Test Suite for Building Energy Analysis of Conceptual Spatial Layout

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1. INTRODUCTION

1.1 Purpose

This report documents a test suite for validation and conformance testing in support of the interoperability among building design and energy analysis applications.

The objectives of this test suite are to:

- Provide to software vendors test cases to evaluate their software implementations of Building Performance and Energy Analysis (BPEA) data exchange specifications and to ensure that their implementations are correct;
- Provide to industry test cases and guidance for conformance testing and interoperability testing;
- Contribute to the validation of the draft BPEA data exchange specification (and its components) for satisfaction of specified requirements and fulfillment of its intended purposes, and
- Identify needed improvements in the draft BPEA data exchange specifications.

The intended audience for this document includes developers of building information modeling (BIM) software and energy analysis applications as well as researchers and industry organizations working on achieving interoperability among these software and applications.

1.2 Scope

This test suite defines a test plan and test cases with verdict criteria for the concepts and data structures regarding spatial layout for energy analysis documented in the BPEA specification. The concepts in BPEA data exchange specification include:

- Conceptual spatial layout (covered in this test suite)
  - Project, site, building, and building element information
- Energy and Performance (not covered in this test suite)
  - Energy targets, ventilation, and thermal-related information
- Analysis Results (not covered in this test suite)
  - Energy analysis and cost information

Details about the three categories of data exchange specifications are provided in section 3.1.1.

Recognizing that exhaustive conformance and interoperability testing is not practical, this test suite is designed to cover selected combinations of concepts in the BPEA conceptual spatial layout specification to provide a maximum initial coverage and to be sufficient to support the objectives listed above. At the next stage the test suite should be expanded for a complete coverage of the concepts in the BPEA data exchange specifications.

DISCLAIMER: Any mention of commercial products or trade names does not imply recommendation or endorsement by NIST.
2. **Acronyms and Definitions**

**AECOO:** Architecture, Engineering, Construction, Owner and Operator  
**ASHRAE:** American Society of Heating, Refrigerating and Air-Conditioning Engineers  
**BIM:** Building Information Model / Modeling  
**BPEA:** Building Performance and Energy Analysis  
**CAD:** Computer Aided Design  
**CAE:** Computer Aided Engineering  
**CEC:** California Energy Commission  
**GSA:** U.S. General Service Administration  
**IAI:** International Alliance for Interoperability  
**IDM:** Information Delivery Manual  
**IFC:** Industry Foundation Classes  
**LBNL:** Lawrence Berkeley National Laboratory  
**MVD:** Model View Definition  
**NIST:** National Institute of Standards and Technology  
**OGC:** Open Geospatial Consortium  

**Postprocessor:** A software unit that translates product information from a product data exchange format to the internal format of a software application.  
**Preprocessor:** A software unit that translates product information from the internal format of a software application to a product data exchange format.  

**Space boundaries:** Virtual objects that are used to calculate quantities for various forms of analysis (including quantity take-off for cost estimating and energy analysis) related to spaces or rooms in buildings [10].  

**1LSB:** First **Level Space Boundaries**, boundaries of a space defined by the surfaces of building elements bounding this space (physical space boundaries) or by virtual surfaces provided by an adjacent space with no dividing wall [10].  

**2LSB:** Second **Level Space Boundaries**, boundaries of a space defined by the surfaces of building elements bounding this space, but are subdivided in any of the following cases: 1. differences in materials and/or material assemblies; 2. differences in spaces or zones on the other side of the building element (e.g. two different spaces on the other side of a wall) [10]. Differentiation between physical or virtual is the same as for 1LSB. There is also a differentiation within 2LSB based on what kind of element is on the other side of the space boundary: it is type “2a” when the other side is a space; it is type “2b” when the other side is a physical element [5].
3. **BPEA TESTING METHODOLOGY**

3.1 **BPEA Overview**

Building performance and energy analysis (BPEA) involves using building information models (BIM) and energy demand data to produce an accurate prediction of the building’s usage profile and cost of energy consumption. The ability to quickly complete informative energy analyses during the conceptual design phase, in particular, is crucial for maximizing building performance and reducing energy demand at later design phases.

Conceptual design phase energy modeling requires a wide range of input data, which includes building orientation, building geometry including the layout and configuration of spaces, construction materials including the thermal properties of all construction elements, HVAC system type and operating characteristics, space condition requirements, weather data, and other energy analysis related information (BPEA IDM [1]).

The output results of energy analysis may include the assessment of the building’s energy performance for compliance with regulations and targets, overall estimate of the energy used by the building, overall estimate of the energy cost, and lifecycle estimate of the energy use and cost for the building (BPEA IDM [1]).

Figure 1 illustrates a process map showing the conceptual design phase of a BPEA project. The process map is a swim lane diagram containing swim lanes which are arranged horizontally. Each swim lane depicts an individual participant involved in the project processes and information exchanges. There is an information exchange lane in between every participant lane, as shown in the figure, to display the information exchanged between participants.

There are two main items in the swim lanes: project processes and information exchanges between project participants. In this BPEA project the participants are the design team, the client staff, and the technical staff or consultant. The information being exchanged is BIM data and energy analysis data. The project processes include sub-processes or tasks that are performed in the BPEA conceptual design phase denoted by a number (e.g., task 1.2 export BIM for analysis) as well as decisions that are involved (e.g., is BIM valid for energy analysis?). At the starting point, in the lower left, of the process map an initial conceptual BIM should be completed, in other words, at this point the architect has defined a building concept design with all the required building elements and space objects. This design provides a proposed building layout including space configurations and placement of geometric elements.
Figure 1. BPEA conceptual design process map  
(Source: BPEA IDM [1])

Figure 2 illustrates the details of sub-process 1.1: Prepare/Adjust BIM for Energy Analysis. In this sub-process the concept design BIM is passed to the appropriate designer to prepare the BIM for energy analysis. The designer may be an architect, a mechanical engineer or energy consultant, or any combination of those three. Sub-process 1.1 contains several tasks, including modifying building design or geometry for energy analysis, creating and assigning construction types and space types, and assigning energy targets. After geometry, construction type, space type, and any other modifications to the building are made, the BIM is ready to be evaluated for conformance to energy analysis specifications, which is shown in task 1.1.11.

The evaluation of the BIM for conformance to energy analysis specifications is performed by checking the IFC file exported from BIM software to ensure that the IFC file includes all data structures specified in the BPEA Model View Definition (MVD). The MVD is generated based on the exchange requirements specified in the BPEA Information Delivery Manual (IDM). Section 3.1.1 and Section 3.1.2 provide a detailed description of the IDM and MVD, respectively. The IFC file needs to contain second level space boundaries (2LSB) information, which relate spaces and building elements and define the heat transfer surfaces required for energy simulation.
This BPEA Test Suite is developed to ensure that reliable software implementations of product data exchange specifications for import and export interfaces are developed in BIM software to completely and correctly support the evaluation of BIM for energy analysis. This test suite provides test cases that are developed based on the exchange requirements and implementation agreements specified in the BPEA IDM and MVD. It provides a baseline for software vendors to assess the correctness and coverage of their software implementations. Essentially, if the software implementations in BIM software fulfill the specifications documented in the IDM and MVD, then it should generate a BIM that fulfills the conformance to energy analysis specifications and passes the BPEA Test Suite.
3.1.1 BPEA Information Delivery Manual (IDM)

The IDM has two main components: one is the process map detailing the end user processes and information exchange between end users, as shown earlier in Figures 1 and 2. The other component is the list of exchange requirements. Before starting the processes described in the IDM, a building model needs to be available from which relevant geometric information required for energy analysis can be derived. The building model should also provide context information about the project including units used, coordinate systems information and the direction of the true north.

There are three categories of exchange requirements in the BPEA IDM:

I. Conceptual spatial layout
   Information about the building and its spatial configuration

II. Energy and performance
   Information about energy data associated with spaces in the building

III. Analysis results
   Information about energy demand, comfort, and energy consumption

Figure 3 below provides a summary of the BPEA exchange requirements.

<table>
<thead>
<tr>
<th>Summary of Exchange Requirements in the BPEA IDM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Conceptual Spatial Layout</td>
<td>II. Energy and Performance</td>
</tr>
<tr>
<td>- Project information</td>
<td>- Energy target</td>
</tr>
<tr>
<td>- Site information</td>
<td>- Space thermal comfort</td>
</tr>
<tr>
<td>- Building information</td>
<td>- Space ventilation</td>
</tr>
<tr>
<td>- Building stories</td>
<td>- Building elements</td>
</tr>
<tr>
<td>- Spaces</td>
<td>- thermal information</td>
</tr>
<tr>
<td>- Space boundaries</td>
<td>- Materials and material</td>
</tr>
<tr>
<td>- Building elements</td>
<td>- layers thermal</td>
</tr>
<tr>
<td>- Materials and material layers</td>
<td>- information</td>
</tr>
<tr>
<td>- Energy analysis zones</td>
<td></td>
</tr>
</tbody>
</table>

Focus of this BPEA Test Suite

---

**Figure 3.** Summary of exchange requirements in the BPEA IDM

This BPEA Test Suite considers only the conceptual spatial layout exchange requirements. The objective is to first construct a well-structured test suite for just one set of exchange requirements, once this test suite exists, then it should be an easier task to expand the test suite to cover other sets of exchange requirements in future works.
In this test suite, the following exchange requirements from the BPEA IDM are taken into account:

- Project shall have project identifier, i.e., project name
- Site shall have global coordinates (latitude and longitude) and elevation
- Building shall have identification, orientation, and elevation
- Building stories shall have identification and elevation
- Building elements shall have building element type, construction type, 3D geometry, exterior or interior classification, and links to space boundaries
- Material layer set shall have identification, description, and list of material layers
- Material layers shall have identification, description, and material identification
- Spaces shall have identification, space type, classification of inside or outside space, 3D geometry, and links to space boundaries
- Second level space boundaries shall have boundary type, boundary tag, 3D planar geometry, link to space, and link to building element

Figure 4 below illustrates how a portion of the information exchange requirements appear in the BPEA IDM documentation. Shown in the figure are conceptual spatial layout exchange requirements regarding project, site, and building information. The exchange requirements in the BPEA IDM provide the following information: the type of information contained in the building model (i.e., project, site, building, spaces, etc.) and the information (either required or optional) needed for the building model, as well as applicable data type and units.

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Information Needed</th>
<th>Required</th>
<th>Optional</th>
<th>Data Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project</strong></td>
<td>The following properties should be included:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Owner/Client info</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Model Author</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Site</strong></td>
<td>The following properties should be included:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Address</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Global Coordinates</td>
<td>X</td>
<td></td>
<td>(2) triples</td>
<td>degree/sec</td>
</tr>
<tr>
<td></td>
<td>Site Elevation</td>
<td>X</td>
<td></td>
<td>Real</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>2D Geometry</td>
<td>X</td>
<td></td>
<td>IFC Geometry</td>
<td>varies</td>
</tr>
<tr>
<td></td>
<td>3D Geometry</td>
<td>X</td>
<td></td>
<td>IFC Geometry</td>
<td>varies</td>
</tr>
<tr>
<td><strong>Site Context</strong></td>
<td>The following properties should be included for existing buildings adjacent to the subject building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>3D Geometry</td>
<td>X</td>
<td></td>
<td>IFC Geometry</td>
<td>m</td>
</tr>
<tr>
<td><strong>Building</strong></td>
<td>The following properties should be included (if not known then probable values should be used):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Global Coordinates</td>
<td>X</td>
<td></td>
<td>(2) triples</td>
<td>degree/sec</td>
</tr>
<tr>
<td></td>
<td>Functional Classification</td>
<td>X</td>
<td></td>
<td>String</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Orientation</td>
<td>X</td>
<td></td>
<td>Real</td>
<td>Angular Degrees</td>
</tr>
<tr>
<td></td>
<td>Elevation</td>
<td>X</td>
<td></td>
<td>Real</td>
<td>m</td>
</tr>
</tbody>
</table>

Figure 4. Portion of the information exchange requirements as appeared in BPEA IDM documentation

(Source: BPEA IDM [1])
3.1.2 Model View Definition (MVD)

The IFC schema contains a wide range of data as it covers the whole lifecycle of a building and its environment. Software products should only deal with a subset of the full IFC schema to avoid processing overwhelming amount of data. Therefore a Model View Definition is created as the tool for defining model subsets that are relevant for the data exchange between specific application types. The goal is that software implementers only need to focus on the parts of the IFC schema relevant to them.

The MVD structure consists of three levels. At the first level is a list of entities that are relevant for the data exchange. For the case of BPEA, the list of entities includes wall, slab, door, window, and other building elements as well as mechanical and electrical systems. Each entity is listed under a group such as “architectural systems”. Figure 5 below displays such a list of entities for BPEA for four of the major groups: model structure, architectural systems, mechanical systems and electrical systems.

![IFC Model View Definition Diagram: MVD Overview IFC 2x3](image)

**Figure 5.** BPEA MVD: list of relevant entities (Source: BPEA MVD [3])

At the second level is a list of concepts associated with a particular entity. These concepts include basic information such as the name and description of the entity as well as specific characterization related to the entity. Figure 6 expands the wall entity to illustrate some of its associated concepts, which include property set, material layer set, object placement and geometric representation.

Finally at the third level is a list of implementer’s agreements associated with a particular concept. Since IFC does not provide detailed information about how it should be used in specific cases because of its wide scope and inclusive nature, making such decisions about the use of IFC has been left to IFC implementers. These decisions are called implementer’s agreements and they are documented as part of MVDs. Figure 7 displays an example of the implementer’s agreements for the concept “material layers”, which is related to the wall entity in this case.

According to the definition provided by the buildingSMART Implementation Support Group, implementer’s agreements define additional restrictions on using particular attributes (or values), geometric representation types or relationships [6]. For example, specifying that “RelatingMaterial” must be “IfcMaterialLayerSetUsage” for “IfcRelAssociatesMaterial” is an agreement because “RelatingMaterial” is being limited to a specific value when other options are available. However, some of the implementer’s agreements listed in Figure 7 are not actually agreements. They are requirements in
the IFC schema. For example, making sure that a GUID and an owner history are provided are requirements of the IFC schema. They are not agreements defined by a certain group of implementers.

Here are some other examples of implementer’s agreement [6]:

- Exporting the construction type: it should be exported as property “Reference”, which is a part of the common property set, e.g. Pset_WallCommon.Reference
- Use of geometric representation context: the context type attribute should be “Model” for all but annotations and “Plan” for annotations
- Extrusion thickness of opening elements should be within reasonable boundaries: the size of the opening element should not exceed the bounding box of the voided element

![Diagram](image.png)

**Figure 6.** BPEA MVD: list of concepts associated with wall entity (Source: BPEA MVD [3])

![Table](image.png)

**Table 1** BPEA MVD: implementer’s agreements associated with material layer sets [3]

It is important to define agreements among the implementers on a consistent interpretation of the IFC specifications to avoid ambiguity and eliminate the existence of multiple options to exchange the same set of information. After an agreement has been made all implementers are required to respect the agreement. The development of this BPEA test suite is an effort to allow implementers to check that their implementation does indeed respect the requirements and agreements in the IDM and MVD.
3.1.3 From IDM and MVD to IFC

This section provides a brief overview and some examples illustrating how exchange requirements in the IDM and implementer’s agreements in the MVD are mapped into the IFC schema. Essentially, the IDM provides a list of information that must appear in the IFC schema and the MVD provides the guideline specifying how the information must appear in the IFC schema. Two examples are provided in this section: one is second level space boundary and the other is wall. Each specific information is highlighted by a number to better illustrate how the information is mapped from the BPEA IDM to the MVD and then to the IFC schema.

3.1.3.1 Second level space boundary

2LSB IDM exchange requirements [1]:

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Information Needed</th>
<th>Required</th>
<th>Optional</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Level Space Boundaries</td>
<td>The following properties should be included for 2nd level space boundaries:</td>
<td>X</td>
<td></td>
<td>Enum</td>
</tr>
<tr>
<td>(1) Space Boundary Type (1=internal, 2=external, 3=virtual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Space Boundary Tag (2nd level, “face”)</td>
<td></td>
<td></td>
<td></td>
<td>String</td>
</tr>
<tr>
<td>(3) 3D planar geometry</td>
<td></td>
<td></td>
<td></td>
<td>IFC Geometry</td>
</tr>
<tr>
<td>(4) Link to Space</td>
<td></td>
<td></td>
<td></td>
<td>Relationship</td>
</tr>
<tr>
<td>(5) Link to Building Element</td>
<td></td>
<td></td>
<td></td>
<td>Relationship</td>
</tr>
</tbody>
</table>

2LSB MVD implementation agreements [3]:

![Implementation agreements diagram](image)

2LSB IFC entities related to IDM and MVD:

```
#3510= IFCRELSPACEBOUNDARY(GUID,#13,(2)'2ndLevel',$, (4)#3234, (5)#2094, (3)#3509,
 (1a).PHYSICAL., (1b).EXTERNAL.);
#3234= IFCSPACE(GUID,#13,'Room',$,$,...);
#2094= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',...);
#3509= IFCCONNECTIONSURFACEGEOMETRY(#3505,$);
```

Note that sometimes the information in the IDM does not map directly to the MVD. An example is space boundary type, in the IDM it has three enumerators (internal, external, and virtual), but in the MVD “physical or virtual” and “internal or external” are two separate agreements.
3.1.3.2 Building elements

Building element IDM exchange requirements [1]:

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Information Needed</th>
<th>Required</th>
<th>Optional</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Elements</td>
<td>The following properties should be included (if not known then probable values should be used):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(General)</td>
<td>o Building Element Type (wall, exterior, interior), curtain wall, roof, floor, ceiling, window, door, shading device</td>
<td>X</td>
<td></td>
<td>Enum</td>
</tr>
<tr>
<td></td>
<td>o Construction type (e.g., wall type, door type, window type, shading device type, etc.) Window constructions from Window 8, opaque constructions from ASHRAE Fundamentals</td>
<td>X</td>
<td></td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>o Classification - UniFormat (reference to a classification – see below)</td>
<td></td>
<td>X</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>o 3D Geometry</td>
<td>X</td>
<td></td>
<td>IFC Geometry</td>
</tr>
<tr>
<td></td>
<td>o Exterior or Interior Element (i.e., Is Exterior)</td>
<td>X</td>
<td></td>
<td>Boolean</td>
</tr>
</tbody>
</table>

Building element (wall) MVD implementation agreements [3]:

**IfcPropertySingleValue**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Implementation agreements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Reference. --- This is used to exchange the wall construction type.</td>
</tr>
<tr>
<td>Description</td>
<td>Not used.</td>
</tr>
<tr>
<td>NominalValue</td>
<td>(1) This is a STRING that indicates IAI Standard 'construction type' property.</td>
</tr>
<tr>
<td>Unit</td>
<td>Not used for this property</td>
</tr>
</tbody>
</table>

**IfcClassificationReference**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Implementation agreements</th>
</tr>
</thead>
<tbody>
<tr>
<td>ItemReference</td>
<td>STRING = The Classification Assignment Number. Example: classification for &quot;Exterior Walls&quot; is: B2010 (2)</td>
</tr>
<tr>
<td>Name</td>
<td>STRING = The Classification Assignment Name. Example: the classification name for B2010 is: Exterior Walls.</td>
</tr>
</tbody>
</table>

Building element (wall) IFC entities related to IDM and MVD:

```plaintext
#2085 = IFCWALLSTANDARDCASE(GUID, #13, 'WA34', [2] 'B2010 Exterior Walls', $, #2082, #2155, $);
#2149 = (3) IFCSHAPEREPRESENTATION(#398, 'Body', 'SweptSolid', (#2146));
#2146 = (3) IFCEXTRUDEDAREASOLID(#2142, #2143, #36, 3.048);
#2197 = IFCPROPERTYSET(GUID, #13, 'Pset_WallCommon', $, (#2202, #2206));
#2202 = IFCPROPERTYSINGLEVALUE([1] 'Reference', $, IFCIDENTIFIER('WA34'), $);
#2206 = IFCPROPERTYSINGLEVALUE([4] 'IsExternal', $, IFCBOOLEAN(.T.), $);
```

Note: UniFormat is an optional requirement in the IDM. For simplicity, in this test suite UniFormat classification will appear in the “description” field of the building element, rather than creating the additional IFC entities (IfcRelAssociatesClassification, IfcClassificationReference, and IfcClassification) specified in the MVD.
3.2 Structure of a Test Case

The BPEA Test Suite consists of several test cases. This section provides a description regarding the structure of a test case. Since the test suite is developed based on the exchange requirements and implementer’s agreements in the BPEA IDM and MVD, one main part that is considered in a test case is the fulfillment of the data exchange requirements in the IDM and MVD. Section 3.1.1 refers to the list of exchange requirements that are considered in this test suite.

The other main part that is considered in a test case is a check on the numeric values that are passed to the IFC file. These numeric values can be coordinate points, dimension measurements, or others. The check is to ensure that the numeric values in the IFC file are within a certain tolerance from the values described in the building model. Also, there is a check on the existence of all building element entities in the IFC file. For each building element in a test case building model, there should be a corresponding entity for that particular building element in the IFC file.

Shown in Figure 8 is a section of Test Case 1, which includes verdict criteria for checking the existence of all building elements and checking the requirements for project and site. The verdict criteria are “pass or fail” conditions to check fulfillment of the IDM and MVD requirements and that the numeric values are within the tolerance. Also in the test case there are some corresponding content from the IFC file that are extracted from a reference IFC file to provide a better illustration.

<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Check that all building elements exist</strong></td>
</tr>
<tr>
<td>4 IfcWallStandardCase</td>
</tr>
<tr>
<td>2 IfcSlab</td>
</tr>
<tr>
<td>2 IfcOpeningElement</td>
</tr>
<tr>
<td>1 IfcDoor</td>
</tr>
<tr>
<td>1 IfcWindow</td>
</tr>
<tr>
<td>1 IfcSpace</td>
</tr>
</tbody>
</table>

**Project**
- **Project identifier is required**
  - IfcProject.LongName = “BPEA Test Case 1”

**Site**
- **Site location is specified**
  - IfcSite.LongName = “Washington D.C.”
- **Global coordinates (latitude and longitude) are required**
  - IfcSite.Reflatitude = (38,55,0)
  - IfcSite.Reflongitude = (-77,0,0)
- **Site elevation (relative to sea level) is required**
  - IfcSite.Refelevation = 120 (in )
- **Coordinate of site origin is correctly specified**
  - Coordinate of site origin is the origin of world coordinate system, (0,0,0)

Figure 8. A section of Test Case 1 for illustrating the test case structure
Shown in Figure 9 is another section of Test Case 1 illustrating the verdict criteria for checking the requirements for the wall entity. According to the IDM, it is necessary for the wall entity to have 3D geometry, wall construction type, exterior or interior classification, and links to space boundaries (not included Figure 9).

| Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ] |
|---|---|---|---|
| Walls (West Wall) | | | |
| • Check wall dimension and geometry¹ | | | |
| ____ Origin² = (0.0.,0.0.,0.) | | | |
| ____ XYZ directions²: X = (0.1.,0.0.), Y = (-1.0.,0.), Z = (0.0.,0.1.) | | | |
| ____ IfcShapeRepresentation.RepresentationIdentifier = “Body” | | | |
| ____ IfcShapeRepresentation.RepresentationType = “SweptSolid” | | | |
| ____ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid | | | |
| ____ IfcExtrudedAreaSolid.Depth = 120 (in.) | | | |
| ____ IfcExtrudedAreaSolid.ExtrudedDirection = (0.0.,0.1) | | | |
| ____ IfcExtrudedAreaSolid.Position = (0.0.,0.) | | | |
| ____ IfcExtrudedAreaSolid.SweptAreaProfileType = “AREA” | | | |
| ____ 4 Cartesian points for the swept area³ = (0.,0.), (288.,0.), (269.125,-18.875), (-18.875,-18.875) | | | |
| • Check wall properties | | | |
| Check wall construction type | | | |
| ____ Pset_WallCommonReference = “WA34” OR IfcWall.Name = “WA34” | | | |
| Check Uniform classification | | | |
| ____ IfcWall.Description = “B2010 Exterior Wall” | | | |
| Check exterior or interior is declared | | | |
| ____ Pset_WallCommon.IsExternal = IfcBoolean(T) | | | |

**Figure 9.** Verdict criteria for a wall entity

It would be redundant to provide a verdict criteria table such as the one shown in Figure 9 for each building elements and space boundaries of a test case model. Hence this is done only for Test Case 1 for a complete illustration, where a detailed verdict criteria table along with corresponding IFC content extraction is provided for each and every building element and space boundary. For subsequent test cases, a more concise verdict criteria table is used. Figure 10 below displays an example of the concise version of the verdict criteria table.

