMYN_',#9,'Alignment-Aplitop-1','',$,$,$,$,#14);
#27=IFCRELAGGREGATES('11AfS8jBjDmR$WPSQBvIFd',#9,$,$,#26,(#25));
#28=IFCROAD('1YqzGB3UT6iv9rSn3ZiChz',$,$,'Some road',$,'IfcRoad',$,$,$,$,.COMPLEX.$,$);
#29=IFCRELAGGREGATES('3ovWpuZRj6SgHHC$37HFxe',#9,$,$,#25,(#28));
#30=IFCALIGNMENT('0jf_kMZ$nZcvfW8BjN2_gf',$,$,'Alignment1',$,$,#24,$,$);
#31=IFCALIGNMENTHORIZONTAL('0IfcjsZ$nE2v5xfcXk_T0i',$,$,'Alignment1',$,$,#24,$,$.0.);
#32=IFCRELNESTS('0EnDoLEyj8c9WsNDJc2NsV',#9,$,$,#30,(#31,#80));
#33=IFCALIGNMENTSEGMENT('0wbpE5Ppv2h8YpAmz1jvCt',$,$,$,#24,$,$,#35);
#34=IFCCARTESIANPOINT((335085.95782221,4084594.13214501));
#35=IFCALIGNMENTHORIZONTALSEGMENT($,$,#34,6.24482463878552,0.,0.,10.,$,$.LINE.);
#36=IFCALIGNMENTSEGMENT('3GuFB_j892ogFRXkUKFjOT',$,$,$,$,#24,$,$,#38);
#37=IFCCARTESIANPOINT((335095.95046541,4084593.74863239));
#38=IFCALIGNMENTHORIZONTALSEGMENT($,$,#37,6.24482463878552,25.,25.,39.84063746,$,$.CIRCULARARC.);
#39=IFCALIGNMENTSEGMENT('3d1079w0TExBB5SBeqnxzs',$,$,$,$,#24,$,$,#41);
#40=IFCCARTESIANPOINT((335121.90623167,4084618.34196855));
```

Figure 1. Sample of STEP Physical File serialization

```
46 <IfcRelContainedInSpatialStructure GlobalId="3_GokZQqz3AfM$ckWYLAN4">
47 <RelatedElements>
48 <IfcAlignment GlobalId="0jf_kMZ$nZcvfW8BjN2_gf" Name="Alignment1">
49 <IsNestedBy>
50 <IfcRelNests GlobalId="0EnDoLEyj8c9WsNDJc2NsV">
51 <OwnerHistory xsi:nil="true" href="i9" />
52 <RelatedObjects>
53 <IfcAlignmentHorizontal GlobalId="0IfcjsZ$nE2v5xfcXk_T0i" Name="Alignment1"
StartDistAlong="0">
<IsNestedBy>
<IfcRelNests GlobalId="1ybgUMDlb60x4Z8Z8W39S$">
<OwnerHistory xsi:nil="true" href="i9" />
<RelatedObjects>
<IfcAlignmentSegment GlobalId="0wbpE5Ppv2h8YpAmz1jvCt">
<ObjectPlacement xsi:nil="true" href="i24" />
<GeometricParameters xsi:type="IfcAlignmentHorizontalSegment" StartDirection="
60 6.24482463878552" StartRadiusOfCurvature="0" EndRadiusOfCurvature="0"
SegmentLength="10" PredefinedType="line">
<StartPoint xsi:type="IfcCartesianPoint" Coordinates="335085.95782
4084594.13215" />
</GeometricParameters>
</IfcAlignmentSegment>
<IfcAlignmentSegment GlobalId="3GuFB_j892ogFRXkUKFjOT">
<ObjectPlacement xsi:nil="true" href="i24" />
<GeometricParameters xsi:type="IfcAlignmentHorizontalSegment" StartDirection="
64 6.24482463878552" StartRadiusOfCurvature="25" EndRadiusOfCurvature="25"
65 SegmentLength="39.84063746" PredefinedType="circulararc">
66
```

Figure 2. Sample of Extended Markup Language Serialization (XML)

3.3 Model View Definitions

IFC is a comprehensive data model that requires considerable effort to support in full. It covers several domains and disciplines, and, for example, an application or process considering cost or quantity take offs for a model, does not require to interpret structural analysis features of a model (i.e. restraints or load features).