<table>
<thead>
<tr>
<th>Numeric Values and Specifications Summary for 1st Floor Exterior Walls (Refer to West Wall Verdict Criteria Table for specific details)</th>
<th>North Wall</th>
<th>East Wall</th>
<th>South Wall</th>
<th>West Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall dimension and geometry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of LCS</td>
<td>(15.,10.,0.)</td>
<td>(15.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,10.,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
<td>X: (-1.0.,0.)</td>
<td>X: (0.,1.0.)</td>
<td>X: (1.0.,0.)</td>
<td>X: (0.,-1.0.)</td>
</tr>
<tr>
<td>Y: (0.,-1.0.)</td>
<td>Y: (-1.0.,0.)</td>
<td>Y: (0.,1.0.)</td>
<td>Y: (1.0.,0.)</td>
<td>Y: (1.0.,0.)</td>
</tr>
<tr>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Shape representation</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
</tbody>
</table>

**Figure 10.** Concise version of verdict criteria table
3.3 **Structure of the Test Suite**

This section provides a description about the structure of the BPEA Test Suite and how each test case in the test suite is chosen. The first step in creating the BPEA Test Suite is to identify and list possible test case scenarios from common building structures and designs. A BPEA Test Matrix is created to organize the listings of test case scenarios.

In the BPEA Test Matrix, the horizontal rows list the test case scenarios and vertical columns identify the characteristics of the test case scenario. These characteristics include building plans, shape of the roof, single or multiple stories, as well as shape, alignment, and other properties of building elements, as shown in Figure 11. For example, the first test case scenario: BPEA-1, has the characteristics of rectangular floor plan, flat roof, and has only one floor.

![Figure 11. The columns of the BPEA Test Matrix identifying the characteristics of test scenarios](image)

The matrix currently contains 28 test case scenarios that are created based on variations of building plan, roof and floor geometry, exterior and interior wall geometry, and inclusion of windows, doors, columns, curtain walls, and shading devices. Figure 12 provides a list of the 28 test case scenarios and their descriptions. Figure 13 provides an overview look of the BPEA Test Matrix. Some test case scenarios are developed based on other sources: the space boundary documentation [8], the GSA building model from the AECOO Testbed (Figure 14), and LBNL test cases [11]. Test case scenarios that have a “LBNL ID” refer to the test cases developed by LBNL for the second level space boundary testing.

BPEA 1-4 are one-story rectangular buildings with no windows, doors, or interior walls, but they are different from each other in floor plans and roof designs. For each subsequent scenario there is either additional building element or a variation in the characteristic of existing building elements.

BPEA 5-8 are one-story rectangular buildings with various variations of interior walls. For example, the interior walls can be perpendicular to the exterior wall or intersect the exterior wall at an angle, or the interior walls can have varying thickness, or the interior wall can be a curve wall. BPEA 9-12 add variations of doors and windows to the rectangular building.

BPEA 13-17 are two-story buildings with variations in floor plans and interior walls. For example, the building can have interior walls on the first floor only, same interior walls on both floors, or different interior walls on both floors. BPEA 18-20 add variations of doors, windows, columns, and openings to the building.

BPEA 20-25 are buildings with more complicated floor plans and variations of building elements. BPEA 26-28 are buildings with shading devices. The test matrix includes three types of shading devices [2]: detached from other building elements, extruded from the interior slab, and free form.
### Figure 12. The listing of the 28 test case scenarios in the BPEA Test Matrix

<table>
<thead>
<tr>
<th>Test ID</th>
<th>LBNL ID</th>
<th>Description</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPEA-1</td>
<td></td>
<td>Simple rectangular building with no windows, doors,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>floors, or interior walls</td>
<td></td>
</tr>
<tr>
<td>BPEA-2</td>
<td></td>
<td>Same as [1], non-rectangular plan</td>
<td></td>
</tr>
<tr>
<td>BPEA-3</td>
<td></td>
<td>Same as [1], sloped roof</td>
<td></td>
</tr>
<tr>
<td>BPEA-4</td>
<td></td>
<td>Same as [1], curved roof</td>
<td></td>
</tr>
<tr>
<td>BPEA-5</td>
<td>WW-1</td>
<td>Same as [1], one interior wall perpendicular to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>exterior</td>
<td></td>
</tr>
<tr>
<td>BPEA-6</td>
<td></td>
<td>Same as [5], one interior wall at an angle to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>exterior</td>
<td></td>
</tr>
<tr>
<td>BPEA-7</td>
<td>WW-2</td>
<td>Same as [5], varied thickness</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Same as [5], curved wall</td>
<td></td>
</tr>
<tr>
<td>BPEA-8</td>
<td></td>
<td>Same as [1], typical window and door</td>
<td></td>
</tr>
<tr>
<td>BPEA-9</td>
<td>Wi-1</td>
<td>Same as [5], non-rectangular window and door</td>
<td></td>
</tr>
<tr>
<td>BPEA-10</td>
<td></td>
<td>Same as [5], glass curtain wall</td>
<td></td>
</tr>
<tr>
<td>BPEA-11</td>
<td>Wi-2</td>
<td>Same as [5], multiple walls</td>
<td></td>
</tr>
<tr>
<td>BPEA-12</td>
<td>CSW-1</td>
<td>Same as [1], two floors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSW-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-13</td>
<td></td>
<td>Same as [13], non-rectangular plan</td>
<td></td>
</tr>
<tr>
<td>BPEA-14</td>
<td></td>
<td>Same as [13], walls on first floor only</td>
<td></td>
</tr>
<tr>
<td>BPEA-15</td>
<td>CSW-1</td>
<td>Same as [13], same walls on both floors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSW-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-17</td>
<td>SWW-1</td>
<td>Same as [13], same walls on both floors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SWW-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-18</td>
<td></td>
<td>Same as [17], with windows, doors</td>
<td></td>
</tr>
<tr>
<td>BPEA-19</td>
<td>CSC-1</td>
<td>Same as [18], with columns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSC-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-20</td>
<td>CSC-1</td>
<td>Same as [16], with openings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CSO-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPEA-21</td>
<td></td>
<td>Room bounded by curve wall, with doors and windows</td>
<td></td>
</tr>
<tr>
<td>BPEA-22</td>
<td></td>
<td>Room bounded by a curve wall and by clipped walls,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with doors and windows</td>
<td></td>
</tr>
<tr>
<td>BPEA-23</td>
<td></td>
<td>Room with a virtual element, with doors and windows</td>
<td></td>
</tr>
<tr>
<td>BPEA-24</td>
<td></td>
<td>Two-story building, contains adjacent spaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>separated by walls, slabs, and doors</td>
<td></td>
</tr>
<tr>
<td>BPEA-25</td>
<td></td>
<td>Two-story building, contains an atrium and, hence</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>has space boundaries spanning over more than one</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>storey</td>
<td></td>
</tr>
<tr>
<td>BPEA-26</td>
<td></td>
<td>With a shading device that is detached from other</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>building elements</td>
<td></td>
</tr>
<tr>
<td>BPEA-27</td>
<td></td>
<td>With a shading device that is extruded from the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>interior slab</td>
<td></td>
</tr>
<tr>
<td>BPEA-28</td>
<td></td>
<td>With a shading device that is free form</td>
<td></td>
</tr>
</tbody>
</table>
### Figure 13. The BPEA Test Matrix
(Not meant to be legible, the purpose is to show a general overview of test case scenarios)
Figure 14. Simplified CAD model of the GSA Headquarters building

(This building model was used in the AECOO-1 Testbed led by OGC and buildingSMART alliance. The Testbed was focused on streamlining communications between parties in the conceptual design phase to get an early understanding of the tradeoffs between construction costs and energy efficiency)

The 28 test case scenarios are a good illustration of variations in building structures and designs. However, making each scenario to be a single test case would imply unnecessary redundant testing because many of the 28 test case scenarios have identical characteristics. For example, many of the 28 test case scenarios have straight exterior walls and flat roof, and it is unnecessary to test a straight wall multiple times. Hence the second step in creating the BPEA Test Suite is to take the test case scenarios from the BPEA Test Matrix and make combinations of unique characteristics to be tested, thereby resulting in a smaller number of test cases and reducing redundant testing.

The BPEA Test Suite in this documentation contains 5 test cases:

1. Test Case 1: Simple One-Story Building
   Description: simple rectangular building with one door and one window
   BPEA Test Matrix: BPEA-9, which also contains the characteristics of BPEA-1

2. Test Case 2: Two-Stories Building with Different Floor Plans
   Description: two-story rectangular building with internal walls and air walls on both floors
   BPEA Test Matrix: BPEA-17, which also contains the characteristics of BPEA-13-16

3. Test Case 3: Two-Stories Building with Doors, Windows, Columns
   Description: two-story rectangular building with internal walls, doors, windows, and columns
   BPEA Test Matrix: BPEA-18 and BPEA-19, which also contains the characteristics of BPEA-17

4. Test Case 4: One-Story Non-rectangular building with Curtain Wall and Shading Devices
   Description: one wall is not orthogonal to its two adjacent walls creating the non-rectangular floor plan, has curtain wall and shading devices
   BPEA Test Matrix: BPEA-2 with characteristics of BPEA-9, BPEA-11, and BPEA-27

5. Test Case 5: One-Story Non-rectangular building with curve wall and sloped roof
   Description: one-story building with a semi-circular curve wall and a sloped roof
   BPEA Test Matrix: BPEA-2, BPEA-3, BPEA-21, and BPEA-22
A detailed description will be provided at the beginning of each test case. Table 1 summarizes the characteristics of each test case. All the information about each test case, including detailed test model description and verdict criteria tables, are in the Appendix section.

It is important to keep in mind that the BPEA Test Matrix is not meant to be exhaustive and covers all possible test case scenarios. The scenarios in the matrix are a selection of commonly seen building designs and structures. There are some scenarios in the matrix that are not covered in the test suite, including curved roof, curved interior wall, interior wall with varying thickness, interior wall non-perpendicular to the exterior wall, non-rectangular doors and windows, floor slab containing openings, two-story building with an atrium, free form and extrusion from interior slab shading devices.

All the test cases are designed using metric units for dimensioning, with the exception of Test Case 1, which contains both a metric and an imperial unit version for the purpose of illustration.
### Table 1. Characteristics of the 5 test cases

<table>
<thead>
<tr>
<th></th>
<th>Test Case 1</th>
<th>Test Case 2</th>
<th>Test Case 3</th>
<th>Test Case 4</th>
<th>Test Case 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Walls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have openings,</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>windows, doors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have interior</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have connection of</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>two different types of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Non-orthogonal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>connection between</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have curvature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Slabs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have only base-slab</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>and roof (one-story)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have base-slab,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>floor(s), and roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(two or multi-stories)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Non-rectangular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>slabs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sloped slabs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>• Shading device</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>slabs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other Building</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Curtain walls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>• Columns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>• Virtual elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(i.e., air walls)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have 2\textsuperscript{nd} level space boundaries: Type 2a</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Have 2\textsuperscript{nd} level space boundaries: Type 2b</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
4. REFERENCE IFC FILES

4.1 Generating Reference IFC Files

The reference IFC files are created to provide an example IFC file for each test case. They can serve two purposes. The first is to allow test suite users to see the mappings between IDM and MVD requirements and the IFC schema. In each test case, parts of the reference IFC file relevant to the verdict criteria are extracted and included in the verdict criteria table to illustrating the mappings. The second purpose is to allow test suite users to compare the IFC files that are generated by their software, when a compatible tool for comparing IFC files is available.

The BIM software that is used to generate the reference IFC files is Graphisoft ArchiCAD 12 (the preprocessor). This software is selected as the preprocessor due to its capability of generating second level space boundaries (2LSB). Currently, many other BIM software do not have the capability of generating 2LSB, they require some middleware tools to do so. A postprocessor (software application for importing the IFC file) is not involved in this test suite.

The reference IFC file for each test case can be accessed at this link: http://cic.nist.gov/BPEA/BPEA_Test_Suite_IFC_Files.zip

4.2 Tools for Testing IFC Files

There are a number of tools that support IFC file checking, many of which are available to the public at no cost. These tools include viewers for visualization of the building model and also for illustration of the project structure and the properties of objects depicted in the IFC file; text browsers for debugging the original IFC file; and syntax checkers for checking for the conformance of the syntax in the IFC file to the IFC schema. The list below provides short descriptions to some of the IFC checking tools.

**Viewers**

- IfcStoreyView (developed by Karlsruhe Institute of Technology): this tool provides 2D and 3D visualization of the building model, information regarding building structure as well as building elements and layers, properties and relations of IFC entities, and display of space boundaries.
- Solibri Model Viewer (developed by Solibri Inc.): this tool provides a 3D visualization of the building model as well as the capability of navigation inside the model, a tree view showing information of model components, properties and relations of IFC entities. This tool can work in conjunction with Solibri Model Checker, which is a tool used to check the integrity of BIM.
- DDS CAD Viewer (developed by Data Design System): this tool provides various options of 3D visualization of the building model such as “hidden-line” and “wireframe” views of the model. This tool also allows navigation inside the model.

Note that screenshots of building models using the above three viewers are provided in each test case.

The tools listed in this section as well as several other IFC checking tools can be downloaded at this link: http://www.ifcwiki.org/index.php/Free_Software
Text browsers

- IfcQuickBrowser (developed by G.E.M. Team Solutions): this is a text browser for large IFC files. The IFC file is displayed in a tree structure.

Syntax checkers

- EXPRESS Data Manager (EDM) Supervisor (developed by EPM Technology)
- IfcObjectCounter (developed by Karlsruhe Institute of Technology)
- Express Engine

The syntax checkers go through the IFC files and check for violations of various rules pertaining to the IFC schema and generally create a log file displaying the results. Two of commonly used rules are “where” rules and “unique” rules, which are described below. Other rules include checking mandatory attributes and array entries, checking inverse attributes, and checking subtype/supertype constraints.

○ “Where” rule: an expression that must evaluate to “True” otherwise the corresponding content does not conform to the IFC schema.

Example: the entity IfcAxis2Placement3D has five “where” rules:

WR1:  SELF\IfcPlacement.Location.Dim = 3;
The dimensionality of the placement location shall be 3.

WR2:  (NOT (EXISTS (Axis))) OR (Axis.Dim = 3);
The Axis when given should only reference a three-dimensional IfcDirection.

WR3:  (NOT (EXISTS (RefDirection))) OR (RefDirection.Dim = 3);
The RefDirection when given should only reference a three-dimensional IfcDirection.

WR4:  (NOT (EXISTS (Axis))) OR (NOT (EXISTS (RefDirection))) OR (IfcCrossProduct (Axis, RefDirection).Magnitude > 0.0);
The Axis and RefDirection shall not be parallel or anti-parallel.

WR5:  NOT ((EXISTS (Axis)) XOR (EXISTS (RefDirection)));
Either both (Axis and RefDirection) are not given and therefore defaulted, or both shall be given.

○ “Unique” rule: an entity instance with certain attribute or a combination of attributes, which makes a unique key for the particular entity instance, can not have duplications, i.e. another entity instance with the same attribute or combination of attributes.

Example: the entity IfcApplication has two “unique” rules:

UR1: ApplicationIdentifier;
The short identifying name for the application can not appear more than once in the IfcApplication entity instances

UR2: ApplicationFullName, Version;
The combination of the full name of the application and its version number as specified by the application developer can not appear more than once in the IfcApplication entity instances.
Figure 15 below shows how the error messages appear in EDM Supervisor, Express Engine, and IfcObjectCounter when the first unique rule of entity IfcApplication is violated. Figure 16 shows a summary report of errors encountered when checking an IFC file using EDM Supervisor.

**EDM Supervisor**

```
Uniqueness rule Id 251667266
ENTITY IfcAPPLICATION,
  UNIQUE
  URI, APPLICATIONIDENTIFIER;
END_ENTITY;

Total number of duplicated values: 1
Total number of instances violating uniqueness rule: 4
Duplicated value:
  APPLICATIONIDENTIFIER = 'ArchicAD'
Instances with equal value for attribute in uniqueness rule (4 instances):
  392320908 392320908 392324792 392320908
```

**Express Engine**

```
::: *********** Run All Rules ....
::: :::::::: Checking Unique Constraints :::::::::
Instance #1032 fails uniqueness rule URI of entity type IFcAPPLICATION.
  It conflicts with instance #9.
Instance #1032 fails uniqueness rule UR2 of entity type IFcAPPLICATION.
  It conflicts with instance #9.
```

**IfcObjectCounter**

```
Selected Entity Category/Layer: Ifc2x3/AllAvailable
Checking options used: check_all - check_local | check_global -
  check_where | check_mandatory | check_inverse | check_unique | check_type | check_global
check_recursive = FALSE
integrity constraint violation: unique rule 'IfcApplication URI' evaluates to FALSE
Instance with equal attribute value '[ArchicAD]': #1032
Instance: 010: #0
Type: IfcApplication
References:
in file c:\programdata\bim\ecoo\v1.1\util\check_lib.exp at line 2763
```

**Figure 15.** Error messages from IFC syntax checkers

```
Time to Run: 2 seconds
Schema File: C:\Documents and Settings\...
Entity Types in Schema: 653
Part 21 File: BPK\Test Case 1 metric.ifc
Entities Read: 1564
Instantiated Entity Types: 138 (21%)
Total Errors: 15
  Errors at entity creation: 0
  EXPRESS program exceptions: 0
  Attribute value type errors: 0
  Inverse relationship errors: 0
  WHERE rule errors: 0
  UNIQUE rule errors: 6
  Global rule errors: 0
15 errors encountered
```

**Figure 16.** Error summary report from EDM Supervisor
4.3 Testing Reference IFC Files

Table 2 shows the results of checking the reference IFC files of each test case using three of the IFC syntax checkers: EDM Supervisor, IfcObjectCounter, and Express Engine. The errors received are: violation of unique rules of entity IfcApplication, violation of where rule of entity IfcNormalisedRatioMeasure, and an error regarding data type. The violation of the two unique rules is caused by the preprocessor Graphisoft ArchiCAD. It creates multiple instances of the same IfcApplication entity in the IFC file.

The other two errors, however, appear only in one of the IFC syntax checkers and appear to be programming mistake within the syntax checker. The where rule of entity IfcNormalisedRatioMeasure states that its attribute value has to be in between 0.0 and 1.0, and EDM Supervisor indicates that the values in the reference IFC file are out of range. A manual crosscheck and the fact that the other two syntax checkers not reporting this error leads to the conclusion that this is a programming mistake within EDM Supervisor. Similarly, IfcBoolean(T) is a valid IFC syntax and is accepted by both EDM Supervisor and IfcObjectCounter, but Express Engine does not recognize IfcBoolean(T) as a valid expression and appears to be a programming mistake within Express Engine.

Table 2: Results of checking reference IFC files using IFC syntax checkers

<table>
<thead>
<tr>
<th>Error descriptions</th>
<th>EDM Supervisor</th>
<th>IfcObjectCounter</th>
<th>Express Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>IfcApplication Unique Rule 1 (UR1)</td>
<td>Test Cases</td>
<td>Test Cases</td>
<td>Test Cases</td>
</tr>
<tr>
<td>- Application Identifier is unique</td>
<td>#1: Yes</td>
<td>#1: Yes</td>
<td>#1: Yes</td>
</tr>
<tr>
<td>Violation: identifier = “ArchiCAD” is duplicated</td>
<td>#2: Yes</td>
<td>#2: Yes</td>
<td>#2: Yes</td>
</tr>
<tr>
<td>(Cause: ArchiCAD creating multiple instances of same IfcApplication)</td>
<td>#3: Yes</td>
<td>#3: Yes</td>
<td>#3: Yes</td>
</tr>
<tr>
<td></td>
<td>#4: Yes</td>
<td>#4: Yes</td>
<td>#4: Yes</td>
</tr>
<tr>
<td></td>
<td>#5: Yes</td>
<td>#5: Yes</td>
<td>#5: Yes</td>
</tr>
<tr>
<td>IfcApplication UR2</td>
<td>Test Cases</td>
<td>Test Cases</td>
<td>Test Cases</td>
</tr>
<tr>
<td>- Application full name and version is unique</td>
<td>#1: Yes</td>
<td>#1: No</td>
<td>#1: Yes</td>
</tr>
<tr>
<td>Violation: “ArchiCAD 12.0” is duplicated</td>
<td>#2: Yes</td>
<td>#2: No</td>
<td>#2: Yes</td>
</tr>
<tr>
<td>(Cause: ArchiCAD creating multiple instances of same IfcApplication)</td>
<td>#3: Yes</td>
<td>#3: No</td>
<td>#3: Yes</td>
</tr>
<tr>
<td></td>
<td>#4: Yes</td>
<td>#4: No</td>
<td>#4: Yes</td>
</tr>
<tr>
<td></td>
<td>#5: Yes</td>
<td>#5: No</td>
<td>#5: Yes</td>
</tr>
<tr>
<td>IfcNormalisedRatioMeasure WR1</td>
<td>Test Cases</td>
<td>Test Cases</td>
<td>Test Cases</td>
</tr>
<tr>
<td>- 0.0 &lt;= value &lt;= 1.0</td>
<td>#1: Yes</td>
<td>#1: No</td>
<td>#1: No</td>
</tr>
<tr>
<td>Violation: none</td>
<td>#2: Yes</td>
<td>#2: No</td>
<td>#2: No</td>
</tr>
<tr>
<td>(Cause: the value are within range but are identified as out of range, appears to be a programming mistake in EDM supervisor)</td>
<td>#3: Yes</td>
<td>#3: No</td>
<td>#3: No</td>
</tr>
<tr>
<td></td>
<td>#4: Yes</td>
<td>#4: No</td>
<td>#4: No</td>
</tr>
<tr>
<td></td>
<td>#5: Yes</td>
<td>#5: No</td>
<td>#5: No</td>
</tr>
<tr>
<td>IfcBoolean (T) is not a valid type</td>
<td>Test Cases</td>
<td>Test Cases</td>
<td>Test Cases</td>
</tr>
<tr>
<td>(Cause: data type is valid, appears to be a programming mistake in Express Engine)</td>
<td>#1: No</td>
<td>#1: No</td>
<td>#1: Yes</td>
</tr>
<tr>
<td></td>
<td>#2: No</td>
<td>#2: No</td>
<td>#2: Yes</td>
</tr>
<tr>
<td></td>
<td>#3: No</td>
<td>#3: No</td>
<td>#3: Yes</td>
</tr>
<tr>
<td></td>
<td>#4: No</td>
<td>#4: No</td>
<td>#4: Yes</td>
</tr>
<tr>
<td></td>
<td>#5: No</td>
<td>#5: No</td>
<td>#5: Yes</td>
</tr>
</tbody>
</table>
5. Closure

The BPEA Test Suite is created to provide test cases to software vendors to evaluate their software implementations of BPEA data exchange specifications and to ensure that their implementations are correct. There are five test cases in the test suite. Each test case is created based on a combination of various commonly seen building structures and designs. It is impractical to provide an exhaustive testing hence this test suite does not cover all the concepts in BPEA data exchange specifications. This test suite aims at providing a sufficient coverage of the BPEA concepts to provide the guidance for conformance testing and interoperability testing to the industry.

The evaluation for conformance to BPEA data exchange specifications is performed by first using preprocessor BIM software to generate an IFC file of the building model specified in the test case, and then check the IFC file to ensure that it includes all data structures specified in the BPEA IDM and MVD. Each test case has its own set of verdict criteria, which are “pass or fail” conditions to check fulfillment of the IDM and MVD requirements and that the numeric values are within the tolerance. Essentially, if the software implementations in BIM software fulfill the specifications documented in the IDM and MVD, then it should generate a BIM that conforms to energy analysis specifications and passes the BPEA Test Suite.

While theoretically a direct mapping should exist between the IDM, the MVD, and the IFC schema where the IDM provides a list of information that must appear in the IFC schema and the MVD provides the guideline specifying how the information must appear in the IFC schema, but in reality there is inconsistency in the mapping as noted in the section 3.1.3. The IDM and the MVD are supposed to be complementary of each other, but in the case of BPEA, this is not completely true. Hence this is certainly one area that needs further improvements. One possible solution is to first thoroughly go through each and every exchange requirement in the IDM and check the corresponding implementer’s agreements in the MVD for consistent mapping of information, then go through the ones that have inconsistency in the mapping and come to agreements on how the direct mapping would be achieved.

This test suite document provides the textual content for BPEA testing. To further allow the test suite users to evaluate their software implementations, the next step is to implement the content of this test suite into an online testing tool that can compare the IFC file that is generated by user’s software with the test case reference IFC file. One major challenge in creating this tool is to implement the capability to identify the content in the IFC file that are relevant to the testing and filter out all the information specific to the preprocessor that generated the IFC file. The ability to identify the content in the IFC file is also a challenge since the IFC files generated by different software usually have completely different layouts and structures. Nonetheless, the successful implementation of this tool would certainly enhance the utility of this test suite as guidance for conformance and interoperability testing.
6. References


3. BPEA Model View Definition (MVD) – IFC 2x3 Binding Concepts Model
   URL: http://www.blis-project.org/IAIMVD/reporting/browseMVD.php?MVD=BSA-002&BND=IFC2x3&LAYOUT=H


6. buildingSMART- Implementation Support Group, “Implementer Agreements”
   URL: http://www.iai.hm.edu/how-to-implement-ifc/Implementer-Agreements

   URL: http://fire.nist.gov/bfrlpubs/build96/art130.html


9. OGC GSA ASHRAE CEC Construction and Space Table


11. 40+ use cases developed by Lawrence Berkeley National Laboratory (LBNL)
7. Appendix: BPEA Test Cases

7.1 BPEA Test Case 1 (imperial)

BPEA Test Case 1 (imperial units)

Test Case Title: Simple One-Story Building

Date of Last Edit: 10/05/2009

Summary Description: Test Case 1 consists of the simple one-story building shown on Figure A1. The building elements included in this test case are: 4 exterior walls, 1 base slab, 1 roof slab, 2 openings, 1 door, 1 window and 1 space.

Test Objectives:
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets

Figure A1: Simple one-story building
Detailed Description:

Project Name: BPEA Test Case 1

Site Location: Washington D.C. (38°55' Latitude, -77°0' Longitude)
Site Elevation = 3.048 m (10 ft)

Building Name: TC1
Building Global Coordinates: 38°55' Latitude, -77°0' Longitude
Building Orientation: 30° from true north
Building Elevation from Sea Level = 3.048 m (10 ft)

Total Number of Building Stories = 1
Name of 1st Building Story: “1st Floor”
Elevation (relative to building datum) = 0 m

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (east)</td>
<td>Length: 7.3152 m (24 ft) Height: 3.048 m (10 ft) Thickness: 0.4794 m (18.875 in)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall* (west)</td>
<td>L: 7.3152 m (24 ft) H: 3.048 m (10 ft) Thickness: 0.48 m (18.875 in)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall* (south)</td>
<td>L: 10.9728 m (36 ft) H: 3.048 m (10 ft) Thickness: 0.48 m (18.875 in)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Exterior Wall* (north)</td>
<td>L: 10.9728 m (36 ft) H: 3.048 m (10 ft) Thickness: 0.48 m (18.875 in)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>5. Floor Slab</td>
<td>L: 10.9728 m (36 ft) W: 7.3152 m (24 ft) Thickness: 0.256 m (10.078 in)</td>
<td>FA5</td>
<td>6-in HW concrete 4-in Gravel</td>
<td>A1030 Slab-on-grade</td>
</tr>
<tr>
<td>6. Roof Slab</td>
<td>L: 10.9728 m (36 ft) W: 7.3152 m (24 ft) Thickness: 0.2 m (7.88 in)</td>
<td>RA14</td>
<td>R-15 insulation 4-in LW concrete</td>
<td>B1020 Roof Construction</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Door</td>
<td>W: 1.8288 m (6 ft)</td>
<td>D2</td>
<td>Steel slab (Foam insulated with metal edge in steel frame) Double door</td>
<td>D2030 External Doors</td>
</tr>
<tr>
<td></td>
<td>H: 2.7432 m (9 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Placement: center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sill to base: 0 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Window</td>
<td>W: 1.524 m (5 ft)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td></td>
<td>H: 1.2192 m (4 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Placement: center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sill to base: 0.9144 m (3 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Door Opening</td>
<td>W: 1.8288 m (6 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H: 2.7432 m (9 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness: 0.4794 m (18 in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Window Opening</td>
<td>W: 1.524 m (5 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H: 1.2192 m (4 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness: 0.4794 m (18 in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Space (Room)</td>
<td>Length: 10.014 m (32 ft and 10 in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Width: 6.3564 m (20 ft and 10 in)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height: 3.048 m (10 ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Screenshots of the building model in different IFC Viewers

IfcStoreyView
## Verdict Criteria

All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

- Check that all building elements exist
  - 4 IfcWallStandardCase
  - 2 IfcSlab
  - 2 IfcOpeningElement
  - 1 IfcDoor
  - 1 IfcWindow
  - 1 IfcSpace

- Project
  - Project identifier is required
    - IfcProject.LongName = “BPEA Test Case 1”

### Sample IFC Code

1

```xml
#63= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 1',$,,'BPEA Test Case 1',$(#60,#119,#40),#35);
```

- Correct unit assignment
  - Length measurement is in “Inch”

### Sample IFC Code

```xml
#17= IFCCONVERSIONBASEDUNIT(#16,.LENGTHUNIT.,'INCH',#15);
```

- Site
  - Site location is specified
    - IfcSite.LongName = “Washington D.C.”
  - Global coordinates (latitude and longitude) are required
    - IfcSite.RefLatitude = (38,55,0)
    - IfcSite.RefLongitude = (-77,0,0)
  - Site elevation (relative to sea level) is required
    - IfcSite.RefElevation = 120 (in.)
  - Coordinate of site origin is correctly specified
    - Coordinate of site origin is the origin of world coordinate system, (0.,0.,0.)

### Sample IFC Code

2

```xml
#73= IFCSITE(GUID,#13,'Default Site','Washington D.C.',$,#70,$,'Washington D.C.',$,ELEMENT.,(38,55,0),(-77,0,0),120.,$,,$);
#70= IFCLocalPlacement($,#53);
#53= IFCAxis2Placement3D(#49,#45,#37);
#49= IFCCartesianPoint((0.,0.,0.));
```

---

1 One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as '0bY52t0r7xHf8OxWo$Y$t'. In the examples, the GUID is shortened to the string ‘GUID’ to save space and improve readability.

2 In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Building
- Building identifier is required
  ____ IfcBuilding.LongName = “TC1”
- Elevation (base elevation of ground level floor above sea level) is required
  ____ IfcBuilding.ElevationOfRefHeight = 120 (in.)
- Coordinate of building origin is correctly specified
  ____ Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
#86= IFCBUILDING(GUID,#13,'Default Building', 'TC1', $, #83, 'TC1', .ELEMENT., 120., $, $);
  #83= IFCLocalPlacement(#70, #53);
  #70= IFCLocalPlacement($, #53);
  #53= IFCAxis2Placement3D(#49, #45, #37);
  #49= IFCCartesianPoint((0., 0., 0.));

- Number of stories is specified
  ____ Pset_BuildingCommon.NumberOfStoreys = 1

Sample IFC Code:
#3620= IFCPROPERTYSINGLEVALUE('NumberOfStoreys', $, IFCINTEGER(1), $);

- Building orientation (the degrees of clockwise from true north) is required
  ____ IfcGeometricRepresentationContext.TrueNorth = (-0.5, 0.866)

Sample IFC Code:
#60= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan', 'Design', 3, 1.0000000E-5, #53, #56);
  #56= IFCDIRECTION((-0.5, 0.866));

Building Stories
- Identification is required
  ____ IfcBuildingStorey.Name = "1st Floor"
- Elevation (relative to building datum) is required
  ____ IfcBuildingStorey.Elevation = 0
- Coordinate of building story origin is correctly specified
  ____ Coordinate of building story origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
#102= IFCBUILDINGSTOREY(GUID, #13, '1st Floor', $, #99, $, .ELEMENT., 0.);
  #99= IFCLocalPlacement(#83, #96);
  #83= IFCLocalPlacement(#70, #53);
  #70= IFCLocalPlacement($, #53);
  #53= IFCAxis2Placement3D(#49, #45, #37);
  #49= IFCCartesianPoint((0., 0., 0.));

1 IDM indicates that buildings should contain latitude and longitude information, as different buildings in the same site may have different latitude and longitude values. However, RefLatitude and RefLongitude are attributes of IfcSite, not IfcBuilding.

2 The building orientation is considered to be the grid rotation from true north, therefore if the building and/or the site is modeled in a different orientation on the original grid, then a combination of rotations from the building and site would need to be considered to determine the actual orientation.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Walls (West Wall)

- Check wall dimension and geometry
  1. Origin = (0.,0.,0.)
  2. XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  3. IfcShapeRepresentation.RepresentationIdentifier = “Body”
  4. IfcShapeRepresentation.RepresentationType = “SweptSolid”
  5. IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  6. IfcExtrudedAreaSolid.Depth = 120 (in.)
  7. IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  8. IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  9. IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
  10. 4 Cartesian points for the swept area

- Check wall properties
  Check wall construction type
  1. Pset_WallCommon.Reference = “WA34” OR IfcWall.Name = “WA34”
  2. Check Uniformat classification
     1. IfcWall.Description = “B2010 Exterior Wall”
  3. Check exterior or interior is declared
     1. Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```plaintext
#2285 = IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
$,#2225,#2298,$);
#2225 = IFCLOCALPLACEMENT(#99,#2222);
#2222 = IFCAXIS2PLACEMENT3D(#49,#45,#41);
  #49 = IFCCARTESIANPOINT(0.,0.,0.);
  #45 = IFCDIRECTION(0.,0.,1.);
  #41 = IFCDIRECTION(0.,1.,0.);
#2298 = IFCPRODUCTDEFINITIONSHAPE($,$,#2281,'Body',
'Vertical solid',(#2289));
#2289 = IFCEXTRUDEDAREASOLID(#2285,#2286,#2287);#2285 = IFCEXTRUDEDAREASOLID(#2285,#2286,#2287);
#2287 = IFCCARTESIANPOINT(18.875,-18.875);
#2286 = IFCAXIS2PLACEMENT3D(#49,#45,#37);
#2394 = IFCRELDEFINESBYPROPERTY(GUID,#13,$,$,#2288,#2368);
#2368 = IFCPROPERTYSET(GUID,#2372,'Pset_WallCommon',$,#2374,#2375);
#2374 = IFCPROPERTYSET(GUID,#2372,'Pset_WallCommon',$,#2374,#2375);
#2375 = IFCPROPERTYSET(GUID,#2372,'Pset_WallCommon',$,#2374,#2375);
```

---

1. The intersection between walls can affect the geometry, i.e., the placement of the Cartesian points of the swept area.
2. The origin and the direction of the wall (and other building elements) are indicated by IfcWall (or IfcWallStandardCase).IfcLocalPlacement.Position. The XYZ directions are the axes of the local coordinate system in reference to the world coordinate system.
3. These are points in the local coordinate system.
4. The position and orientation in #2222 are related to the wall. The position and orientation in #2286 are related to the extrusion.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Walls (North Wall)
- Check wall dimension and geometry
  - Origin = (0.,288.,0.)
  - XYZ directions: X = (1.,0.,0.), Y = (0.,1.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 120 (in.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (432.,0.), (413.125,-18.875), (18.875,-18.875)

- Check wall properties
  - Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  - Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```
#2094= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
   $,#2091,#2164,$);
 #2091= IFCLocalPlacement(#99,#2088);
 #2088= IFCAxis2Placement3D(#2084,#45,#37);
 #2084= IFCCartesianPoint((0.,288.,0.));
 #45= IFCDirection((0.,0.,1.));
 #37= IFCDirection((1.,0.,0.));
 #2164= IFCPresetDefinitionShape($,$,(#2194,#2206));
 #2194= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2155));
 #2155= IFCEXTRUDEDAREASOLID(#2151,#2152,#45,120.);
 #2151= IFCCARTESIANPOINT(18.875,-18.875);
 #2152= IFCAxis2Placement3D(#49,#45,#37);
 #49= IFCCARTESIANPOINT(0.,0.,0.);
 #45= IFCDIRECTION((1.,0.,0.));
 #37= IFCDIRECTION((1.,0.,0.));
```

1 Pset_WallCommon currently doesn't include "Construction type", hence construction type is placed under "Reference".
2 In addition, construction type and classification can also be placed under building element's name and description.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Walls (East Wall)

- Check wall dimension and geometry
  - Origin = (432.288.,0.)
  - XYZ directions: X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 120 (in.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (288.,0.), (269.125,-18.875), (18.875,-18.875)

- Check wall properties
  - Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  - Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```
#1076=IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls', $
$,#1073,#1146,$);
#1073=IFCLOCALPLACEMENT(#99,#1070);
  #1070=IFCAXIS2PLACEMENT3D(#1066,#45,#1062);
  #1066=IFCCARTESIANPOINT((432.,288.,0.));
  #45=IFCDIRECTION((0.,0.,1.));
  #1062=IFCDIRECTION((0.,-1.,0.));
#1146=IFCPRODUCTDEFINITIONSHPESHAPE($,$,#(1107,#1140));
#1140=IFCSPHEREPRESENTATION(#407,‘Body’,‘SweptSolid’,(#1137));
#1137=IFCEXTRUDEDAREASOLID(#1133,#1134,#45,120.);
#1133=IFCAXIS2PLACEMENT3D(#49,#45,#37);
  #49=IFCCARTESIANPOINT((0.,0.,0.));
  #45=IFCDIRECTION((0.,0.,1.));
  #37=IFCDIRECTION((1.,0.,0.));
#2074=IFCREDEFINESBYPREFERENCES(GUID,#13,$,#(1076,#2048));
#2048=IFCPROPERTYSET(GUID,#2052,‘Pset_WallCommon’,$,(#2054,#2058));
#2054=IFCPROPERTYSINGLEVALUE(‘Reference’,$,#‘WA34’);$
#2058=IFCPROPERTYSINGLEVALUE(‘IsExternal’,$,#‘T’);$
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Walls (South Wall)
- Check wall dimension and geometry
  - Origin = (432.,0.,0.)
  - XYZ directions: X = (-1.,0.,0.), Y = (0.,-1.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
    - IfcExtrudedAreaSolid.Depth = 120 (in.)
    - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
    - IfcExtrudedAreaSolidd.Position = (0.,0.,0.)
    - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
    - 4 Cartesian points for the swept area = (0.,0.), (432.,0.), (413.125,-18.875), (18.875,-18.875)

- Check wall properties
  Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
#372 = IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
$,#369,#449,$);  
 #369 = IFCLOCALPLACEMENT(#99,#366);  
   #366 = IFCAxis2Placement3D(#362,#45,#358);  
   #362 = IFCCARTESIANPOINT((432.,0.,0.));  
   #45 = IFCDIRECTION((0.,0.,1.));  
 #358 = IFCDIRECTION((-1.,0.,0.));  
 #449 = IFCPRODUCTDEFINITIONSHAPE($,$,#410,#443));  
 #443 = IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#440));  
 #407 = IFCGEOMETRICREPRESENTATIONCONTEXT('Plan','Model',3,1.0000000E-5,#53,#403);  
 #53 = IFCAxis2Placement3D(#49,#45,#37);  
 #403 = IFCDIRECTION((-0.5,0.866));  
 #440 = IFCEXTRUDEDAREASOLID(#436,#437,#45,120.);  
 #436 = IFCARBITRARYCLOSEDPOLYLINEDEF('AREA',$,#432);  
 #432 = IFCPOLYLINE((#416,#420,#424,#428,#416));  
 #416 = IFCCARTESIANPOINT((18.875,-18.875));  
 #420 = IFCCARTESIANPOINT((413.125,-18.875));  
 #424 = IFCCARTESIANPOINT((432.,0.));  
 #428 = IFCCARTESIANPOINT((0.,0.));  
 #437 = IFCAxis2Placement3D(#49,#45,#37);  
 #49 = IFCCARTESIANPOINT((0.,0.,0.));  
 #45 = IFCDIRECTION((0.,0.,1.));  
 #37 = IFCDIRECTION((1.,0.,0.));

#1052 = IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,#(372),#1026);  
#1026 = IFCPROPERTYSET(GUID,#1030,'Pset_WallCommon',$,(#1032,#1036));  
#1032 = IFCPROPERTYSETVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);  
#1036 = IFCPROPERTYSETVALUE('IsExternal',$,IFCBOOLEAN(T),$);
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Walls (All Walls)

- Check material association (for all walls)
  - IfcMaterialLayerSet.LayerSetName = "WA34"
  - IfcMaterialLayer.LayerThickness = 0.004 (in.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 12.000 (in.)
  - IfcMaterial.Name = "12 in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 6.250 (in.)
  - IfcMaterial.Name = "R-19 batt insulation"
  - IfcMaterialLayer.LayerThickness = 0.625 (in.)
  - IfcMaterial.Name = "Gyp board"
  - IfcMaterialLayer.LayerThickness = 0.004 (in.)
  - IfcMaterial.Name = "Inside surface resistance"

Sample IFC Code:
```
#453= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#372,#357);
  #357= IFCMATERIALLAYERSETUSAGE(#355,.AXIS2.,.POSITIVE.,-18.875);

#1150= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#1076,#1061);
  #1061= IFCMATERIALLAYERSETUSAGE(#355,.AXIS2.,.POSITIVE.,-18.875);

#2168= IFCRELASSOCIATESMATERIAL(GUID',#13,$,$,(#2083,#2083);
  #2083= IFCMATERIALLAYERSETUSAGE(#355,.AXIS2.,.POSITIVE.,-18.875);

#2302= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2221,#2221);
  #2221= IFCMATERIALLAYERSETUSAGE(#355,.AXIS2.,.POSITIVE.,-18.875);

  #355= IFCMATERIALLAYERSET(#125,#267,#313,#348,#353),'Wall Type 34 WA34 Precast and CIP Concrete Walls');
  #125= IFCMATERIALLAYER(#112,0.004,.U.);
    #112= IFCMATERIAL('F01 Outside Surface Resistance');
  #267= IFCMATERIALLAYER(#127,12.,.U.);
    #127= IFCMATERIAL('M16 12 in. Heavyweight Concrete');
  #269= IFCMATERIALLAYER(#127,6.25, .U.);
    #269= IFCMATERIAL('I05 R-19, 6-1/4 in. Batt Insulation');
  #315= IFCMATERIALLAYER(#315,0.625, .U.);
    #315= IFCMATERIAL('G01 5/8 in. Gyp Board');
  #350= IFCMATERIALLAYER(#350,0.004, .U.);
    #350= IFCMATERIAL('F02 Inside Vertical Surface Resistance');
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Floor Slab

- **Check slab dimension and geometry**
  - Origin = (0.,0.,-10.078)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = “Body”
  - IfcShapeRepresentation.RepresentationType = “SweptSolid”
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 10 (in.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
  - 4 Cartesian points for the swept area = (0.,0.), (288.,0.), (288.,-432.), (0.,-432.)

- **Check slab properties**
  - Check slab construction type
    - Pset_SlabCommon.Reference = “FA5” OR IfcSlab.Name = “FA5”
  - Check UniFormat classification
    - IfcSlab.Description = “A1030 Slabs on Grade”
  - Check exterior or interior is declared
    - Pset_SlabCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```java
#2411 = IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',S,#2474,#2463,$.BASESLAB.);
#2474 = IFCLOCALPLACEMENT(#99,#2471);
#2471 = IFCAXIS2PLACEMENT3D(#2467,#45,#41);
#2467 = IFCCARTESIANPOINT((0.,0.,-10.078));
#45 = IFCDIRECTION((0.,0.,1.));
#41 = IFCDIRECTION((1.,0.,0.));
#2463 = IFCPRODUCTDEFINITIONSHAPE(S,S,(#2457));
#2457 = IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2454));
#2454 = IFCEXTRUDEDAREASOLID(#2450,#2451,#45,10.078);
#2450 = IFCARBITRARYCLOSEDPOLYLINE(#AREA.,$,#2446);
#2446 = IFCCARTESIANPOINT((0.,0.,0.));
#2430 = IFCCARTESIANPOINT((288.,0.));
#2438 = IFCCARTESIANPOINT((288.,-432.));
#2442 = IFCCARTESIANPOINT((0.,-432.));
#2451 = IFCAXIS2PLACEMENT3D(#49,#45,#37);
#49 = IFCCARTESIANPOINT((0.,0.,0.));
#45 = IFCDIRECTION((0.,0.,1.));
#37 = IFCDIRECTION((1.,0.,0.));
```

```java
#2733 = IFCREDEFINESBYPROPERTIES(GUID,#13,$,#2411,#2720);
#2720 = IFCPROPERTYSET(GUID,#13,'Pset_SlabCommon',$,#2725,#2729);
#2725 = IFCPROPERTYINGLEVALUE('Reference',$,IFCIDENTIFIER('FA5'),$);
#2729 = IFCPROPERTYINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

**Roof Slab**

- **Check slab dimension and geometry**
  - Origin = (0.,0.,120.)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 7.88 (in.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (288.,0.), (288.,-432.), (0.,-432.)

- **Check slab properties**
  - Check slab construction type
    - Pset_SlabCommon.Reference = “RA14” OR IfcSlab.Name = “RA14”
  - Check UniFormat classification
    - IfcSlab.Description = "B1020 Roof Construction"
  - Check exterior or interior is declared
    - Pset_SlabCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```ifc
#2737 = IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,#2800,#2789,$,.ROOF.);
#2800 = IFCLOCALPLACEMENT(#99,#2797);
 #2797 = IFCAxis2Placement3D(#2793,#45,#41);
 #2793 = IFCCartesianPoint((0.,0.,120.));
 #45 = IFCDirection((0.,0.,1.));
 #41 = IFCDirection((0.,1.,0.));
#2789 = IFCProductDefinitionShape($,$,(#2783));
 #2783 = IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2780));
 #2780 = IFCEXTRUDEDAREASOLID(#2776,#2777,#45,7.88);
 #2776 = IFCCartesianPoint((0.,0.,120.));
 #2777 = IFCCartesianPoint((288.,0.));
 #2764 = IFCCartesianPoint((288.,-432.));
 #2768 = IFCCartesianPoint((0.,-432.));
 #2772 = IFCPOLYLINE((#2756,#2760,#2764,#2768,#2756));
 #2756 = IFCCartesianPoint((0.,0.,120.));
 #2760 = IFCCartesianPoint((288.,0.));
 #2764 = IFCCartesianPoint((288.,-432.));
 #2768 = IFCCartesianPoint((0.,-432.));
#3183 = INCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2737),#3170);
 #3170 = IFCPropertySet(GUID,#13,'Pset_SlabCommon',$,(#3175,#3179));
 #3175 = IFCPROPERTYSINGLEVALUE('Reference',$,IFCIdentifier('RA14'),$);
 #3179 = IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBoolean(.T.$));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Slabs (Floor and Roof Slabs)

- Check material association
  - IfcMaterialLayerSet.LayerSetName = "FA5"
  - IfcMaterialLayer.LayerThickness = 6.000 (in.)
  - IfcMaterial.Name = "6in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.078 (in.)
  - IfcMaterial.Name = "Vapor barrier"
  - IfcMaterialLayer.LayerThickness = 4.000 (in.)
  - IfcMaterial.Name = "4in. gravel"

Sample IFC Code:

```plaintext
#2710 = IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2411),#2709);
#2709 = IFCMATERIALASSOCIATESLAYERSETUSAGE(#2707,AXIS3.,NEGATIVE.,10.);
#2707 = IFCMATERIALASSOCIATESLAYERSET((#2620,#2625,#2705),'Floor Type 05_FA5 Slab On Grade');
  #2620 = IFCMATERIALLAYER(#2480,6.,U.);
    #2480 = IFCMATERIAL(' M14 | 6 in. Heavyweight Concrete');
  #2622 = IFCMATERIALLAYER(#2622,0.078.,U.);
    #2622 = IFCMATERIAL(' F20 | Vapor Barrier');
  #2705 = IFCMATERIALLAYER(#2655,4.,U.);
    #2655 = IFCMATERIAL(' M18 | 4 in. Gravel');

#2655 = IFCMATERIALLAYER(#2655,4.,U.);
    #2655 = IFCMATERIAL(' M18 | 4 in. Gravel');

#3150 = IFCMATERIALASSOCIATESLAYERSET((#2655,#2658,#3010,#3150),'Roof Type 14_RA14 Concrete Roofs');
  #2806 = IFCMATERIALLAYER(#112,0.004.,U.);
    #112 = IFCMATERIAL('F01 Outside Surface Resistance');
  #2808 = IFCMATERIALLAYER(#2808,0.375.,U.);
    #2808 = IFCMATERIAL('F13 | Built-Up Roofing');
  #2964 = IFCMATERIALLAYER(#2964,3.,U.);
    #2964 = IFCMATERIAL('I03 | R15, 3 in. Insulation Board');
  #3150 = IFCMATERIALLAYER(#3010,4.,U.);
    #3010 = IFCMATERIAL('M1 | 4 in. Lightweight Concrete');
  #3155 = IFCMATERIALLAYER(#3152,0.004.,U.);
    #3152 = IFCMATERIAL('F03 Inside Horizontal Surface Resistance');
```

- IfcMaterialLayerSet.LayerSetName = "RA14"
  - IfcMaterialLayer.LayerThickness = 0.004 (in.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 0.375 (in.)
  - IfcMaterial.Name = "Build-up roofing"
  - IfcMaterialLayer.LayerThickness = 0.500 (in.)
  - IfcMaterial.Name = "1/2 in. fiberboard sheathing"
  - IfcMaterialLayer.LayerThickness = 3.000 (in.)
  - IfcMaterial.Name = "R-15 insulation board"
  - IfcMaterialLayer.LayerThickness = 4.000 (in.)
  - IfcMaterial.Name = "4 in. lightweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.004 (in.)
  - IfcMaterial.Name = "Inside surface resistance"
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [Pass / Fail]

**Opening (Door)**

- **Check opening dimension and geometry**
  
  ___ Origin = (216.,18.875,0.)
  
  ___ XYZ directions: X = (-1.,0.,0.), Y = (0.,-1.,0.), Z = (0.,0.,1.)
  
  ___ IfcShapeRepresentation.RepresentationIdentifier = "Body"
  
  ___ IfcShapeRepresentation.RepresentationType = "SweptSolid"
  
  ___ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  
  ___ IfcExtrudedAreaSolid.Depth = 18.875 (in.)
  
  ___ IfcExtrudedAreaSolid.ExtrudedDirection = Y Direction
  
  ___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  
  ___ IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  
  ___ 4 Cartesian points for the swept area
  
  1. Center point = (0.,54.,0.)
  
  2. OR if Rectangle Profile is used to define the area
  
  3. Since extrusion is in the (0.,-1.,0.) direction, these points would be on the X-Z plane.
  
  4. The Cartesian point (216, -18.875, 0) is placed relative to the point (432, 0, 0) in the world coordinate system, which is the origin of the south wall. Also note that in this local coordinate system, the X direction is (-1, 0, 0).

Sample IFC Code:

```plaintext
#497 = IFCOPENINGELEMENT(GUID,#13,$,$,'Opening',#494,#483,'');
#494 = IFCLLOCALPLACEMENT(#369,#491);
#369 = IFCLLOCALPLACEMENT(#99,#366);
#366 = IFCAxis2Placement3D(#362,#45,#358);
#362 = IFCCARTESIANPOINT((432.,0.,0.));
#45 = IFCDIRECTION((0.,0.,1.));
#358 = IFCDIRECTION((-1.,0.,0.));
#491 = IFCAxis2Placement3D(#487,#45,#37);
#487 = IFCCARTESIANPOINT((216.,-18.875,0.));
#45 = IFCDIRECTION((0.,0.,1.));
#37 = IFCDIRECTION((1.,0.,0.));
#483 = IFCPRODUCTDEFINITIONSHAPE($,$,(#477));
#477 = IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#474));
#474 = IFCEXTRUDEDAREASOLID(#466,#471,#45,18.875);
#466 = IFCCARTESIANPOINT((432.,0.,0.));
#463 = IFCAxis2Placement2D(#459,#455);
#459 = IFCCARTESIANPOINT((0.,54.,0.));
#455 = IFCDIRECTION((-1.,0.,0.));
#471 = IFCAxis2Placement3D(#49,#41,#467);
#49 = IFCCARTESIANPOINT((0.,0.,0.));
#41 = IFCDIRECTION((0.,1.,0.));
#467 = IFCDIRECTION((-1.,0.,0.));
```

---

1. In other words, it is the (0.,-1.,0) direction in the world coordinate system.
2. Since extrusion is in the (0.,-1.,0) direction, these points would be on the X-Z plane.
3. Center point is the location of the center of the rectangle, XDim defines the length measure for the length of the rectangle, and YDim defines the length measure for the width of the rectangle.
4. The Cartesian point (216, -18.875, 0) is placed relative to the point (432, 0, 0) in the world coordinate system, which is the origin of the south wall. Also note that in this local coordinate system, the X direction is (-1, 0, 0).
In other words, it is the (1., 0., 0) direction in the world coordinate system.

Since extrusion is in the (1., 0., 0) direction, these points would be on the Y-Z plane.

The Cartesian point (144, -18.875, 36) is placed relative to the point (432, 288, 0) in the world coordinate system, which is the origin of the east wall. Also note that in this local coordinate system, the X direction is (0, -1, 0).

<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch</th>
<th>[Pass / Fail]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opening (Window)</strong></td>
<td></td>
</tr>
<tr>
<td>• Check opening dimension and geometry</td>
<td></td>
</tr>
<tr>
<td>- Origin = (413., 144., 36.)</td>
<td></td>
</tr>
<tr>
<td>- XYZ directions: X = (0., -1., 0.), Y = (1., 0., 0.), Z = (0., 0., 1.)</td>
<td></td>
</tr>
<tr>
<td>- IfcShapeRepresentation.RepresentationIdentifier = &quot;Body&quot;</td>
<td></td>
</tr>
<tr>
<td>- IfcShapeRepresentation.RepresentationType = &quot;SweptSolid&quot;</td>
<td></td>
</tr>
<tr>
<td>- IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid</td>
<td></td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.Depth = 18.875 (in.)</td>
<td></td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.ExtrudedDirection = Y Direction</td>
<td></td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.Position = (0., 0., 0.)</td>
<td></td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.SweptArea.ProfileType = &quot;AREA&quot;</td>
<td></td>
</tr>
<tr>
<td>- 4 Cartesian points for the swept area = (30., 0.), (30., 48.), (-30., 48.), (-30., 0.)</td>
<td></td>
</tr>
<tr>
<td>OR if Rectangle Profile is used to define the area</td>
<td></td>
</tr>
<tr>
<td>- Center point = (0., 24.), XDim = 60, YDim = 48</td>
<td></td>
</tr>
</tbody>
</table>

Sample IFC Code:

```ibmxl
#1194= IFCOPENINGELEMENT(GUID,#13,"Opening",#1191,#1180,""));
#1191= IFCLOCALPLACEMENT(#1073,#1188);
#1073= IFCLOCALPLACEMENT3D(#99,#1070);
#1070= IFCAXIS2PLACEMENT3D(#1066,#45,#1062);
#1066= IFCCARTESIANPOINT((432.288,0.));
#45= IFCDIRECTION((0.,0.,1.));
#1062= IFCDIRECTION((0.,-1.,0.));
#1188= IFCAXIS2PLACEMENT3D(#1184,#45,#37);
#1184= IFCCARTESIANPOINT((144.,-18.875,36.));
#45= IFCDIRECTION((0.,0.,1.));
#37= IFCDIRECTION((1.,0.,0.));
#1180= IFCPRODUCTDEFINITIONSHAPE($,$,(#1174));
#1174= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#1171));
#1171= IFCEXTRUDEDAREASOLID(#1163,#1168,#45,18.875);
#1163= IFCRECTANGLEPROFILEDEF('.AREA.',#1160,60,48.);
#1160= IFCAXIS2PLACEMENT2D(#1156,#1152);
#1156= IFCCARTESIANPOINT((0.,24.));
#1152= IFCDIRECTION((1.,0.));
#1168= IFCAXIS2PLACEMENT3D(#49,#41,#1164);
#49= IFCCARTESIANPOINT((0.,0.,0.));
#41= IFCDIRECTION((0.,1.,0.));
#1164= IFCDIRECTION((-1.,0.,0.).);
```

---

1 In other words, it is the (1., 0., 0) direction in the world coordinate system.
2 Since extrusion is in the (1., 0., 0) direction, these points would be on the Y-Z plane.
3 The Cartesian point (144, -18.875, 36) is placed relative to the point (432, 288, 0) in the world coordinate system, which is the origin of the east wall. Also note that in this local coordinate system, the X direction is (0, -1, 0).
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Door

- Check door dimension and geometry
  - IfcShapeRepresentation.RepresentationIdentifier = “Body” OR “Parametric Representation” OR “Bounding Box”
  - (If shape is “Body”) IfcShapeRepresentation.RepresentationType = “Brep” OR “Surface Model” OR “SweptSolid”
  - IfcDoor.OverallHeight = 108 (in.)
  - IfcDoor.OverallWidth = 72 (in.)

- Check door properties
  Check door construction type
    - Pset_DoorCommon.Reference = “D2” OR IfcDoor.Name = “D2”
  Check UniFormat classification
    - IfcDoor.Description = “D2030 Exterior Doors”
  Check exterior or interior is declared
    - Pset_DoorCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```plaintext
#958= IFCDOOR(GUID,#13,'D2', 'D2030 Exterior Doors', $, #53, #954, $, 108., 72.);
#945= IFCPRODUCTDEFINITIONSHAPE($, $, (#948));
#948= IFCSHAPEREPRESENTATION(#407, 'Body', 'Brep', (#771, #854, #937));

#999= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,($958),#986);
#986= IFCPROPERTYSET(GUID,#13,'Pset_DoorCommon', $, (#991, #995));
#991= IFCPROPERTYSINGLEVALUE('Reference', $, IFCIDENTIFIER('D2'), $);
#995= IFCPROPERTYSINGLEVALUE('IsExternal', $, IFCBOOLEAN(.T.), $);
```

Window

- Check window dimension and geometry
  - IfcShapeRepresentation.RepresentationIdentifier = “Body” OR “Parametric Representation” OR “Bounding Box”
  - (If shape is “Body”) IfcShapeRepresentation.RepresentationType = “Brep” OR “Surface Model” OR “SweptSolid”
  - IfcWindow.OverallHeight = 48 (in.)
  - IfcWindow.OverallWidth = 60 (in.)

- Check window properties
  Check window construction type and classification
    - Pset_WindowCommon.Reference = “WIA2” OR IfcWindow.Name = “WIA2”
  Check UniFormat classification
    - IfcWindow.Description = “B2020 Exterior Windows”
  Check exterior or interior is declared
    - Pset_WindowCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```plaintext
#1960= IFCWINDOW(GUID,#13,'WIA2', 'B2020 Exterior Windows', $, #1227, #1956, 48., 60.);
#1956= IFCPRODUCTDEFINITIONSHAPE($, $, (#1950));
#1950= IFCSHAPEREPRESENTATION(#407, 'Body', 'Brep', ($1578, #1717, #1856, #1937));

#2001= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,($1960),#1988);
#1988= IFCPROPERTYSET(GUID,#13,'Pset_WindowCommon', $, (#1993, #1997));
#1993= IFCPROPERTYSINGLEVALUE('Reference', $, IFCIDENTIFIER('WIA2'), $);
#1997= IFCPROPERTYSINGLEVALUE('IsExternal', $, IFCBOOLEAN(.T.), $);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

Space
- **Check space dimension and geometry**
  - Origin = (18.875,18.875,0.)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 120 (in.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (250.25,0.), (250.25,-394.25), (0.,-394.25)

- **Check space properties**
  - IfcSpace.Name OR IfcSpace.LongName = "Room"
  - IfcSpace.InteriorOrExteriorSpace = "INTERNAL"

Sample IFC Code:
```
#3234= IFCSPACE(GUID,#13,'Room',$,#3231,#3220,'Room',.ELEMENT.,.INTERNAL.,$);
  #3231= IFLOCALPLACEMENT(#99,#3228);
    #3228= IFCS2PLACEMENT3D(#3224,#45,#41);
    #3224= IFCCARTESIANPOINT((18.875,18.875,0.));
    #45= IFCDIRECTION((0.,0.,1.));
    #41= IFCDIRECTION((0.,1.,0.));
  #3220= IFPRODUCTDEFINITIONSHAPE(.,$,(#3214));
    #3214= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#3211));
    #3211= IFCEXTRUDEDAREASOLID(#3207,#3208,#45,120.);
    #3207= IFCARBITRARYCLOSEDPOLYLINE(#3214);
    #3208= IFCS2PLACEMENT3D(#49,#45,#37);
    #49= IFCCARTESIANPOINT((0.,0.,0.));
    #45= IFCDIRECTION((0.,0.,1.));
    #37= IFCDIRECTION((1.,0.,0.));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.0625 (1/16) inch [ Pass / Fail ]

<table>
<thead>
<tr>
<th>Space Boundaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total space boundary count = 8</td>
</tr>
<tr>
<td>IfcRelSpaceBoundary.Name = “2ndLevel” (for all space boundaries)</td>
</tr>
<tr>
<td>IfcRelSpaceBoundary.PhysicalOrVirtualBoundary = “PHYSICAL” (for all)</td>
</tr>
<tr>
<td>IfcRelSpaceBoundary.InternalOrExternalBoundary = “EXTERNAL” (for all)</td>
</tr>
<tr>
<td>All space boundaries have a relating space</td>
</tr>
<tr>
<td>All space boundaries have a related building element</td>
</tr>
<tr>
<td>All space boundaries have a connection geometry</td>
</tr>
</tbody>
</table>

Door Space Boundary
- Placement relative to the local coordinate system (LCS)$^1$ of the space = (0.,0.,0.)
- Z axis = (-1.,0.,0.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (161.125,0.,0.)
  - P2: (233.125,0.,0.)
  - P3: (233.125,108.,0.)
  - P4: (161.125,108.,0.)

Window Space Boundary
- Placement relative to the LCS of the space = (0.,-394.25,0.)
- Z axis = (0.,-1.,0.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (155.125,84.,0.)
  - P2: (155.125,36.,0.)
  - P3: (95.125,36.,0.)
  - P4: (95.125,84.,0.)

Floor Slab Space Boundary
- Placement relative to the LCS of the space = (0.,0.,0.)
- Z axis = (0.,0.,-1.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (250.25,0.,0.)
  - P3: (250.25,394.25,0.)
  - P4: (0.,394.25,0.)

Roof Slab Space Boundary
- Placement relative to the LCS of the space = (0.,0.,120.)
- Z axis = (0.,0.,1.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (394.25,0.,0.)
  - P3: (394.25,250.25,0.)
  - P4: (0.,250.25,0.)

West Wall Space Boundary
- Placement relative to the LCS of the space = (250.25,0.,0.)
- Z axis = (0.,1.,0.) and X axis = (-1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (250.25,0.,0.)
  - P3: (250.25,120.,0.)
  - P4: (0.,120.,0.)

North Wall Space Boundary
- Placement relative to the LCS of the space = (250.25,-394.25,0.)
- Z axis = (1.,0.,0.) and X axis = (0.,1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (394.25,0.,0.)
  - P3: (394.25,120.,0.)
  - P4: (0.,120.,0.)

South Wall Space Boundary
- Placement relative to the LCS of the space = (0.,0.,0.)
- Z axis = (-1.,0.,0.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (394.25,0.,0.)
  - P3: (394.25,120.,0.)
  - P4: (0.,120.,0.)

East Wall Space Boundary
- Placement relative to the LCS of the space = (0.,-394.25,0.)
- Z axis = (0.,-1.,0.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (250.25,0.,0.)
  - P3: (250.25,120.,0.)
  - P4: (0.,120.,0.)

---

$^1$ The LCS of the space has origin = (18.875, 18.875, 0) and X = (0.,1.,0.), Y = (-1.,0.,0), Z = (0.,0.,1.) in the world coordinate system.

$^2$ Note that openings (including door/window) have space boundaries and that they do not generate “holes” or “inner loops” in the space boundaries of the walls or slabs in which they are contained.
Sample IFC Code:

```
#3562 = IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3234,#958,#3561,
.PHYSICAL,.EXTERNAL.);
#3243 = IFCSPACE(GUID,#13,'Room',$,,$,...);
#958 = IFCDOOR(GUID,#13,'D2', 'D2030 Exterior Doors', $,...);
#3561 = IFCCONNECTIONSURFACEGEOMETRY(#3557,$);
  #357 = IFCCURVEBOUNDDEPLANE(#3522,#3553,());
    #3522 = IFCLINE(#3519);
    #3519 = IFCAXIS2PLACEMENT3D(#49,#3515,#3511);
    #49 = IFCCARTESIANPOINT(0.,0.,0.);
    #3515 = IFCDIRECTION(-1.,0.,0.);
    #3511 = IFCDIRECTION(0.,-1.,0.);
    #3553 = IFCCOMPOSITECURVE((#3549),.U.);
    #3549 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS...,F.,#3545);
    #3545 = IFCPOLYLINE(#3525,#3529,#3537,#3541);
    #3525 = IFCCARTESIANPOINT(161.125,0.,0.);
    #3529 = IFCCARTESIANPOINT(233.125,0.,0.);
    #3533 = IFCCARTESIANPOINT(233.125,186.,0.);
    #3537 = IFCCARTESIANPOINT(161.125,186.,0.);
    #3541 = IFCCARTESIANPOINT(161.125,0.,0.);

#3338 = IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3234,#2411,#3337,
.PHYSICAL,.EXTERNAL.);
#3243 = IFCSPACE(GUID,#13,'Room',$,,$,...);
#2411 = IFCSLAB(GUID,#13,'FA5', 'Slabs-On-Grade', $,...);
#3337 = IFCCONNECTIONSURFACEGEOMETRY(#3333,$);
  #333 = IFCCURVEBOUNDDEPLANE(#3306,#3329,());
    #3306 = IFCLINE(#3303);
    #3303 = IFCAXIS2PLACEMENT3D(#49,#3299,#37);
    #49 = IFCCARTESIANPOINT(0.,0.,0.);
    #3299 = IFCDIRECTION(0.,0.,-1.);
    #37 = IFCDIRECTION(1.,0.,0.);
    #3329 = IFCCOMPOSITECURVE((#3325),.U.);
    #3325 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS...,F.,#3321);
    #3321 = IFCPOLYLINE(#49,#3309,#3313,#3317,#49);
    #49 = IFCCARTESIANPOINT(0.,0.,0.);
    #3309 = IFCCARTESIANPOINT(250.25,0.,0.);
    #3313 = IFCCARTESIANPOINT(250.25,394.25,0.);
    #3317 = IFCCARTESIANPOINT(0.,394.25,0.);