To permit specific and focussed implementations, a model view definition (MVD) relates to a use case of BIM interoperability or exchange. This will nominate concepts that are required to facilitate this exchange, and concepts that are prevented from facilitating the exchange. This includes constraint on geometric descriptions such as non-uniform rational b-splines being prevented or only triangulated face set being necessary.

There are three key model view definitions offered by buildingSMART, with other derivations or alternatives in progress or offered by others. IFC2x3 Coordination view is the dominant MVD still in use today. IFC4 Reference View is a more constrained MVD focussing on visualization or model reference using constrained tessellation geometry definitions. IFC4 Design Transfer View offers semantic or intelligent descriptions of models but has not progressed from a draft status, primarily due to difficulties in agreement on semantic concepts that should or should not be included.

4 INDUSTRY FOUNDATION CLASSES CONCEPTS

IFC has been the standout openBIM data model for buildings in the past decade for buildings. In infrastructure projects, alternatives such as landXML or GENIO. IFC offers several concepts that are not adequately offered in these alternatives and IFC4.3 release improved IFC in many key aspects needed for infrastructure project interoperability.

Detailed explanations of useful BIM concepts contained in IFC are described by Borrmann et al. (2018) and will only be highlighted in this paper with infrastructure context for insights and comparisons.

4.1 Spatial Structure

Spatial structure within IFC is a project hierarchy about how to locate an element or system. In a building sense, it might be a room (IfcSpace) on a building storey (IfcBuildingStorey) within a building (IfcBuilding) on a site (IfcSite). In an infrastructure sense, it might be on a median (IfcRoadPart) on a corridor (IfcRoadPart), or on a road facility (IfcRoad).

4.2 Material

IFC offers comprehensive standard descriptions and attributes of materials that can be assigned to products (or components of products).

4.3 Geometric Description

A key component to BIM in contrast to alternative Information Models is the expectation that geometric descriptions of products will be provided in typically 3-dimensional context. Actors interacting with BIM can have the ability to traverse the model in a virtual environment.

IFC offers a variety of shape descriptions, including constructive solid geometry, sweeps and NURBS boundary representations. There is a trade-off in that the more complex semantic descriptions seem to have less consistent implementation/support by software vendors.

Most BIM models are dominated by extrusion or primarily faceted geometry, which are the most reliable geometry, or the use case permits approximate faceted geometry to be utilized.

4.4 Placement

IFC elements have a placement/position relative to the element above it in the spatial or aggregation hierarchy.

4.5 Property Sets

IFC objects have attributes that have been identified as standard/typical. Sets of properties are utilized to define element features not nominated as an attribute.

Each IFC specification nominates "standard" sets of properties for common elements (example, fire rating).

Clients / Projects may define or refine the definitions of the properties and at what stages of a project they should be provided.

IFC offers a comprehensive set of measure types to define property values.

4.6 Quantity Sets

An element can be exchanged with a set of derived measures for quantity take off to permit planning or costing of the project. Measures can be of a count, weight, length, area, volume or time nature.

4.7 Classification

IFC offers a built-in classification system to identify concepts (i.e. IfcSite, or IfcStair). This classification is comprehensive, but it is observed that many clients/agencies either have an in-house classification system, or a common classification system such as Uniclass2015.

IFC permits multiple classifications to be nominated within the data model.

4.8 Types and Instancing

IFC offers a relationship of a common type relating to multiple instances. Elements with common characteristics may have the common features applied to a relating type, which is related to all appropriate instances. This includes a common geometry description, which is transformed into individual product placements.

4.9 Systems

A system is an organized combination of related products, grouped for a common purpose or function. As an example, a group of elements might comprise a building foundation system.

4.10 Georeferenced Model

An IFC data set is typically defined in the context of a project local engineering coordinate system. This coordinate system can be located relative to a projected coordinate system such as EPSG.

5 INFRASTRUCTURE ENHANCEMENTS

Over the past 5 years, a core team of stakeholders and technical resources, including software implementers, have worked on advancing the Industry Foundation Classes to better support exchange concepts required for infrastructure projects. This paper will now outline the key concepts revised or added to the standard for release IFC4.3 relating to Geotechnical and other enhancements.

Specialist domain characteristics are less likely to be explicitly nominated within IFC. More typically, the concepts respond to requirements of exchanging data across discipline or domain, for example, from

geotechnical interpretation of bearing pressures to engineer or contractor for foundation design or review. Geotechnical interpretation might be overlaid with alignment design software to influence choices with respect to earth conditions encountered (Figure 3).

5.1 Geotechnical

The fundamental product introduced for Geotechnical elements in IFC4.3 is `IfcGeotechnicalElement`. The first subclass of `IfcGeotechnicalElement` is `IfcGeotechnicalAssembly` which in turn has subclasses, `IfcBoreHole`, `IfcGeomodel` and `IfcGeoslice`. The second subclass of `IfcGeotechnicalElement` is `IfcGeotechnicalStratum`. The stratum class has predefined types of Solid, Water and Void.

Property sets have been introduced, such as `GeotechnicalStratumCommon` featuring individual properties `Stratum Colour`, `Is Topographic`, `Piezometric Head`, `Piezometric Pressure`, `Status` and `Texture`.

Another solid stratum property set introduced is `SolidStratumCapacity` which features properties `Cohesive Behaviour`, `Friction Angle`, `Friction Behaviour`, `GrainSize`, `Hydraulic Connectivity`, `Load Bearing Capacity`, `N Value` `Permeability Behaviour`, `Poissons Ratio`, `Pwave Velocity`, `Resistivity`, `Settlement Behaviour`, `Swave Velocity`.

An additional solid stratum property set introduced is `SolidStratumComposition` which features properties `Air Volume`, `Boulders Volume`, `Clay Volume`, `Cobbles Volume`, `Containment Volume`, `Fill Volume`, `Gravel Volume`, `Organic Volume`, `Rock Volume`, `Sand Volume`, `Silt Volume`, `Water Volume` and `Composite Fractions`.

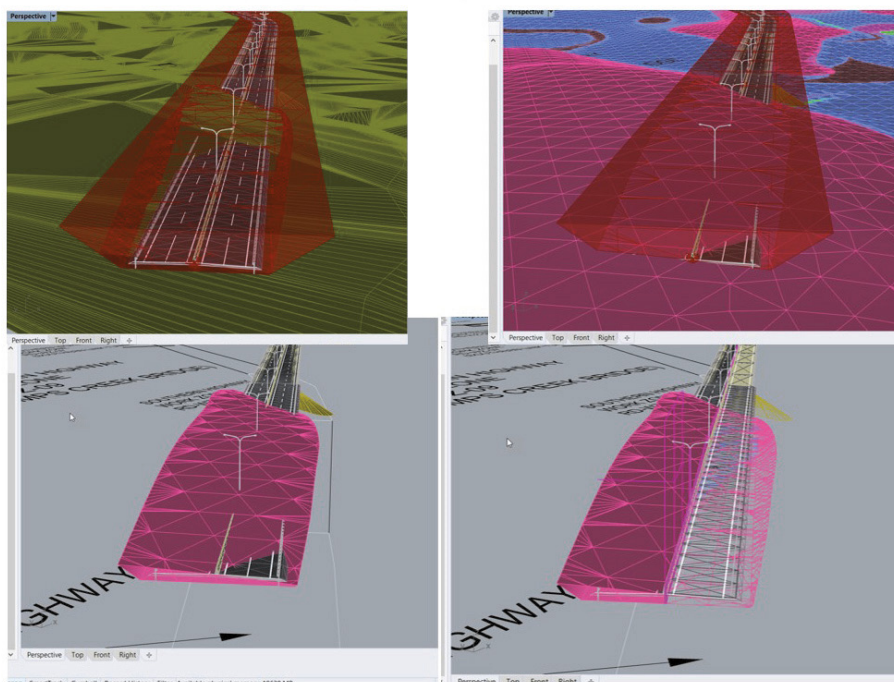


Figure 3. Demonstration of Geotechnical Site interpretation in tandem with linear infrastructure setout.

A property set introduced for boreholes feature properties State, Cap Depth, Cap Material, Filling Depth, Filling Material, Groundwater Depth, Lining Material, and Lining Thickness.

An Uncertainty property set has been introduced to nominate uncertainty in measurements and relate how the uncertainty was assessed.

5.2 Alignments

Alignments are the key concept to define and set out a linear infrastructure project, or also components of an infrastructure project, such as drainage or transmission distribution lines.

Alignments are semantically defined as a series of projections. As a horizontal curve to describe the path. A vertical profile is projected onto the horizontal curve to define elevation and grade. For railway projects, cant (track inclination to compensate for lateral accelerations) can be exchanged.