#3614 = IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3234,#1960,#3613,
.PHYSICAL,.EXTERNAL.);
#3243 = IFCSPACE(GUID,#13,'Room',$,,$,...);
#1960 = IFCWINDOW(GUID,#13,'W1A2', 'B2020 Exterior Windows', $,...);
#3613 = IFCCONNECTIONSURFACEGEOMETRY(#3609,$);
  #3609 = IFCCURVEBOUNDDEPLANE(#3574,#3605,());
    #3574 = IFCLINE(#3571);
    #3571 = IFCAXIS2PLACEMENT3D(#3567,#3563,#37);
    #3567 = IFCCARTESIANPOINT(0.,-394.25,0.);
    #3563 = IFCDIRECTION(0.,-1.,0.);
    #37 = IFCDIRECTION(1.,0.,0.);
    #3605 = IFCCOMPOSITECURVE((#3601),.U.);
    #3601 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS...,F.,#3597);
    #3597 = IFCPOLYLINE(#3577,#3581,#3585,#3589,#3593);
    #3577 = IFCCARTESIANPOINT(155.125,84.,0.);
    #3581 = IFCCARTESIANPOINT(155.125,36.,0.);
    #3585 = IFCCARTESIANPOINT(95.125,36.,0.);
    #3589 = IFCCARTESIANPOINT(95.125,84.,0.);
    #3593 = IFCCARTESIANPOINT(155.125,84.,0.);
```
#3426 = IFCRELSPACEBOUNDARY(GUID, #13, '2ndLevel', $, #3234, #2737, #3425, 
    .PHYSICAL, .EXTERNAL);
#3234 = IFCSPACE(GUID, #13, 'Room', $, $, $, $);
#2737 = IFCSLAB(GUID, #13, 'RA14', 'B1020 Roof Construction', $, $, $);
#3425 = IFCCONNECTIONSURFACEGEOMETRY(#3421, $);
#3421 = IFCCURVEBOUNDEDPLANE(#3394, #3417, ());

#3394 = IFCPLANE(#3391);
#3391 = IFCAXIS2PLACEMENT3D(#3387, #45, #3383);
#3387 = IFCCARTESIANPOINT((0., 0., 120.));
#45 = IFCDIRECTION((0., 0., 1.));
#3383 = IFCDIRECTION((0., -1., 0.));
#3417 = IFCCOMPOSITECURVE((#3413), .U.);
#3413 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS., .F., #3409);
#3409 = IFCPOLYLINE((#49, #3397, #3401, #3405, #49));
#49 = IFCCARTESIANPOINT((0., 0., 0.));
#3397 = IFCCARTESIANPOINT((394.25, 0., 0.));
#3401 = IFCCARTESIANPOINT((394.25, 250.25, 0.));
#3405 = IFCCARTESIANPOINT((0., 250.25, 0.));

#3470 = IFCRELSPACEBOUNDARY(GUID, #13, '2ndLevel', $, #3234, #2228, #3469, 
    .PHYSICAL, .EXTERNAL);
#3234 = IFCSPACE(GUID, #13, 'Room', $, $, $, $);
#2228 = IFCWALLSTANDARDCASE(GUID, #13, 'WA34', 'B2010 Exterior Walls', $, $, $);
#3469 = IFCCONNECTIONSURFACEGEOMETRY(#3465, $);
#3465 = IFCCURVEBOUNDEDPLANE(#3438, #3461, ());

#3438 = IFCPLANE(#3435);
#3435 = IFCAXIS2PLACEMENT3D(#3431, #41, #3427);
#3431 = IFCCARTESIANPOINT((250.25, 0., 0.));
#41 = IFCDIRECTION((0., 1., 0.));
#3427 = IFCDIRECTION((0., 0., 0.));
#3461 = IFCCOMPOSITECURVE((#3457), .U.);
#3457 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS., .F., #3453);
#3453 = IFCPOLYLINE((#49, #3441, #3445, #3449, #49));
#49 = IFCCARTESIANPOINT((0., 0., 0.));
#3441 = IFCCARTESIANPOINT((250.25, 0., 0.));
#3445 = IFCCARTESIANPOINT((250.25, 120., 0.));
#3449 = IFCCARTESIANPOINT((0., 120., 0.));

#3510 = IFCRELSPACEBOUNDARY(GUID, #13, '2ndLevel', $, #3234, #2094, #3509, 
    .PHYSICAL, .EXTERNAL);
#3234 = IFCSPACE(GUID, #13, 'Room', $, $, $, $);
#2094 = IFCWALLSTANDARDCASE(GUID, #13, 'WA34', 'B2010 Exterior Walls', $, $, $);
#3509 = IFCCONNECTIONSURFACEGEOMETRY(#3505, $);
#3505 = IFCCURVEBOUNDEDPLANE(#3478, #3501, ());

#3478 = IFCPLANE(#3475);
#3475 = IFCAXIS2PLACEMENT3D(#3471, #37, #41);
#3471 = IFCCARTESIANPOINT((250.25, -394.25, 0.));
#37 = IFCDIRECTION((1., 0., 0.));
#41 = IFCDIRECTION((0., 1., 0.));
#3501 = IFCCOMPOSITECURVE((#3497), .U.);
#3497 = IFCCOMPOSITECURVESEGMENT(.CONTINUOUS., .F., #3493);
#3493 = IFCPOLYLINE((#49, #3481, #3485, #3489, #49));
#49 = IFCCARTESIANPOINT((0., 0., 0.));
#3481 = IFCCARTESIANPOINT((394.25, 0., 0.));
#3485 = IFCCARTESIANPOINT((394.25, 120., 0.));
#3489 = IFCCARTESIANPOINT((0., 120., 0.));
#3298= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$.#3234,#372,#3297,
  .PHYSICAL.,.EXTERNAL.);
#3234= IFCSPACE(GUID,#13,'Room',$.$.,...);
#372= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',...);
#3297= IFCCONNECTIONSURFACEGEOMETRY(#3293,$);
#3293= IFCCURVEBOUNDEDPLANE(#3266,#3289,());
  #3266= IFCPOLYLINE((#49,#3269,#3273,#3277,#49));
  #3269= IFCCARTESIANPOINT((0.,0.,0.));
  #3273= IFCCARTESIANPOINT((394.25,0.,0.));
  #3277= IFCCARTESIANPOINT((0.,120.,0.));

#3382= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$.#3234,#1076,#3381,
  .PHYSICAL.,.EXTERNAL.);
#3234= IFCSPACE(GUID,#13,'Room',$.$.,...);
#1076= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',...);
#3381= IFCCONNECTIONSURFACEGEOMETRY(#3377,$);
#3377= IFCCURVEBOUNDEDPLANE(#3350,#3373,());
  #3350= IFCPOLYLINE((#49,#3353,#3357,#3361,#49));
  #3353= IFCCARTESIANPOINT((0.,0.,0.));
  #3357= IFCCARTESIANPOINT((250.25,0.,0.));
  #3361= IFCCARTESIANPOINT((0.,120.,0.));
7.2 BPEA Test Case 1 (metric)

BPEA Test Case 1

Test Case Title: Simple One-Story Building

Date of Last Edit: 10/01/2009

Summary Description: Test Case 1 consists of the simple one-story building shown on Figure A2. The building elements included in this test case are: 4 exterior walls, 1 base slab, 1 roof slab, 2 openings, 1 door, 1 window and 1 space.

Test Objectives:
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets

Figure A2: Simple one-story building
**Detailed Description:**

**Project Name: BPEA Test Case 1 (metric)**

Site Location: Washington D.C. (38°55’ Latitude, -77°0’ Longitude)  
Site Elevation = 3 m

Building Name: TC1  
Building Global Coordinates: 38°55’ Latitude, -77°0’ Longitude  
Building Orientation: 30° from true north  
Building Elevation from Sea Level = 3 m

Total Number of Building Stories = 1  
Name of 1st Building Story: “1st Floor”  
Elevation (relative to building datum) = 0 m

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (east)</td>
<td>Length: 7.3152 m Height: 3.048 m Thickness: 0.4794 m Origin: (10.9728, 7.3152, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall* (west)</td>
<td>Length: 7.3152 m Height: 3.048 m Thickness: 0.4794 m Origin: (0, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall* (south)</td>
<td>Length: 10.9728 m Height: 3.048 m Thickness: 0.4794 m Origin: (10.9728, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Exterior Wall* (north)</td>
<td>Length: 10.9728 m Height: 3.048 m Thickness: 0.4794 m Origin: (0, 7.3152, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>5. Floor Slab</td>
<td>Length: 10.9728 m Width: 7.3152 m Thickness: 0.256 m Origin: (0, 0, -0.256) X-axis: (1, 0, 0)</td>
<td>FA5</td>
<td>6-in HW concrete 4-in Gravel</td>
<td>A1030 Slab-on-grade</td>
</tr>
<tr>
<td>6. Roof Slab</td>
<td>Length: 10.9728 m Width: 7.3152 m Thickness: 0.2 m Origin: (0, 0, 3.048) X-axis: (1, 0, 0)</td>
<td>RA14</td>
<td>R-15 insulation 4-in LW concrete</td>
<td>B1020 Roof Construction</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls  
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
</table>
| 7. Door           | Width: 1.8288 m  
                    Height: 2.7432 m  
                    Placement: south wall, center  
                    Sill to base: 0 m | D2                | Steel slab (Foam insulated with metal edge in steel frame) Double door | D2030 Exterior Doors |
| 8. Window         | Width: 1.524 m  
                    Height: 1.2192 m  
                    Placement: east wall, center  
                    Sill to base: 0.9144 m | WIA2              | Double clear air window | B2020 Exterior Windows |
| 9. Door Opening   | Width: 1.8288 m  
                    Height: 2.7432 m  
                    Thickness: 0.4794 m  
                    Origin: (5.4864, 0.4794,0) |                  |                      |                          |
| 10. Window Opening| Width: 1.524 m  
                    Height: 1.2192 m  
                    Thickness: 0.4794 m  
                    Origin: (10.4934, 3.6576, 0.9144) |                  |                      |                          |
| 11. Space (Room)  | Length: 10.014 m  
                    Width: 6.3564 m  
                    Height: 3.048 m  
                    Origin: (0.4794, 0.4794,0)  
                    X-axis: (1, 0, 0) |                  |                      |                          |

When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.

**Screenshots of the building model in different IFC Viewers**

- *IfcStoreyView*
Testing Details for BPEA Test Case 1 (metric)

<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Check that all building elements exist</strong></td>
</tr>
<tr>
<td>4 IfcWallStandardCase</td>
</tr>
<tr>
<td>2 IfcSlab</td>
</tr>
<tr>
<td>2 IfcOpeningElement</td>
</tr>
<tr>
<td>1 IfcDoor</td>
</tr>
<tr>
<td>1 IfcWindow</td>
</tr>
<tr>
<td>1 IfcSpace</td>
</tr>
</tbody>
</table>

**Project**

- **Project identifier is required**
  - IfcProject.LongName = “BPEA Test Case 1”

Sample IFC Code:
```
#54= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 1','$','BPEA Test Case 1','$,(#51,#110,#398),#26);
```

- **Correct unit assignment**
  - Length measurement is in “Meter”

Sample IFC Code:
```
#14= IFCSIUNIT(*,.LENGTHUNIT.,$,.METRE.);
```

**Site**

- **Site location is specified**
  - IfcSite.LongName = “Washington D.C.”
- **Global coordinates (latitude and longitude) are required**
  - IfcSite.RefLatitude = (38.55,0)
  - IfcSite.RefLongitude = (-77,0,0)
- **Site elevation (relative to sea level) is required**
  - IfcSite.RefElevation = 3 (m.)
- **Coordinate of site origin is correctly specified**
  - Coordinate of site origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
```
#64= IFCSITE(GUID,#13,'Default Site','Washington D.C.',$,#61,$,'Washington D.C.',.ELEMENT.,(38,55,0),(-77,0,0),3.,$,$);
#61= IFCLocalPlacement($,#44);
#44= IFCAXIS2PLACEMENT3D(#40,#36,#28);
#40= IPCCARTESIANPOINT((0.,0.,0.));
```

---

1 One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as '0bY52t0r7xHf8OxWOsY$t'. In the examples, the GUID is shortened to the string 'GUID' to save space and improve readability.

2 In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

<table>
<thead>
<tr>
<th>Building</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building identifier is required</strong></td>
<td></td>
</tr>
<tr>
<td><em>IfcBuilding.LongName = “TC1”</em></td>
<td></td>
</tr>
<tr>
<td><strong>Elevation (base elevation of ground level floor above sea level) is required</strong></td>
<td></td>
</tr>
<tr>
<td><em>IfcBuilding.ElevationOfRefHeight = 3 (m.)</em></td>
<td></td>
</tr>
<tr>
<td><strong>Coordinate of building origin is correctly specified</strong></td>
<td></td>
</tr>
<tr>
<td><em>Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)</em></td>
<td></td>
</tr>
</tbody>
</table>

Sample IFC Code:

```
#77= IFCBUILDING(GUID,#13,'Default Building','TC1',$,#74,$,'TC1',.ELEMENT.,3.,$,$);
  #74= IFCLocalPlacement(#61,#44);  
    #61= IFCLocalPlacement($,#44);  
    #44= IFCAxis2Placement3D(#40,#36,#28);  
    #40= IFCCartesianPoint((0.,0.,0.));  

#3611= IFCPropertySingleValue('NumberOfStoreys',$,IFCInteger(1),$);  

#51= IFCGeometricRepresentationContext('Plan','Design',3,1.0000000E-5,#44,#47);  
  #47= IFCDirection((-0.5,0.866));  
```

| Number of stories is specified |   |
| _Pset_BuildingCommon.NumberOfStoreys = 1_ |   |

<table>
<thead>
<tr>
<th>Building Stories</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Identification is required</strong></td>
<td></td>
</tr>
<tr>
<td><em>IfcBuildingStorey.Name = “1st Floor”</em></td>
<td></td>
</tr>
<tr>
<td><strong>Elevation (relative to building datum) is required</strong></td>
<td></td>
</tr>
<tr>
<td><em>IfcBuildingStorey.Elevation = 0</em></td>
<td></td>
</tr>
</tbody>
</table>

Sample IFC Code:

```
#93= IFCBuildingStorey(GUID,#13,'1st Floor',$,$,#90,$,$,.ELEMENT.,0.);  
  #90= IFCLocalPlacement(#74,#87);  
    #74= IFCLocalPlacement(#61,#44);  
    #61= IFCLocalPlacement($,#44);  
    #44= IFCAxis2Placement3D(#40,#36,#28);  
    #36= IFCAxis2Placement3D(#40,#36,#28);  
    #28= IFCCartesianPoint((0.,0.,0.));  
```

1 IDM indicates that buildings should contain latitude and longitude information, as different buildings in the same site may have different latitude and longitude values. However, RefLatitude and RefLongitude are attributes of IfcSite, not IfcBuilding.

2 The building orientation is considered to be the grid rotation from true north, therefore if the building and/or the site is modeled in a different orientation on the original grid, then a combination of rotations from the building and site would need to be considered to determine the actual orientation.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Walls (West Wall)
- **Check wall dimension and geometry**
  
  1. Origin\(^2\) = (0.,0.,0.)
  2. XYZ directions\(^2\): X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  3. `IfcShapeRepresentation.RepresentationIdentifier` = "Body"
  4. `IfcShapeRepresentation.RepresentationType` = "SweptSolid"
  5. `IfcShapeRepresentation.Items` must be one `IfcExtrudedAreaSolid`
  6. `IfcExtrudedAreaSolid.Depth` = 3.048 (m.)
  7. `IfcExtrudedAreaSolid.ExtrudedDirection` = (0.,0.,1.)
  8. `IfcExtrudedAreaSolid.Position` = (0.,0.,0.)
  9. `IfcExtrudedAreaSolid.SweptArea.ProfileType` = "AREA"
  10. 4 Cartesian points for the swept area\(^3\) = (0.0), (7.3152,0.), (6.8358,-0.4794), (0.4794,-0.4794)

- **Check wall properties**
  
  Check wall construction type
  
  1. `Pset_WallCommon.Reference` = "WA34" OR `IfcWall.Name` = "WA34"

  Check Uniformat classification
  
  1. `IfcWall.Description` = "B2010 Exterior Wall"

  Check exterior or interior is declared
  
  1. `Pset_WallCommon.IsExternal` = `IfcBoolean(T)`

Sample IFC Code\(^4\):  

```plaintext
#2219= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',$
,2216,#2289,$);
#2216= IFCLocalPlacement(#90,#2213);
 #2213= IFCAxis2Placement3D(#40,#36,#32);
 #40= IFCCartesianPoint(0.,0.,0.);
 #36= IFCDirection((0.,0.,1.));
 #32= IFCDirection((0.,1.,0.));
 #2289= IFCProductDefinitionShape($,$,'Body','SweptSolid',($2280));
 #2280= IFCExtrudedAreaSolid(#2276,#2277,#36,3.048);
 #2276= IFCArbitraryClosedProfileDef(\AREA\,$,$,#2272);
 #2272= IFCPolyline((#2256,#2260,#2264,#2268,#2256));
 #2256= IFCCartesianPoint((0.4794,0.4794));
 #2260= IFCCartesianPoint((6.8358,0.4794));
 #2264= IFCCartesianPoint((7.3152,0.0));
 #2268= IFCCartesianPoint((0.,0.));
 #2277= IFCAxis2Placement3D(#40,#36,#28);
 #40= IFCCartesianPoint(0.,0.,0.);
 #36= IFCDirection((0.,0.,1.));
 #28= IFCDirection((1.,0.,0.));
```

\(^1\) The intersection between walls can affect the geometry, i.e., the placement of the Cartesian points of the swept area.

\(^2\) The origin and the direction of the wall (and other building elements) are indicated by `IfcWall` (or `IfcWallStandardCase`).`IfcLocalPlacement.Position`. The XYZ directions are the axes of the local coordinate system in reference to the world coordinate system.

\(^3\) These are points in the local coordinate system.

\(^4\) The position and orientation in #2213 are related to the wall. The position and orientation in #2277 are related to the extrusion.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Walls (North Wall)
- Check wall dimension and geometry
  ___ Origin = (0., 7.3152, 0.)
  ___ XYZ directions: X = (1., 0., 0.), Y = (0., 1., 0.), Z = (0., 0., 1.)
  ___ IfcShapeRepresentation.RepresentationIdentifier = "Body"
  ___ IfcShapeRepresentation.RepresentationType = "SweptSolid"
  ___ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  ___ IfcExtrudedAreaSolid.Depth = 3.048 (m.)
  ___ IfcExtrudedAreaSolid.ExtrudedDirection = (0., 0., 1.)
  ___ IfcExtrudedAreaSolid.Position = (0., 0., 0.)
  ___ IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  ___ 4 Cartesian points for the swept area =
          (0., 0.), (10.9728, 0.), (10.4934, -0.4794), (0.4794, -0.4794)

- Check wall properties
  Check wall construction type
    ___ Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  Check Uniformat classification
    ___ IfcWall.Description = "B2010 Exterior Wall"
  Check exterior or interior is declared
    ___ Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
#2085= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',$
  #2082,#2155,$);
  #2082= IFCLOCALPLACEMENT(#90,#2079);
  #2079= IFCAXIS2PLACEMENT3D(#2075,#36,#28);
  #2075= IFCCARTESIANPOINT((0., 7.3152, 0.));
  #36= IFCDIRECTION((0., 0., 1.));
  #28= IFCDIRECTION((1., 0., 0.));
#2155= IFCPRODUCTDEFINITIONSHAPE($, $, (#2116,#2149));
#2149= IFCSHAPEREPRESENTATION(#398, 'Body', 'SweptSolid', (#2146));
#2146= IFCEXTRUDEDAREASOLID(#2142,#2143,#36,3.048);
#2142= IFCARBITRARYCLOSEDPROFILEDEF('AREA', $, #2138);
  #2138= IFCPOLYLINE((#2122,#2126,#2130,#2134,#2122));
  #2122= IFCCARTESIANPOINT((0.4794,-0.4794));
  #2126= IFCCARTESIANPOINT((10.4934,-0.4794));
  #2130= IFCCARTESIANPOINT((10.9728,0.));
  #2134= IFCCARTESIANPOINT((0., 0.));
#2143= IFCAXIS2PLACEMENT3D(#40,#36,#28);
  #40= IFCCARTESIANPOINT((0., 0., 0.));
  #36= IFCDIRECTION((0., 0., 1.));
  #28= IFCDIRECTION((1., 0., 0.));

#2210= IFCRELDEFINESBYPROPERTIES(GUID,#13,$, $, (#2085,#2197));
#2197= IFCPROPERTYSET(GUID,#13,'Pset_WallCommon',$, (#2202,#2206));
#2202= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
#2206= IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);

1 Pset_WallCommon currently doesn’t include “Construction type”, hence construction type is placed under “Reference”.
2 In addition, construction type and classification can also be placed under building element’s name and description.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [Pass / Fail]

Walls (East Wall)

- Check wall dimension and geometry
  - Origin = (10.9728,7.3152,0.)
  - XYZ directions: X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 3.048 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (7.3152,0.), (6.8358,-0.4794), (0.4794,-0.4794)

- Check wall properties
  Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```plaintext
#1067= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
$,#1064,#1137,$);
  #1064= IFCLocalPlacement(#90,#1061);
    #1061= IFCAxis2Placement3D(#1057,#36,#1053);
      #1057= IFCCartesianPoint((10.9728,7.3152,0.));
      #36= IFCDirection((0.,0.,1.));
      #1053= IFCDirection((0.,-1.,0.));
  #1137= IFCPProductDefinitionShape($,$,(#1098,#1131));
  #1131= IFCShapeRepresentation(#398,'Body','SweptSolid',(#1128));
  #1128= IFCEXTRUDEDAREASOLID(#1124,#1125,#36,3.048);
    #1124= IFCArbitraryClosedProfileDef('AREA', $, #1120);
      #1120= IFCPolyLine((#1104,#1108,#1112,#1116,#1114));
      #1104= IFCCartesianPoint((0.4794,-0.4794));
      #1108= IFCCartesianPoint((6.8358,-0.4794));
      #1112= IFCCartesianPoint((7.3152,0.));
      #1116= IFCCartesianPoint((0.,0.));
    #1125= IFCAxis2Placement3D(#40,#36,#28);
      #40= IFCCartesianPoint((0.,0.,0.));
      #36= IFCDirection((0.,0.,1.));
      #28= IFCDirection((1.,0.,0.));

#2065= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#1067),#2039);
#2039= IFCPROPERTYSET(GUID,#2043,'Pset_WallCommon',$,(#2045,#2049));
#2045= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
#2049= IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Walls (South Wall)

- Check wall dimension and geometry
  - Origin = (10.9728, 0., 0.)
  - XYZ directions: X = (-1., 0., 0.), Y = (0., -1., 0.), Z = (0., 0., 1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
    - IfcExtrudedAreaSolid.Depth = 3.048 (m.)
    - IfcExtrudedAreaSolid.ExtrudedDirection = (0., 0., 1.)
    - IfcExtrudedAreaSolid.Position = (0., 0., 0.)
    - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0., 0.), (10.9728, 0.), (10.4934, -0.4794), (0.4794, -0.4794)

- Check wall properties
  - Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  - Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```plaintext
#363= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls', $,#360,#440,$);
  #360= IFCLOCALPLACEMENT(#90,#357);
    #357= IFCAXIS2PLACEMENT3D(#353,#36,#349);
      #353= IFCCARTESIANPOINT((10.9728,0.,0.));
      #36= IFCDIRECTION((0.,0.,1.));
      #349= IFCDIRECTION((-1.,0.,0.));
    #400= IFCPRODUCTDEFINITIONSHAPE($,$, (#401,#434));
      #401= IFCSHAPEREPRESENTATION('#398', 'Body', 'SweptSolid',('#431'));
      #398= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan','Model',3,
        1.0000000E-5,#44,#394);
      #44= IFCAxis2Placement3D(#40,#36,#28);
      #394= IFCDIRECTION((-0.5,0.866));
    #431= IFCEXTRUDEDAREASOLID(#427,#428,#36,#3048);
    #427= IFCARBITRARYCLOSEDPOLYLINEDEF('AREA', $,#423);
      #423= IFCPOLYLINE(#407,#411,#415,#419,#407);
      #407= IFCCARTESIANPOINT((0.4794,-0.4794));
      #411= IFCCARTESIANPOINT((10.4934,-0.4794));
      #415= IFCCARTESIANPOINT((10.9728,0.));
      #419= IFCCARTESIANPOINT((0.,0.,0.));
    #428= IFCAxis2Placement3D(#40,#36,#28);
    #40= IFCCARTESIANPOINT((0.,0.,0.));
    #36= IFCDIRECTION((0.,0.,1.));
    #28= IFCDIRECTION((1.,0.,0.));
#1043= IFCREDEFINEPROPERTY(GUID,#13,$,$,(#363),#1017);
#1017= IFCPROPERTYSET(GUID,#1021,'Pset_WallCommon',$,(#1023,#1027));
#1023= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
#1027= IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

<table>
<thead>
<tr>
<th>Walls (All Walls)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Check material association (for all walls)</strong></td>
</tr>
<tr>
<td>___ IfcMaterialLayerSet.LayerSetName = &quot;WA34&quot;</td>
</tr>
<tr>
<td>___ IfcMaterialLayer.LayerThickness = 0.0001 (m.)</td>
</tr>
<tr>
<td>___ IfcMaterial.Name = &quot;Outside surface resistance&quot;</td>
</tr>
<tr>
<td>___ IfcMaterialLayer.LayerThickness = 0.3048 (m.)</td>
</tr>
<tr>
<td>___ IfcMaterial.Name = &quot;12 in. heavyweight concrete&quot;</td>
</tr>
<tr>
<td>___ IfcMaterialLayer.LayerThickness = 0.15875 (m.)</td>
</tr>
<tr>
<td>___ IfcMaterial.Name = &quot;R-19 batt insulation&quot;</td>
</tr>
<tr>
<td>___ IfcMaterialLayer.LayerThickness = 0.015875 (m.)</td>
</tr>
<tr>
<td>___ IfcMaterial.Name = &quot;Gyp board&quot;</td>
</tr>
<tr>
<td>___ IfcMaterialLayer.LayerThickness = 0.0001 (m.)</td>
</tr>
<tr>
<td>___ IfcMaterial.Name = &quot;Inside surface resistance&quot;</td>
</tr>
</tbody>
</table>

Sample IFC Code:

```plaintext
#444 = IFCRELASSOCIATESMATERIAL(GUID, #13, $, $, (#363), #348);
  #348 = IFCMATERIALLAYERSETUSAGE(#346, .AXIS2., .POSITIVE., -0.4794);

#1141 = IFCRELASSOCIATESMATERIAL(GUID, #13, $, $, (#1067), #1052);
  #1052 = IFCMATERIALLAYERSETUSAGE(#346, .AXIS2., .POSITIVE., -0.4794);

#2159 = IFCRELASSOCIATESMATERIAL(GUID', #13, $, $, (#2085), #2074);
  #2074 = IFCMATERIALLAYERSETUSAGE(#346, .AXIS2., .POSITIVE., -0.4794);

#2293 = IFCRELASSOCIATESMATERIAL(GUID, #13, $, $, (#2219), #2212);
  #2212 = IFCMATERIALLAYERSETUSAGE(#346, .AXIS2., .POSITIVE., -0.4794);

  #346 = IFCMATERIALLAYERSET((#116, #258, #304, #339, #344), 'Wall Type 34 WA34 Precast and CIP Concrete Walls');
    #116 = IFCMATERIALLAYER(#103, 0.0001, .U.);
    #103 = IFCMATERIAL('F01 Outside Surface Resistance');
    #258 = IFCMATERIALLAYER(#118, 0.3048, .U.);
    #118 = IFCMATERIAL('M16 12 in. Heavyweight Concrete');
    #304 = IFCMATERIALLAYER(#260, 0.15875, .U.);
    #260 = IFCMATERIAL('I05 R-19, 6-1/4 in. Batt Insulation');
    #339 = IFCMATERIALLAYER(#306, 0.015875, .U.);
    #306 = IFCMATERIAL('G01 5/8 in. Gyp Board');
    #344 = IFCMATERIALLAYER(#341, 0.0001, .U.);
    #341 = IFCMATERIAL('F02 Inside Vertical Surface Resistance');
```

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Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [Pass / Fail]

**Floor Slab**

- Check slab dimension and geometry
  - Origin = (0.,0.,-0.256)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 0.256 (m)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (7.3152,0.), (7.3152,-10.9728), (0.,-10.9728)

- Check slab properties
  - Check slab construction type
    - Pset_SlabCommon.Reference = "FA5" OR IfcSlab.Name = "FA5"
  - Check UniFormat classification
    - IfcSlab.Description = "A1030 Slabs on Grade"
  - Check exterior or interior is declared
    - Pset_SlabCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:

```xml
#2402= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,#2465,#2454,$.BASESLAB.);
#2465= IFLOCALPLACEMENT(#90,#2462);
 #2462= IFCAxis2Placement3D(#2458,#36,#32);
 #2458= IFCCartesianPoint((0.,0.,-0.256));
 #36= IFCDirection((0.,0.,1.));
 #32= IFCDirection((0.,1.,0.));
 #2454= IFCPROPERTYDEFINITIONS(H,$,(#2402));
 #2448= IFCSHAPEREPRESENTATION(#396,'Body','SweptSolid',(2445));
 #2445= IFCEXTRUDEDAREASOLID(#2441,#2442,#36,0.256);#
 #2441= IFCArbitraryClosedProfileDef('AREA',$,#2437);
 #2437= IFCPOLYLINE((2421,2425,2429,2433,2421));
 #2421= IFCCartesianPoint((0.,0.));
 #2425= IFCCartesianPoint((7.3152,0.));
 #2429= IFCCartesianPoint((7.3152,-10.9728));
 #2433= IFCCartesianPoint((0.,-10.9728));
 #2442= IFCAxis2Placement3D(#40,#36,#28);
 #40= IFCCartesianPoint((0.,0.,0.));
 #36= IFCDirection((0.,0.,1.));
 #28= IFCDirection((1.,0.,0.));
 #2724= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(2402),#2711);
 #2711= IFCPROPERTYSET(GUID,#13,'Pset_SlabCommon',$,(2716,#2720);
 #2716= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('FA5'),$);
 #2720= IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Roof Slab

- **Check slab dimension and geometry**
  - Origin = (0.,0.,3.048)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = “Body”
  - IfcShapeRepresentation.RepresentationType = “SweptSolid”
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 0.2 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
  - 4 Cartesian points for the swept area = (0.,0.), (7.3152,0.), (7.3152,-10.9728), (0.,-10.9728)

- **Check slab properties**
  - Check slab construction type
    - Pset_SlabCommon.Reference = “RA14” OR IfcSlab.Name = “RA14”
  - Check UniFormat classification
    - IfcSlab.Description = “B1020 Roof Construction”
  - Check exterior or interior is declared
    - Pset_SlabCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```
#2728= IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,#2791,#2780,$,.ROOF.);
#2791= IFCLocalPlacement(#90,#2788);
  #2788= IFCAxis2Placement3D(#2784,#36,#32);
    #2784= IFCCartesianPoint((0.,0.,3.048));
    #36= IFCDirection((0.,0.,1.));
    #32= IFCDirection((1.,0.,0.));
#2780= IFCPProductDefinitionShape($,$,(#2728));
#2774= IFCSHAPERepresentation(#398,'Body','SweptSolid',(#2771));
#2771= IFCEXTRUDEDAREASOLID(#2767,#2768,#36,0.2);
#2767= IFCCartesianPoint((0.,0.,0.));
#2768= IFCCartesianPoint((7.3152,0.,0.));
#2755= IFCCartesianPoint((7.3152,-10.9728));
#2759= IFCCartesianPoint((0.,-10.9728));
#2765= IFCAxis2Placement3D(#40,#36,#28);
#40= IFCCartesianPoint((0.,0.,0.));
#36= IFCDirection((0.,0.,1.));
#28= IFCDirection((1.,0.,0.));
#3174= IFCREDEFINESBYPROPERTIES(GUID,#13,$,$,(#2728),#3161);
#3161= IFCPROPERTYSet(GUID,#13,'Pset_SlabCommon',$,(#3166,#3170));
#3166= IFCPROPERTYSingleValue('Reference',$,IFCIDENTIFIER('RA14'),$);
#3170= IFCPROPERTYSingleValue('IsExternal'$,IFCBOOLEAN(.T.$),$);
```
Ve
rdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Slabs (Floor and Roof Slabs)

- Check material association
  - IfcMaterialLayerSet.LayerSetName = "FA5"
  - IfcMaterialLayer.LayerThickness = 0.1524 (m.)
  - IfcMaterial.Name = "6in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.002 (m.)
  - IfcMaterial.Name = "Vapor barrier"
  - IfcMaterialLayer.LayerThickness = 0.1016 (m.)
  - IfcMaterial.Name = "4in. gravel"

Sample IFC Code:
#2701 = IFCRELASSOCIATESMATERIAL(GUID, #13, $, $, (#2402), #2700);
  #2700 = IFCMATERIALLAYERSETUSAGE(#2698, .AXIS3., .NEGATIVE., 0.256);
  #2698 = IFCMATERIALLAYERSET((#2611, #2444, #2696), ' Floor Type 05_FA5 Slab On Grade');
    #2611 = IFCMATERIALLAYER(#2471, 0.1524, .U.);
    #2471 = IFCMATERIAL(' M14 | 6 in. Heavyweight Concrete');
    #2444 = IFCMATERIALLAYER(#2613, 0.002, .U.);
    #2613 = IFCMATERIAL(' F20 | Vapor Barrier');
    #2696 = IFCMATERIALLAYER(#2646, 0.1016, .U.);
    #2646 = IFCMATERIAL(' M18 | 4 in. Gravel');

- IfcMaterialLayerSet.LayerSetName = "RA14"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 0.0095 (m.)
  - IfcMaterial.Name = "Build-up roofing"
  - IfcMaterialLayer.LayerThickness = 0.0127 (m.)
  - IfcMaterial.Name = "1/2 in. fiberboard sheathing"
  - IfcMaterialLayer.LayerThickness = 0.0762 (m.)
  - IfcMaterial.Name = "R-15 insulation board"
  - IfcMaterialLayer.LayerThickness = 0.1016 (m.)
  - IfcMaterial.Name = "4 in. lightweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Inside surface resistance"

Sample IFC Code:
#3151 = IFCRELASSOCIATESMATERIAL(GUID, #13, $, $, (#2728), #3150);
  #3150 = IFCMATERIALLAYERSETUSAGE(#3148, .AXIS3., .NEGATIVE., 0.2);
  #3148 = IFCMATERIALLAYERSET((#2797, #2843, #2953, #2999, #3141, #3146), ' Roof Type 14_RA14 Concrete Roofs');
    #2797 = IFCMATERIALLAYER(#103, 0.0001, .U.);
    #103 = IFCMATERIAL(' F01 Outside Surface Resistance');
    #2843 = IFCMATERIALLAYER(#2799, 0.0095, .U.);
    #2799 = IFCMATERIAL(' F13 | Built-Up Roofing');
    #2953 = IFCMATERIALLAYER(#2845, 0.0127, .U.);
    #2845 = IFCMATERIAL(' G03 | 1/2 in. Fiberboard Sheathing');
    #2999 = IFCMATERIALLAYER(#2955, 0.0762, .U.);
    #2955 = IFCMATERIAL(' I03 | R15.3 in. insulation board');
    #3141 = IFCMATERIALLAYER(#3001, 0.1016, .U.);
    #3001 = IFCMATERIAL(' M11 | 4 in. Lightweight Concrete');
    #3146 = IFCMATERIALLAYER(#3143, 0.0001, .U.);
    #3143 = IFCMATERIAL(' F03 Inside Horizontal Surface Resistance');
<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opening (Door)</strong></td>
</tr>
<tr>
<td>1. Check opening dimension and geometry</td>
</tr>
<tr>
<td>- Origin = (5.4864, -0.4794, 0.)</td>
</tr>
<tr>
<td>- XYZ directions: X = (-1., 0., 0.), Y = (0., -1., 0.), Z = (0., 0., 1.)</td>
</tr>
<tr>
<td>- IfcShapeRepresentation.RepresentationIdentifier = &quot;Body&quot;</td>
</tr>
<tr>
<td>- IfcShapeRepresentation.RepresentationType = &quot;SweptSolid&quot;</td>
</tr>
<tr>
<td>- IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid</td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.Depth = 0.4794 (m)</td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.ExtrudedDirection = Y Direction</td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.Position = (0., 0., 0.)</td>
</tr>
<tr>
<td>- IfcExtrudedAreaSolid.SweptArea.ProfileType = &quot;AREA&quot;</td>
</tr>
<tr>
<td>- 4 Cartesian points for the swept area $^{2}$ = (0.9144, 0), (0.9144, 2.7432), (-0.9144, 2.7432), (-0.9144, 0) OR if Rectangle Profile is used to define the area $^{3}$</td>
</tr>
<tr>
<td>- Center point = (0., 1.3716), XDim = 1.8288, YDim = 2.7432</td>
</tr>
</tbody>
</table>

**Sample IFC Code:**

```plaintext
#485 = IFCLOCALPLACEMENT(#360,#482);
#360 = IFCLOCALPLACEMENT(#90,#357);
  #357 = IFCAXIS2PLACEMENT3D(#353,#36,#349);
  #353 = IFCCARTESIANPOINT((10.9728, 0, 0.));
  #36 = IFCDIRECTION((0., 0., 1.));
  #349 = IFCDIRECTION((-1., 0., 0.));
#482 = IFCAXIS2PLACEMENT3D(#478,#36,#28);
#478 = IFCCARTESIANPOINT((5.4864, -0.4794, 0.));
#36 = IFCDIRECTION((0., 0., 1.));
#28 = IFCDIRECTION((1., 0., 0.));
#474 = IFCPRODUCTDEFINITIONSHAPE($,$,#468));
#468 = IFCSHAPEREPRESENTATION(#398, 'Body', 'SweptSolid', (#465));
#465 = IFCEXTRUDEDAREASOLID(#457,#462,#36,0.4794));
#457 = IFCRECTANGLEPROFILEDEF(.AREA.,$,#454,1.8288,2.7432); #454 = IFCAXIS2PLACEMENT2D(#450,#446);
#450 = IFCCARTESIANPOINT((0.,1.3716));
#446 = IFCDIRECTION((-1.,0.));
#462 = IFCAXIS2PLACEMENT3D(#440,#32,#458);
#440 = IFCCARTESIANPOINT((0.,0.,0.));
#32 = IFCDIRECTION((0.,1.,0.));
#458 = IFCDIRECTION((-1.,0.,0.));
```

1. In other words, it is the (0., -1., 0) direction in the world coordinate system.
2. Since extrusion is in the (0., -1., 0) direction, these points would be on the X-Z plane.
3. Center point is the location of the center of the rectangle, XDim defines the length measure for the length of the rectangle, and YDim defines the length measure for the width of the rectangle.
4. The Cartesian point (5.4864, -0.4794, 0) is placed relative to the point (10.9728, 0, 0) in the world coordinate system, which is the origin of the south wall. Also note that in this local coordinate system, the X direction is (-1, 0, 0).
In other words, it is the (1.,0.,0) direction in the world coordinate system.

Since extrusion is in the (1.,0.,0) direction, these points would be on the Y-Z plane.

The Cartesian point (3.6576, -0.4794, 0.9144) is placed relative to the point (10.9728, 7.3152, 0) in the world coordinate system, which is the origin of the east wall. Also note that in this local coordinate system, the X direction is (0, -1, 0).

<table>
<thead>
<tr>
<th>Verdict Criteria</th>
<th>All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]</th>
</tr>
</thead>
</table>
| **Opening (Window)** | **Check opening dimension and geometry**  
| | ___ Origin = (10.4934,3.6576,0.9144)  
| | ___ XYZ directions: X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)  
| | ___ IfcShapeRepresentation.RepresentationIdentifier = "Body"  
| | ___ IfcShapeRepresentation.RepresentationType = "SweptSolid"  
| | ___ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid  
| | ___ IfcExtrudedAreaSolid.Depth = 0.4794 (m.)  
| | ___ IfcExtrudedAreaSolid.ExtrudedDirection = Y Direction\(^1\)  
| | ___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)  
| | ___ IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"  
| | ___ 4 Cartesian points for the swept area\(^2\) = (0.762.0.), (0.762.1.2192), (-0.762.1.2192), (-0.762.0.)  
| | ___ OR if Rectangle Profile is used to define the area  
| | ___ Center point = (0.,0.6096), XDim = 1.524, YDim = 1.2192  

Sample IFC Code:\(^3\):

```plaintext
#1158= IFCOPENINGELEMENT(GUID,#13,$,,$,'Opening',#1182,#1171,'');
#1182= IFCLOCALPLACEMENT(#1064,#1179);
#1064= IFCLOCALPLACEMENT(#90,#1061);
#1061= IFCAxis2Placement3D(#1057,#36,#1053);
#1057= IFCCARTESIANPOINT((10.9728,7.3152,0.));
#36= IFCDIRECTION((0.,0.,1.));
#1053= IFCDIRECTION((0.,-1.,0.));
#1179= IFCAxis2Placement3D(#1175,#36,#28);
#1175= IFCCARTESIANPOINT((3.6576,-0.4794,0.9144));
#36= IFCDIRECTION((0.,0.,1.));
#28= IFCDIRECTION((1.,0.,0.));
#1171= IFCPRODUCTDEFINITIONSHAPE($,$,(#1165));
#1165= IFCSHAPEREPRESENTATION(#398,'Body','SweptSolid',(#1162));
#1162= IFCEXTRUDEDAREASOLID(#1154,#1159,#36,0.4794);
#1154= IFCRECTANGLEPROFILEDEF('AREA',#1151,1.524,1.2192);
#1151= IFCAxis2Placement2D(#1147,#1143);
#1143= IFCDIRECTION((1.,0.,0.));
#1147= IFCCARTESIANPOINT((0.,0.6096));
#1159= IFCAxis2Placement3D(#40,#32,#1155);
#40= IFCCARTESIANPOINT((0.,0.,0.));
#32= IFCDIRECTION((0.,1.,0.));
#1155= IFCDIRECTION((-1.,0.,0.));
```

\(^1\) In other words, it is the (1.,0.,0) direction in the world coordinate system.

\(^2\) Since extrusion is in the (1.,0.,0) direction, these points would be on the Y-Z plane.

\(^3\) The Cartesian point (3.6576, -0.4794, 0.9144) is placed relative to the point (10.9728, 7.3152, 0) in the world coordinate system, which is the origin of the east wall. Also note that in this local coordinate system, the X direction is (0, -1, 0).
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

**Door**
- **Check door dimension and geometry**
  - IfcShapeRepresentation.RepresentationIdentifier = “Body” OR “Parametric Representation” OR “Bounding Box”
  - (If shape is “Body”) IfcShapeRepresentation.RepresentationType = “Brep” OR “Surface Model” OR “SweptSolid”
  - IfcDoor.OverallHeight = 2.7432 (m.), IfcDoor.OverallWidth = 1.8288 (m.)

- **Check door properties**
  - Check door construction type
    - Pset_DoorCommon.Reference = “D2” OR IfcDoor.Name = “D2”
  - Check UniFormat classification
    - IfcDoor.Description = “D2030 Exterior Doors”
  - Check exterior or interior is declared
    - Pset_DoorCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```
#949 = IFCDOOR(GUID,#13,'D2','D2030 Exterior Doors',$,#521,#945,$,2.7432,1.8288);
#945 = IFCPRODUCTDEFINITIONSHAPE($,$,(#939));
  #939 = IFCSHAPEREPRESENTATION(#398,'Body','Brep',(#762,#845,#928));
#990 = IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#949),#977);
#977 = IFCPROPERTYSET(GUID,#13,'Pset_DoorCommon',$,(#982,#986));
  #982 = IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('D2'),$);
  #986 = IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```

**Window**
- **Check window dimension and geometry**
  - IfcShapeRepresentation.RepresentationIdentifier = “Body” OR “Parametric Representation” OR “Bounding Box”
  - (If shape is “Body”) IfcShapeRepresentation.RepresentationType = “Brep” OR “Surface Model” OR “SweptSolid”
  - IfcWindow.OverallHeight = 1.2192 (m.), IfcWindow.OverallWidth = 1.524 (m.)

- **Check window properties**
  - Check window construction type and classification
    - Pset_WindowCommon.Reference = “WIA2” OR IfcWindow.Name = “WIA2”
  - Check UniFormat classification
    - IfcWindow.Description = “B2020 Exterior Windows”
  - Check exterior or interior is declared
    - Pset_WindowCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```
#1951 = IFCHWINDOW(GUID,#13,'WIA2','B2020 Exterior Windows',$,#1218,#1947,$,1.2192,1.524);
#1947 = IFCPRODUCTDEFINITIONSHAPE($,$,(#1941));
  #1941 = IFCSHAPEREPRESENTATION(#398,'Body','Brep',(#1569,#1708,#1847,#1928));
#1992 = IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#1951),#1979);
#1979 = IFCPROPERTYSET(GUID,#13,'Pset_WindowCommon',$,(#1984,#1988));
  #1984 = IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WIA2'),$);
  #1988 = IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [ Pass / Fail ]

Space
- **Check space dimension and geometry**
  - Origin = (0.4794,0.4794,0.)
  - XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 3.048 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 Cartesian points for the swept area = (0.,0.), (6.3564,0.), (6.3564,-10.014), (0.,-10.014)

- **Check space properties**
  - IfcSpace.Name OR IfcSpace.LongName = "Room"
  - IfcSpace.InteriorOrExteriorSpace = "INTERNAL"

Sample IFC Code:
```plaintext
#325= IFCSPACE(GUID,#13,'Room',$,,$,#322,#3211,'Room',.ELEMENT.,
 .INTERNAL.,$);
 #322= IFCLLOCALPLACEMENT(#90,#3219);
   #3219= IFCCAXIS2PLACEMENT3D(#3215,#36,#32);
     #3215= IFCCARTESIANPOINT((0.4794,0.4794,0.));
     #36= IFCDIRECTION((0.,1.,0.));
     #32= IFCDIRECTION((0.,0.,1.));
 #3211= IFCPRODUCTDEFINITIONSHAPE($,$,(#3205));
 #3205= IFCSHAPEREPRESENTATION(#398,'Body','SweptSolid',(#3202));
 #3202= IFCEXTRUDEDAREASOLID(#3198,#3199,#36,3.048);
   #3198= IFCARBITRARYCLOSEDPROFILEDEF(.AREA,$,#3194);
     #3194= IFCPOLYLINE((#3178,#3182,#3186,#3190,#3178));
     #3178= IFCCARTESIANPOINT((0.,0.,0.));
     #3182= IFCCARTESIANPOINT((6.3564,0.,0.));
     #3186= IFCCARTESIANPOINT((6.3564,-10.014));
     #3190= IFCCARTESIANPOINT((0.,-10.014));
 #3199= IFCCAXIS2PLACEMENT3D(#40,#36,#28);
   #40= IFCCARTESIANPOINT((0.,0.,0.,));
   #36= IFCDIRECTION((0.,0.,1.,));
   #28= IFCDIRECTION((1.,0.,0.,));
```
## Verdict Criteria

All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.002 meter [Pass / Fail]

### Space Boundaries

- Total space boundary count = 8
- IfcRelSpaceBoundary.Name = "2ndLevel" (for all space boundaries)
- IfcRelSpaceBoundary.PhysicalOrVirtualBoundary = "PHYSICAL" (for all)
- IfcRelSpaceBoundary.InternalOrExternalBoundary = "EXTERNAL" (for all)
- All space boundaries have a relating space
- All space boundaries have a related building element
- All space boundaries have a connection geometry

### Door Space Boundary

- Placement relative to the local coordinate system (LCS)
- Z axis = (-1.,0.,0.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (4.0926,0.,0.)
  - P2: (5.9214,0.,0.)
  - P3: (5.9214,2.7432,0.)
  - P4: (4.0926,2.7432,0.)

### Window Space Boundary

- Placement relative to the LCS of the space = (0.,-10.014,0.)
- Z axis = (0.,-1.,0.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (3.9402,2.1336,0.)
  - P2: (3.9402,0.9144,0.)
  - P3: (2.4162,0.9144,0.)
  - P4: (2.4162,2.1336,0.)

### Floor Slab Space Boundary

- Placement relative to the LCS of the space = (0.,0.,0.)
- Z axis = (0.,0.,-1.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (6.3564,0.,0.)
  - P3: (6.3564,10.014,0.)
  - P4: (0.,10.014,0.)

### Roof Slab Space Boundary

- Placement relative to the LCS of the space = (0.,0.,3.014)
- Z axis = (0.,0.,1.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (10.014,0.,0.)
  - P3: (10.014,6.3564,0.)
  - P4: (0.,6.3564,0.)

### West Wall Space Boundary

- Placement relative to the LCS of the space = (6.3564,0.,0.)
- Z axis = (0.,1.,0.) and X axis = (-1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (6.3564,0.,0.)
  - P3: (6.3564,3.048,0.)
  - P4: (0.,3.048,0.)

### North Wall Space Boundary

- Placement relative to the LCS of the space = (6.3564,-10.014,0.)
- Z axis = (1.,0.,0.) and X axis = (0.,-1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (10.014,0.,0.)
  - P3: (10.014,3.048,0.)
  - P4: (0.,3.048,0.)

### South Wall Space Boundary

- Placement relative to the LCS of the space = (0.,0.,0.)
- Z axis = (-1.,0.,0.) and X axis = (0.,1.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (10.014,0.,0.)
  - P3: (10.014,3.048,0.)
  - P4: (0.,3.048,0.)

### East Wall Space Boundary

- Placement relative to the LCS of the space = (0.,-10.014,0.)
- Z axis = (0.,-1.,0.) and X axis = (1.,0.,0.) with respect to LCS of the space
- Points defining the outer bound of the space boundary:
  - P1: (0.,0.,0.)
  - P2: (6.3564,0.,0.)
  - P3: (6.3564,3.048,0.)
  - P4: (0.,3.048,0.)

---

1 The LCS of the space has origin = (0.4794, 0.4794, 0) and X = (0.,1.,0.), Y = (-1.,0.,0), Z = (0.,0.,1.) in the world coordinate system.

2 Note that openings (including door/window) have space boundaries and that they do not generate "holes" or "inner loops" in the space boundaries of the walls or slabs in which they are contained.
Sample IFC Code:

```
Sample IFC Code:

#3553= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3225,#949,#3552,
  .PHYSICAL..,EXTERNAL,); 
#3225= IFCSPACE(GUID,#13,'Room',$,S,...); 
#949= IFCDOOR(GUID,#13,'D2','D2030 Exterior Doors',$,...); 
#3552= IFCCONNECTIONSURFACEGEOMETRY(#3548,$); 
  #3548= IFCCURVEBOUNDDEPLANE(#3513,#3544,()); 
    #3513= IFCLINE(#3510); 
    #3510= IFCAXIS2PLACEMENT3D(#40,#3506,#3502); 
    #3502= IFCDIRECTION((-1.,0.,0.,)); 
    #3506= IFCDIRECTION((1.,0.,0.,)); 
  #3544= IFCCOMPOSITECURVE((#3540).,U,); 
    #3540= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS..F.,#3536); 
    #3536= IFCPOLYLINE((#3516,#3520,#3524,#3528,#3532)); 
    #3516= IFCCARTESIANPOINT((4.0926,0.,0.,)); 
    #3520= IFCCARTESIANPOINT((5.9214,0.,0.,)); 
    #3524= IFCCARTESIANPOINT((5.9214,2.7432,0.,)); 
    #3528= IFCCARTESIANPOINT((4.0926,2.7432,0.,)); 
    #3532= IFCCARTESIANPOINT((4.0926,0.,0.,)); 
#3329= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3225,#2402,#3328,
  .PHYSICAL..,EXTERNAL,); 
#3225= IFCSPACE(GUID,#13,'Room',$,S,...); 
#2402= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,...); 
#3328= IFCCONNECTIONSURFACEGEOMETRY(#3324,$); 
  #3324= IFCCURVEBOUNDDEPLANE(#3297,#3320,()); 
    #3297= IFCLINE(#3294); 
    #3294= IFCAXIS2PLACEMENT3D(#40,#3290,#28); 
    #3290= IFCDIRECTION((0.,0.,-1,)); 
    #28= IFCDIRECTION((1.,0.,0.,)); 
  #3320= IFCCOMPOSITECURVE((#3316).,U,); 
    #3316= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS..F.,#3312); 
    #3312= IFCPOLYLINE((#40,#3300,#3304,#3308,#40)); 
    #40= IFCCARTESIANPOINT((0.,0.,0.,)); 
    #3300= IFCCARTESIANPOINT((6.3564,0.,0.,)); 
    #3304= IFCCARTESIANPOINT((6.3564,10.014,0.,)); 
    #3308= IFCCARTESIANPOINT((0.,10.014,0.,)); 
#3605= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3225,#1951,#3604,
  .PHYSICAL..,EXTERNAL,); 
#3225= IFCSPACE(GUID,#13,'Room',$,S,...); 
#1951= IFCWINDOW(GUID,#13,'W1A2','B2020 Exterior Windows',$,...); 
#3604= IFCCONNECTIONSURFACEGEOMETRY(#3600,$); 
  #3600= IFCCURVEBOUNDDEPLANE(#3565,#3596,()); 
    #3565= IFCLINE(#3562); 
    #3562= IFCAXIS2PLACEMENT3D(#3558,#3554,#28); 
    #3558= IFCCARTESIANPOINT((0.,-10.014,0.,)); 
    #3554= IFCDIRECTION((1.,0.,0.,)); 
    #28= IFCDIRECTION((0.,0.,-1,)); 
  #3596= IFCCOMPOSITECURVE((#3592).,U,); 
    #3592= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS..F.,#3588); 
    #3588= IFCPOLYLINE((#3568,#3572,#3576,#3580,#3584)); 
    #3568= IFCCARTESIANPOINT((3.9402,2.1336,0.,)); 
    #3572= IFCCARTESIANPOINT((3.9402,0.9144,0.,)); 
    #3576= IFCCARTESIANPOINT((2.4162,0.9144,0.,)); 
    #3580= IFCCARTESIANPOINT((2.4162,2.1336,0.,)); 
    #3584= IFCCARTESIANPOINT((3.9402,2.1336,0.,)); 
```
#3417= IFCRELSpaceBoundary(GUID,#13,'2ndLevel',$,#3225,#2728,#3416, .PHYSICAL,,.EXTERNAL,);
#3225= IFCSPACE(GUID,#13,'Room',$,,$,...);
#2728= IFCSTAIR(GUID,#13,'RA14','B1020 Roof Construction',$,...);
#3416= IFCCONNECTIONSURFACEGEOMETRY(#3412,$);
#3412= IFCCURVEBOUND E DPLANE(#3395,#3408,());
#3385= IFCP LANE(#3382);
#3382= IFCAxis2Placement3D(#3378,#36,#3374);
#3378= IFCCartesianPoint((0.,0.,3.048));
#36= IFCDirection((0.,0.,1.));
#3374= IFCDirection((0.,1.,0.));
#3408= IFCCompositeCurve((#3404),..U.);
#3404= IFCCompositeCurveSegment(.CONTINUOUS.,.F.,#3400);
#3400= IFCCompositeCurve((#40,#3388,#3392,#3396,#40));
#40= IFCCartesianPoint((0.,0.,0.));
#3388= IFCCartesianPoint((10.014,0.0.,$));
#3392= IFCCartesianPoint((10.014,6.3564,0.0,$));
#3396= IFCCartesianPoint((0.,6.3564,0.$));

#3461= IFCRELSpaceBoundary(GUID,#13,'2ndLevel',$,#3225,#2219,#3460, .PHYSICAL,,.EXTERNAL,);
#3225= IFCSPACE(GUID,#13,'Room',$,,$,...);
#2219= IFCCONNECTIONSURFACEGEOMETRY(#3456,});
#3456= IFCCURVEBOUND E DPLANE(#3429,#3452,());
#3429= IFCP LANE(#3426);
#3426= IFCAxis2Placement3D(#3422,#32,#3418);
#3422= IFCCartesianPoint((6.3564,0.,0.$));
#32= IFCDirection((0.,1.,0.));
#3418= IFCDirection((1.,0.,0.$));
#3452= IFCCompositeCurve((#3448),..U.);
#3448= IFCCompositeCurveSegment(.CONTINUOUS.,.F.,#3444);
#3444= IFCCartesianPoint((0.,0.,0.));
#3440= IFCCartesianPoint((#40,#3432,#3436,#3440,#40));
#40= IFCCartesianPoint((0.,0.,0.));
#3432= IFCCartesianPoint((6.3564,0.0.,$));
#3436= IFCCartesianPoint((6.3564,3.048,0.$));
#3440= IFCCartesianPoint((0.,3.048,0.$));

#3501= IFCRELSpaceBoundary(GUID,#13,'2ndLevel',$,#3225,#2085,#3500, .PHYSICAL,,.EXTERNAL,);
#3225= IFCSPACE(GUID,#13,'Room',$,,$,...);
#2085= IFCCONNECTIONSURFACEGEOMETRY(#3496,});
#3496= IFCCURVEBOUND E DPLANE(#3469,#3492,());
#3469= IFCP LANE(#3466);
#3466= IFCAxis2Placement3D(#3462,#28,#32);
#3462= IFCCartesianPoint((6.3564,-10.014,0.$));
#28= IFCDirection((1.,0.,0.$));
#3492= IFCCompositeCurve((#3488),..U.);
#3488= IFCCompositeCurveSegment(.CONTINUOUS.,.F.,#3484);
#3484= IFCCartesianPoint((0.,0.,0.));
#40= IFCCartesianPoint((10.014,0.0.,$));
#3472= IFCCartesianPoint((10.014,3.048,0.$));
#3476= IFCCartesianPoint((0.,3.048,0.$));
#3289 = IFCRELSPACEBOUNDARY(GUID, #13, '2ndLevel', $, #3225, #363, #3288, .PHYSICAL, ., EXTERNAL, .);  
#3225 = IFCSPACE(GUID, #13, 'Room', $, $, $, ...);  
#363 = IFCWALLSTANDARDCASE(GUID, #13, 'WA34', 'B2010 Exterior Walls', ...);  
#3288 = IFCCONNECTIONSURFACEGEOMETRY(#3284, $);  
#3284 = IFCCURVEBOUNDEDPLANE(#3257, #3280, ());  
#3257 = IFCPLANE(#3254);  
#3254 = IFCCARTESIANPOINT((0., 0., 0.));  
#3250 = IFCCARTESIANPOINT((0., 0.1, 0.));  
#3246 = IFCDIRECTION((1., 0., 0.));  
#3246 = IFCDIRECTION((0., -1., 0.));  
#3260 = IFCCARTESIANPOINT((10.041, 0., 0.));  
#3264 = IFCCARTESIANPOINT((10.041, 3.048, 0.));  
#3268 = IFCCARTESIANPOINT((0., 3.048, 0.));  
#3373 = IFCRELSPACEBOUNDARY(GUID, #13, '2ndLevel', $, #3225, #1067, #3372, .PHYSICAL, ., EXTERNAL, .);  
#3225 = IFCSPACE(GUID, #13, 'Room', $, $, $, ...);  
#1067 = IFCWALLSTANDARDCASE(GUID, #13, 'WA34', 'B2010 Exterior Walls', ...);  
#3372 = IFCCONNECTIONSURFACEGEOMETRY(#3368, $);  
#3368 = IFCCURVEBOUNDEDPLANE(#3341, #3364, ());  
#3341 = IFCPLANE(#3338);  
#3338 = IFCCARTESIANPOINT((0., 0., 0.));  
#3330 = IFCCARTESIANPOINT((0., 0.1, 0.));  
#3330 = IFCDIRECTION((1., 0., 0.));  
#3330 = IFCDIRECTION((0., -1., 0.));  
#3360 = IFCCARTESIANPOINT((6.3564, 0., 0.));  
#3356 = IFCPOLYLINE((#40, #3344, #3348, #3352, #40));  
#3344 = IFCCARTESIANPOINT((0., 0., 0.));  
#3344 = IFCCARTESIANPOINT((6.3564, 0., 0.));  
#3348 = IFCCARTESIANPOINT((6.3564, 3.048, 0.));  
#3352 = IFCCARTESIANPOINT((0., 3.048, 0.));
7.3  **BPEA Test Case 2**

**BPEA Test Case 2**

Test Case Title: Two Stories Building with Different Floor Plan

Date of Last Edit: 10/07/2009

**Summary Description:** Test Case 2 consists of a two-stories building in which there are internal walls and air walls on both floors, as shown on Figure A3. The building elements included in this test case are: 8 exterior walls (4 for each floor), 3 interior walls (2 on 1st floor and 1 on 2nd floor), 2 air walls (1 on each floor), 1 base slab, 1 floor slab, and 1 roof slab.

**Test Objectives:**
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets
- Check for accurate counts of spaces and space boundaries
- Check space boundary attributes, reference to space and building elements, and connection geometry.

![Figure A3: Two Stories Building with Different Floor Plan](image-url)
**Detailed Description:**

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (1st floor east)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (15, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall (1st floor west)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (0, 10, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall (1st floor south)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 0)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Exterior Wall (1st floor north)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 0)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>5. Exterior Wall (2nd floor east)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (15, 0, 3.61)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>6. Exterior Wall (2nd floor west)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (0, 10, 3.61)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls

** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Exterior Wall (2nd floor south)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 3.61)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>8. Exterior Wall (2nd floor north)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 3.61)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>9. Interior Wall (1st floor hori.)</td>
<td>Length: 4 m Height: 3 m Thickness: 0.12 m Origin: (0, 6, 0)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>10. Interior Wall (1st floor vert.)</td>
<td>Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (5, 0, 0)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>11. Interior Wall (2nd floor)</td>
<td>Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (3, 0, 3.61)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>12. Base Slab</td>
<td>15 m by 10 m Thickness: 0.256 m Origin: (0, 0, -0.254) X-axis: (1, 0, 0)</td>
<td>FA5</td>
<td>6-in HW concrete 4-in Gravel</td>
<td>A1030 Slab-on-grade</td>
</tr>
<tr>
<td>13. Floor Slab (between 1st and 2nd)</td>
<td>15 m by 10 m Thickness: 0.61 m Origin: (0, 0, 3) X-axis: (1, 0, 0)</td>
<td>FA2</td>
<td>Acoustical tile Air wall resistance 6-in HW concrete</td>
<td>B1010 Floor Construction</td>
</tr>
<tr>
<td>14. Roof Slab</td>
<td>15 m by 10 m Thickness: 0.2 m Origin: (0, 0, 6.61) X-axis: (1, 0, 0)</td>
<td>RA14</td>
<td>R-15 insulation 4-in LW concrete</td>
<td>B1020 Roof Construction</td>
</tr>
<tr>
<td>15. Virtual Element (air wall in Room 103)</td>
<td>Length: 9.9 m Thickness: N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Virtual Element (air wall in Room 202)</td>
<td>Length: 9.1 m Thickness: N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Elements</td>
<td>Dimension and Origin in World Coordinate Sys.</td>
<td>Construction Type (ASHRAE)</td>
<td>Description (ASHRAE)</td>
<td>UniFormat Classification</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>--------------------------</td>
</tr>
</tbody>
</table>
| 17. Space (Room 101) | Length: 4 m  
Width: 3 m  
Height: 3 m  
Origin: (0.48, 6.6, 0) | | | |
| 18. Space (Room 102) | Length: 4 m  
Width: 6 m  
Height: 3 m  
Origin: (0.48, 0.48, 0) | | | |
| 19. Space (Room 103a) | Length: 9.9 m  
Width: 4 m  
Height: 3 m  
Origin: (4.6, 0.48, 0) | | | |
| 20. Space (Room 103b) | Length: 9.9 m  
Width: 5.1 m  
Height: 3 m  
Origin: (4.6, 4.48, 0) | | | |
| 21. Space (Room 201) | Length: 2 m  
Width: 9.1 m  
Height: 3 m  
Origin: (0.48, 0.48, 3.61) | | | |
| 22. Space (Room 202a) | Length: 7 m  
Width: 9.1 m  
Height: 3 m  
Origin: (2.6, 0.48, 3.61) | | | |
| 23. Space (Room 202b) | Length: 4.9 m  
Width: 9.1 m  
Height: 3 m  
Origin: (9.6 0.48, 3.61) | | | |

All space have X-axis = (1,0,0)

When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.

**Screenshots of the building model in different IFC Viewers**

![IFcStoreyView](image-url)
Solibri Model Checker

DDS-CAD Viewer
Testing Details for BPEA Test Case 2

<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Check that all building elements exist</td>
</tr>
<tr>
<td>11 IfcWallStandardCase</td>
</tr>
<tr>
<td>3 IfcSlab</td>
</tr>
<tr>
<td>2 IfcVirtualElement</td>
</tr>
<tr>
<td>7 IfcSpace</td>
</tr>
</tbody>
</table>

Project

• Project identifier is required
  11 IfcProject.LongName = "BPEA Test Case 2"

Sample IFC Code¹:

```
#54= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 2',$,,'BPEA Test Case 2',$(#51,#110,#271),#26);
```

• Correct unit assignment
  Length measurement is in “Meter”

Sample IFC Code:

```
#14= IFCSIUNIT(*,.LENGTHUNIT.,$,.$METRE.);
```

Site

• Site location is specified
  11 IfcSite.LongName = "Washington D.C."

• Global coordinates (latitude and longitude) are required
  11 IfcSite.RefLatitude = (38,55,0)
  11 IfcSite.RefLongitude = (-77,0,0)

• Site elevation (relative to sea level) is required
  11 IfcSite.RefElevation = 0 (m.)

• Coordinate of site origin is correctly specified
  Coordinate of site origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code²:

```
#64= IFCSITE(GUID,#13,'Default Site','Washington D.C.','Washington D.C.',$,#61,$,'Washington D.C.',$.ELEMENT.,(38,55,0),(-77,0,0),0.,$,$);
#61= IFCLocalPlacement($,$44);$;
#44= IFCAxis2Placement3D(#40,#36,#28);$;
#40= IFCCartesianPoint((0.,0.,0.));
```

¹ One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as ‘0bY52t0r7xHfI6OxW0sY$t’. In the examples, the GUID is shortened to the string ‘GUID’ to save space and improve readability.

² In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

**Building**
- **Building identifier is required**
  - IfcBuilding.LongName = "TC2"
- **Elevation (base elevation of ground level floor above sea level) is required**
  - IfcBuilding.ElevationOfRefHeight = 0 (m.)
- **Coordinate of building origin is correctly specified**
  - Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
```java
#77= IFCBUILDING(GUID,#13,'Default Building','TC2',$,#74,$,'TC2',.ELEMENT.,0.,$,,$);
  #74= IFCLLOCALPLACEMENT(#61,#44);
  #61= IFCLLOCALPLACEMENT($,#44);
  #44= IFCAAXIS2PLACEMENT3D(#40,#36,#28);
  #40= IFCCARTESIANPOINT((0.,0.,0.));
```

- **Number of stories is specified**
  - Pset_BuildingCommon.NumberOfStoreys = 2

Sample IFC Code:
```java
#6400= IFCPROPERTYSINGLEVALUE('NumberOfStoreys',$,IFCINTEGER(2),$);
```

- **Building orientation (the degrees of clockwise from true north) is required**
  - IfcGeometricRepresentationContext.TrueNorth = (-0.5,0.866)

Sample IFC Code:
```java
#51= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan','Design',3,1.0000000E-5,#44,#47);
  #47= IFCDIRECTION((-0.5,0.866));
```

**Building Stories**
- **Identification is required**
  - IfcBuildingStorey.Name = "1st Floor", IfcBuildingStorey.Name = "2nd Floor"
- **Elevation (relative to building datum) is required**
  - IfcBuildingStorey.Elevation = 0, IfcBuildingStorey.Elevation = 3.61 (m.)
- **Coordinate of building story origin is correctly specified**
  - Coordinate of building story origin is the origin of world coordinate system, (0.,0.,0.)
  - Coordinate of building story origin (2nd floor) is (0.,0.,3.61)

Sample IFC Code:
```java
#93= IFCBUILDINGSTOREY(GUID,#13,'1st Floor',$,#90,$,$,.ELEMENT.,0.);
  #90= IFCLLOCALPLACEMENT(#74,#87);
  #74= IFCLLOCALPLACEMENT(#61,#44);
  #61= IFCLLOCALPLACEMENT($,#44);
  #44= IFCAAXIS2PLACEMENT3D(#40,#36,#28);
  #40= IFCCARTESIANPOINT((0.,0.,0.));

#2129= IFCBUILDINGSTOREY(GUID,#13,'2nd Floor',$,#2126,$,$,.ELEMENT.,3.61);
  #2126= IFCLLOCALPLACEMENT(#74,#2123);
  #74= IFCLLOCALPLACEMENT(#61,#44);
  #61= IFCAAXIS2PLACEMENT3D(#2119,#36,#28);
  #2119= IFCCARTESIANPOINT((0.,0.,3.61));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

### Walls (West Wall)
- **Check wall dimension and geometry**
  - Origin\(^1\) = (0.10, 0.0, 0.0)
  - XYZ directions: \(X = (0., -1.0, 0.), Y = (1.0, 0., 0.), Z = (0., 0., 1.0)\)
  - IfcShapeRepresentation.RepresentationIdentifier = “Body”
  - IfcShapeRepresentation.RepresentationType = “SweptSolid”
  - IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  - IfcExtrudedAreaSolid.Depth = 3 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0., 0., 1.)
  - IfcExtrudedAreaSolid.Position = (0., 0., 0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
  - 4 Cartesian points for the swept area\(^3\) = (0., 0., 0.), (10., 0., 0.), (9.52, 0.48), (0.48, 0.48)

- **Check wall properties**
  - Check wall construction type
    - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - Check Uniformat classification
    - IfcWall.Description = "B2010 Exterior Wall"
  - Check exterior or interior is declared
    - Pset_WallCommon.IsExternal = IfcBoolean(T)

#### Sample IFC Code:\(^4\)
```
#960= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
$,#957,#1030,$);
#957= IFCLOCALPLACEMENT(#90,#954);
#954= IFCAxis2Placement3D(#950,#36,#946);
#950= IFCCARTESIANPOINT((0.,10.,0.));
#36= IFCDIRECTION((0.,0.,1.));
#946= IFCDIRECTION((0.,-1.,0.));
#1030= IFCPRODUCTDEFINITIONSHAPE($,#991,#1024);
#1024= IFCSHAPEREPRESENTATION(#271,'Body','SweptSolid',(#1021));
#1021= IFCEXTRUDEDAREASOLID(#1017,#1018,#36,#1018);
#1017= IFCCARTESIANPOINT((9.93,0.0));
#1018= IFCCARTESIANPOINT((9.52,0.48));
#1009= IFCCARTESIANPOINT((0.48,0.48));
#1018= IFCAxis2Placement3D(#40,#36,#28);
#40= IFCCARTESIANPOINT((0.,0.,0.));
#36= IFCDIRECTION((0.,0.,1.));
#28= IFCDIRECTION((1.,0.,0.));
```

---

\(^1\) The intersection between walls can affect the geometry, i.e., the placement of the Cartesian points of the swept area.