5.3 Linear Placement

Linear infrastructure projects often utilize a linear placement to locate assets using an alignment with a longitudinal location typically referred to as a chainage or station. Lateral and vertical offsets from this linear point can define a product placement. IFC4.3 permits a geometric placement in addition to a semantic relationship.

5.4 Sectioned Shapes

Tessellated or faceted geometry can quickly accumulate file size in serialization, in particular when writing to text. Sectioned shapes have been introduced with other advanced sweeps to facilitate efficient geometric description of rails or other longitudinal geometry. Figure 4 visualizes the sectional profile shapes and the resultant surface from the resultant sweep.

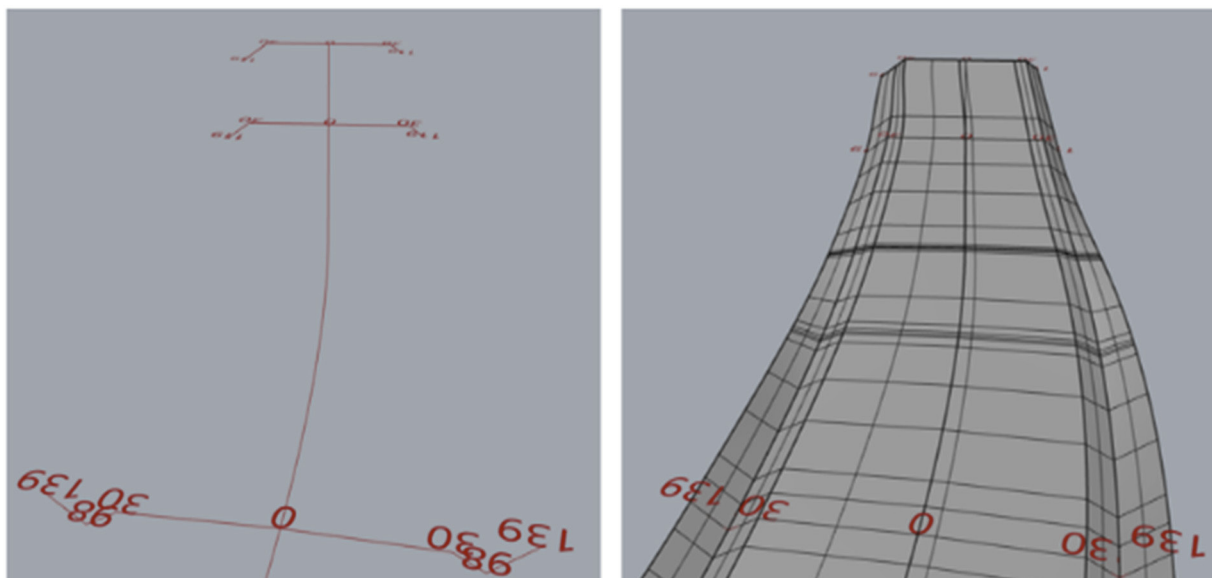


Figure 4. Demonstration of sectioned shape to nominate geometric road surface.

5.5 Earthworks

Explicit products have been introduced in IFC4.3 to nominate earthworks elements, including cut and fill elements with volumes.

5.6 Classification

Classes have been added to the domains for Rail, Road, Ports/Waterways and common infrastructure projects to denote facilities, facility parts and the elements that comprise them. This includes spatial breakdown as a combination of longitudinal, lateral and/or vertical hierarchy.

6 FUTURE EXTENSION OF IFC

The IFC4.3 extension project did not cover all the desired exchanges for infrastructure and geotechnical requirements. At the time of writing this paper, a project to further enhance IFC4.3 with a focus on tunnels was nearing conclusion, with an anticipated IFC4.4 release to be published. This includes refinement of concepts such as geo referencing model placement.

As IFC4.3 is implemented, supported and utilized, it is expected that other improvements will be identified and submitted to buildingSMART for consideration in future versions of the standard.

7 CONCLUSION

IFC offers a comprehensive data model to facilitate data interoperability for the built environment, and recent IFC4.3 improvements make it a first class solution for infrastructure projects. Building projects will also benefit from improvements relating to geotechnical data exchange.

IFC might not be the data model of choice for advanced interoperability between specialist geotechnical software or processes, although it can facilitate that with bespoke or agreed properties.

IFC is a first class solution for data interoperability for cross discipline or domain information exchange.

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