\(^2\) The origin and the direction of the wall (and other building elements) are indicated by IfcWall (or IfcWallStandardCase).IfcLocalPlacement.Position. The XYZ directions are the axes of the local coordinate system (LCS) in reference to the world coordinate system.

\(^3\) These are points in the local coordinate system.

\(^4\) The position and orientation in \#954 are related to the wall. The position and orientation in \#1018 are related to the extrusion.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Walls (All Walls)
- Check material association (for east and west walls)
  - IfcMaterialLayerSet.LayerSetName = "WA34"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 0.00 (m.)
  - IfcMaterial.Name = "12 in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.15875 (m.)
  - IfcMaterial.Name = "R-19 batt insulation"
  - IfcMaterialLayer.LayerThickness = 0.015875 (m.)
  - IfcMaterial.Name = "Gyp board"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Inside surface resistance"

Sample IFC Code:
#694 = IFCREASSOCIATESMATERIAL(GUID,#13,$,$,#609,#609);  #609= IFCMATERIALLAYERSETUSAGE(#607,.AXIS2.,.NEGATIVE.,0.48);  #607= IFCMATERIALLAYERS((#377,#379,#519,#567,#602,#605),' Wall Type 34 WA34 Precast and CIP Concrete Walls');  #377= IFCMATERIALLAYER(#374,0.0001,.U.);  #374= IFCMATERIAL('F01 Outside Surface Resistance');  #379= IFCMATERIALLayer(#379,0.3048,.U.);  #519= IFCMATERIAL('M16 12 in. Heavyweight Concrete');  #567= IFCMATERIALLayer(#567,0.15875,.U.);  #602= IFCMATERIALLayer(#602,0.0001,.U.);  #605= IFCMATERIALLayer(#605,0.015875,.U.);

- Check material association (for north and south walls)
  - IfcMaterialLayerSet.LayerSetName = "WA26"
  - IfcMaterialLayer.LayerThickness = 0.3048 (m.)
  - IfcMaterial.Name = "Block masonry"
  - IfcMaterialLayer.LayerThickness = 0.092075 (m.)
  - IfcMaterial.Name = "Insulation batt"
  - IfcMaterialLayer.LayerThickness = 0.015875 (m.)
  - IfcMaterial.Name = "Gypsum board"

Sample IFC Code:
#317= IFCREASSOCIATESMATERIAL(GUID,#13,$,$,#236,#229);  #229= IFCMATERIALLAYERSETUSAGE(#227,.AXIS2.,.NEGATIVE.,0.48);  #227= IFCMATERIALLAYERS(#144,#190,#225),' Wall Type 26 WA26 Concrete Block Walls');  #144= IFCMATERIALLAYER(#103,0.3048,.U.);  #103= IFCMATERIAL('04 Block Masonry');  #190= IFCMATERIALLAYER(#146,0.092075,.U.);  #146= IFCMATERIAL('07 Insulation Batt ');  #225= IFCMATERIALLAYER(#192,0.015875,.U.);  #192= IFCMATERIAL('09 Gypsum Board');
### Numeric Values and Specifications Summary for 1st Floor Exterior Walls (Refer to West Wall Verdict Criteria Table for specific details)

<table>
<thead>
<tr>
<th>Wall dimension and geometry</th>
<th>North Wall</th>
<th>East Wall</th>
<th>South Wall</th>
<th>West Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of LCS</td>
<td>(15.,10.,0.)</td>
<td>(15.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,10.,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
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<td>X: (0.,1.,0.)</td>
<td>X: (1.,0.,0.)</td>
<td>X: (0.,-1.,0.)</td>
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<tr>
<td></td>
<td>Y: (0.,-1.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
<td>Y: (0.,1.,0.)</td>
<td>Y: (1.,0.,0.)</td>
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<tr>
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<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
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<tr>
<td>Shape representation</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td>Extrusion:</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Profile type</td>
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<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
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<td>Position</td>
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<td>3 m.</td>
<td>3 m.</td>
<td>3 m.</td>
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<tr>
<td>Depth</td>
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<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
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<tr>
<td>Direction</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
<td>(0.,0.07),(15.,0.07)</td>
<td>(0.07,0.), (9.93,0.), (9.52,0.48), (0.48,0.48)</td>
<td>(0.,0.07),(15.,0.07)</td>
<td>(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)</td>
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### Wall properties

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<tr>
<th>Construction type</th>
<th>WA26</th>
<th>WA34</th>
<th>WA26</th>
<th>WA34</th>
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<td>B2010 Exterior Wall Construction</td>
<td>B2010 Exterior Wall Construction</td>
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### Wall material association

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<th>WA26</th>
<th>WA34</th>
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<tr>
<td>Material layer and thickness</td>
<td>- Block Masonry Thickness: 0.3048 m</td>
<td>- Outside Surface Resistance 0.0001 m</td>
<td>- Block Masonry 0.3048 m</td>
<td>- Outside Surface Resistance 0.001 m</td>
</tr>
<tr>
<td></td>
<td>- Insulation Batt Thickness: 0.092075 m</td>
<td>- 12-in HW Concrete 0.3048 m</td>
<td>- Insulation Batt 0.092075 m</td>
<td>- 12-in HW Concrete 0.3048 m</td>
</tr>
<tr>
<td></td>
<td>- Gypsum Board Thickness: 0.015875 m</td>
<td>- R-19 Batt Insulation 0.15875 m</td>
<td>- Gypsum Board 0.015875 m</td>
<td>- R-19 Batt Insulation 0.15875 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Gypsum Board 0.015875 m</td>
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<td></td>
<td>- Inside Surface Resistance 0.0001 m</td>
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<td>- Inside Surface Resistance 0.001 m</td>
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<table>
<thead>
<tr>
<th>Corresponding code line number in reference IFC file</th>
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<th>#620 (dimension and geometry)</th>
<th>#236 (dimension and geometry)</th>
<th>#960 (dimension and geometry)</th>
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<tr>
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<td>#864 (materials)</td>
<td>#694 (materials)</td>
<td>#317 (materials)</td>
<td>#1034 (materials)</td>
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<td>#928 (properties)</td>
<td>#758 (properties)</td>
<td>#355 (properties)</td>
<td>#1126 (properties)</td>
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<tr>
<td></td>
<td>North Wall</td>
<td>East Wall</td>
<td>South Wall</td>
<td>West Wall</td>
</tr>
<tr>
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<td><strong>Wall dimension</strong>&lt;br/&gt;and geometry</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of LCS</td>
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<td>(15.,0.,3.61)</td>
<td>(0.,0.,3.61)</td>
<td>(0.,10.,3.61)</td>
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<tr>
<td>XYZ directions of LCS&lt;br/&gt;</td>
<td>X: (-1.,0.,0.)</td>
<td>X: (0.,1.,0.)</td>
<td>X: (1.,0.,0.)</td>
<td>X: (0.,1.,0.)</td>
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<tr>
<td></td>
<td>Y: (0.,-1.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
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<td>Y: (0.,-1.,0.)</td>
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<tr>
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<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td><strong>Shape representation</strong></td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td><strong>Extrusion</strong>&lt;br/&gt;Profile type</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Position</td>
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<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
</tr>
<tr>
<td>Depth</td>
<td>3 m.</td>
<td>3 m.</td>
<td>3 m.</td>
<td>3 m.</td>
</tr>
<tr>
<td>Direction</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
</tr>
<tr>
<td>Cartesian points for the swept area&lt;br/&gt;from origin of LCS</td>
<td>(0.,0.07),(15.,0.07)</td>
<td>(0.07,0.), (9.93,0.)</td>
<td>(0.07,0),(15.,0.07)</td>
<td>(0.07,0.), (9.93,0.), (9.52,0.48), (0.48,0.48)</td>
</tr>
</tbody>
</table>

| **Wall properties** |            |           |            |           |
| **Construction type** | WA26 | WA34 | WA26 | WA34 |
| **UniFormat classification** | B2010 Exterior Wall Construction | B2010 Exterior Wall Construction | B2010 Exterior Wall Construction | B2010 Exterior Wall Construction |
| **Exterior / Interior** | Exterior | Exterior | Exterior | Exterior |
| **Wall material association** |            |           |            |           |
| **Layer name** | WA26 | WA34 | WA26 | WA34 |
| **Material layer and thickness** | - Block Masonry Thickness: 0.3048 m | - Outside Surface Resistance 0.0001 m | - Block Masonry 0.3048 m | - Outside Surface Resistance 0.0001 m |
|                  | - Insulation Batt Thickness: 0.092075 m | - 12-in HW Concrete 0.3048 m | - Insulation Batt 0.092075 m | - 12-in HW Concrete 0.3048 m |
|                  | - Gypsum Board Thickness: 0.015875 m | - R-19 Batt Insulation 0.15875 m | - Gypsum Board 0.015875 m | - R-19 Batt Insulation 0.15875 m |
|                  | | - Inside Surface Resistance 0.0001 m | | - Inside Surface Resistance 0.0001 m |

<p>| Corresponding code line number in reference IFC file | #2454 (dimension and geometry) | #2528 (materials) #2592 (properties) | #2284 (dimension and geometry) | #2358 (materials) #2422 (properties) | #2146 (dimension and geometry) | #2220 (materials) #2256 (properties) | #2624 (dimension and geometry) | #2698 (materials) #2790 (properties) |</p>
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<thead>
<tr>
<th></th>
<th>1st Floor Horizontal Wall</th>
<th>1st Floor Vertical Wall</th>
<th>2nd Floor Wall</th>
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<td><strong>Wall dimension and geometry</strong></td>
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<td></td>
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</tr>
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<td>Origin of LCS</td>
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<td>(4.54,0.,0.)</td>
<td>(2.54,0.,3.61)</td>
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<td>X: (0.,1.,0.)</td>
<td>X: (0.,1.,0.)</td>
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<td>Y: (0.,1.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
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<tr>
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<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
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<td><strong>Shape representation</strong></td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td><strong>Extrusion:</strong></td>
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<tr>
<td>Profile type</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Position</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
</tr>
<tr>
<td>Depth</td>
<td>3 m.</td>
<td>3 m.</td>
<td>3 m.</td>
</tr>
<tr>
<td>Direction</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
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<tr>
<td>Cartesian points for the swept area</td>
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<td></td>
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</tr>
<tr>
<td>(from origin of LCS)</td>
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<td><strong>Wall properties</strong></td>
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<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
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<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
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<td>#1243 (materials)</td>
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<td>Floor slab</td>
<td>Roof slab</td>
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</tr>
<tr>
<td>Shape representation</td>
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<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
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<tr>
<td>Extrusion:</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Profile type</td>
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<td>(0.,0.,0.)</td>
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<tr>
<td>Direction</td>
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<tr>
<td>Cartesian points for the swept area</td>
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<td>(0.,0.), (15.,0), (15.,10), (0.,10.)</td>
<td>(0.,0.), (15.,0), (15.,10), (0.,10.)</td>
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| Slab properties             |           |           |           |
| Construction type           | FA5       | FA2       | RA14      |
| UniFormat classification    | A1030 Slabs-On-Grade | B1010 Floor Construction | B1020 Roof Construction |
| Exterior / Interior         | Exterior  | Interior  | Exterior  |

| Slab material association   |           |           |           |
| Layer name                  | FA5       | FA2       | RA14      |
| Material layer and thickness| - 6-in Heavyweight Concrete 0.1524 m - Vapor Barrier 0.002 m - 4-in Gravel 0.1016 m | - 6-in Heavyweight Concrete 0.1524 m - Ceiling Air Space Resistance 0.441325 m - Acoustic Tile 0.015875 m | - Outside Surface Resistance Thickness: 0.0001 m - Built-up Roofing Thickness: 0.0095 m - Fiberboard Sheathing Thickness: 0.0127 m - R-15 3-in Insulation Board Thickness: 0.0762 m - 4-in LW Concrete Thickness: 0.1016 m - Inside Surface Resistance Thickness: 0.0001 m |

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<td>#1870 (properties)</td>
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Verdict Criteria Summary for all Spaces

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<th>Origin of LCS</th>
<th>XYZ Direction of LCS</th>
<th>Shape Repr.</th>
<th>Extrusion: Profile type, Position, Depth, Direction</th>
<th>Cartesian points of swept area (from origin of LCS)</th>
<th>Space Properties: Longname, Ext. / Int.</th>
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<tbody>
<tr>
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</tr>
<tr>
<td>Room 102</td>
<td>(0.48,0.48,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
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</tr>
<tr>
<td>Room 103a</td>
<td>(4.6,0.48,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
<td>(0.,0.), (9.92,0.), (9.92,5.04), (0.,5.04) “Room 103a” Internal</td>
</tr>
<tr>
<td>Room 103b</td>
<td>(4.6,4.48,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<td>Room 201</td>
<td>(0.48,0.48,3.61)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<tr>
<td>Room 202a</td>
<td>(2.6,0.48,3.61)</td>
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<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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</tr>
<tr>
<td>Room 202b</td>
<td>(9.6,0.48,3.61)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
<td>(0.,0.), (4.92,0.), (4.92,9.04), (0.,9.04) “Room 202b” Internal</td>
</tr>
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### Verdict Criteria Summary for all Space Boundaries relating to Room 101

<table>
<thead>
<tr>
<th>Attributes: Name</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
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<tbody>
<tr>
<td><strong>Room 101 Space Boundary 1</strong>&lt;br&gt;(#4254 in Reference IFC)&lt;br&gt;&quot;2nd Level&quot; Physical External</td>
<td>Room 101 (#1921)</td>
<td>1st Floor North Wall (#790)</td>
<td>Origin: (4.3,0.)&lt;br&gt;X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (4.,0.,0.) P3: (4.,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td><strong>Room 101 Space Boundary 2</strong>&lt;br&gt;(#4210)&lt;br&gt;&quot;2nd Level&quot; Physical External</td>
<td>Room 101 (#1921)</td>
<td>1st Floor West Wall (#960)</td>
<td>Origin: (0.,3.,0.)&lt;br&gt;X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (0.,0.,0.) P2: (3.,0.,0.) P3: (3.,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td><strong>Room 101 Space Boundary 3</strong>&lt;br&gt;(#4122)&lt;br&gt;&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>Room 101 (#1921)</td>
<td>1st Floor Vertical Interior Wall (#1169)</td>
<td>Origin: (4.0,0.)&lt;br&gt;X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (3.,0.,0.) P3: (3.,3.,0.) P4: (0.,3.,0.)</td>
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<td><strong>Room 101 Space Boundary 4</strong>&lt;br&gt;(#4042)&lt;br&gt;&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>Room 101 (#1921)</td>
<td>1st Floor Horizontal Interior Wall (#1365)</td>
<td>Origin: (0.,0.,0.)&lt;br&gt;X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (4.,0.,0.) P3: (4.,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td><strong>Room 101 Space Boundary 5</strong>&lt;br&gt;(#4082)&lt;br&gt;&quot;2nd Level&quot; Physical External</td>
<td>Room 101 (#1921)</td>
<td>Base Slab (#1548)</td>
<td>Origin: (0.0,0.)&lt;br&gt;X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (3.,0.,0.) P3: (3.,4.,0.) P4: (0.,4.,0.)</td>
</tr>
<tr>
<td><strong>Room 101 Space Boundary 6</strong>&lt;br&gt;(#4162)&lt;br&gt;&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>Room 101 (#1921)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.0,3.)&lt;br&gt;X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (0.,0.,0.) P2: (2.,0.,0.) P3: (2.,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td><strong>Room 101 Space Boundary 7</strong>&lt;br&gt;(#4302)&lt;br&gt;&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>Room 101 (#1921)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.0,3.)&lt;br&gt;X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (4.,0.,0.) P2: (4.,3.,0.) P3: (2.12,3.,0.) P4: (2.12,0.,0.)</td>
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<tr>
<td><strong>Room 101 Space Boundary 8</strong>&lt;br&gt;(#4350)&lt;br&gt;&quot;2nd Level&quot; Physical Internal Type 2b (due to 2nd floor interior wall)</td>
<td>Room 101 (#1921)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.0,3.)&lt;br&gt;X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (2.,3.,0.) P2: (2.,0.,0.) P3: (2.12,0.,0.) P4: (2.12,3.,0.)</td>
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</table>

1 For all physical internal 2nd level space boundaries, there is a differentiation of two types of boundary that is influenced by “what kind of element is on the other side” of the space boundary. Type 2a is for space boundary that has a space behind and Type 2b is for space boundary that has no space behind, but a physical element. Type 2b is also called 3rd level space boundary.
Verdict Criteria Summary for all Space Boundaries relating to Room 102

| Room 102 Space Boundary 1  
(#4390 in Reference IFC) |
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<tr>
<td>Physical/External</td>
</tr>
<tr>
<td>Room 102 (#1985)</td>
</tr>
<tr>
<td>1st Floor South Wall (#236)</td>
</tr>
<tr>
<td>Origin: (0.,0.,0.)</td>
</tr>
<tr>
<td>X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.)</td>
</tr>
<tr>
<td>P1: (0.,0.,0.) P2: (4.,0.,0.)</td>
</tr>
<tr>
<td>P3: (4.,3.,0.) P4: (0.,3.,0.)</td>
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| Room 102 Space Boundary 2  
(#4566) |
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<tr>
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</tr>
<tr>
<td>1st Floor West Wall (#960)</td>
</tr>
<tr>
<td>Origin: (0.5.92,0.)</td>
</tr>
<tr>
<td>X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.)</td>
</tr>
<tr>
<td>P1: (0.,0.,0.) P2: (5.92,0.,0.)</td>
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<tr>
<td>P3: (5.92,3.,0.) P4: (0.,3.,0.)</td>
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| Room 102 Space Boundary 3  
(#4650) |
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<td>&quot;2° Level&quot;</td>
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<td>Physical/Internal Type 2a</td>
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<td>Room 102 (#1985)</td>
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<tr>
<td>1st Floor Vertical Interior Wall (#1169)</td>
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<tr>
<td>Origin: (4.,0.,0.)</td>
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<tr>
<td>X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.)</td>
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<tr>
<td>P1: (0.,0.,0.) P2: (4.,0.,0.)</td>
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<td>P3: (4.,3.,0.) P4: (0.,3.,0.)</td>
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| Room 102 Space Boundary 4  
(#4478) |
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<tr>
<td>Physical/Internal Type 2a</td>
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<tr>
<td>Room 102 (#1985)</td>
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<tr>
<td>1st Floor Vertical Interior Wall (#1169)</td>
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<tr>
<td>Origin: (4.5.92,0.)</td>
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<td>X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.)</td>
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<td>P1: (4.,0.,0.) P2: (5.92,0.,0.)</td>
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<td>P3: (5.92,3.,0.) P4: (4.,3.,0.)</td>
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| Room 102 Space Boundary 5  
(#4610) |
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<td>Physical/Internal Type 2a</td>
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<td>Room 102 (#1985)</td>
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<tr>
<td>1st Floor Horizontal Interior Wall (#1365)</td>
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<td>Origin: (4.,0.,0.)</td>
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<td>X: (0.,1.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.)</td>
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<tr>
<td>P1: (0.,0.,0.) P2: (4.,0.,0.)</td>
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<td>P3: (4.,3.,0.) P4: (0.,3.,0.)</td>
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| Room 102 Space Boundary 6  
(#4430) |
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<td>Physical/External</td>
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<tr>
<td>Room 102 (#1985)</td>
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<tr>
<td>Base Slab (#1548)</td>
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<tr>
<td>Origin: (0.,0.,0.)</td>
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<tr>
<td>X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,-1.)</td>
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<tr>
<td>P1: (0.,0.,0.) P2: (5.92,0.,0.)</td>
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<td>P3: (5.92,4.,0.) P4: (0.,4.,0.)</td>
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| Room 102 Space Boundary 7  
(#4518) |
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<td>Physical/Internal Type 2a</td>
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<td>Room 102 (#1985)</td>
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<tr>
<td>Floor Slab (#3001)</td>
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<tr>
<td>Origin: (0.,0.,3.)</td>
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<tr>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
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<td>P1: (0.,0.,0.) P2: (2.,0.,0.)</td>
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<td>P3: (2.5.92,0.) P4: (0.,5.92,0.)</td>
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| Room 102 Space Boundary 8  
(#4746) |
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<td>Floor Slab (#3001)</td>
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<td>Origin: (0.,0.,3.)</td>
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<tr>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
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<tr>
<td>P3: (2.12,5.92,0.) P4: (2.5.92,0.)</td>
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| Room 102 Space Boundary 9  
(#4698) |
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<td>Room 102 (#1985)</td>
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<tr>
<td>Floor Slab (#3001)</td>
</tr>
<tr>
<td>Origin: (0.,0.,3.)</td>
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<tr>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>P1: (2.12,0.,0.) P2: (4.,0.,0.)</td>
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<tr>
<td>P3: (4.,5.92,0.) P4: (2.12.5.92,0.)</td>
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Count of Space Boundaries relating to Room 102 = 9
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<tr>
<th>Room 103a Space Boundary 1 (#5158 in Reference IFC)</th>
<th>Room 103a Space Boundary 2 (#5238)</th>
<th>Room 103a Space Boundary 3 (#5326)</th>
<th>Room 103a Space Boundary 4 (#3885)</th>
<th>Room 103a Space Boundary 5 (#5198)</th>
<th>Room 103a Space Boundary 6 (#5278)</th>
<th>Room 103a Space Boundary 7 (#5374)</th>
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<td>&quot;2nd Level&quot; Physical External</td>
<td>&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>&quot;2nd Level&quot; Virtual Internal</td>
<td>&quot;2nd Level&quot; Physical External</td>
<td>&quot;2nd Level&quot; Physical Internal Type 2a</td>
<td>&quot;2nd Level&quot; Physical Internal Type 2a</td>
</tr>
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<td>Room 103a (#2103)</td>
<td>Room 103a (#2103)</td>
<td>Room 103a (#2103)</td>
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<td>Room 103a (#2103)</td>
<td>Room 103a (#2103)</td>
<td>Room 103a (#2103)</td>
</tr>
<tr>
<td>1st Floor South Wall (#236)</td>
<td>1st Floor East Wall (#620)</td>
<td>1st Floor Vertical Interior Wall (#1169)</td>
<td>1st Floor Virtual Element (#3865)</td>
<td>Base Slab (#1548)</td>
<td>Floor Slab (#3001)</td>
<td>Floor Slab (#3001)</td>
</tr>
<tr>
<td>Origin: (0.,0.,0.)</td>
<td>Origin: (9.920.,0.)</td>
<td>Origin: (9.924.,0.)</td>
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<td>X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.)</td>
<td>X: (0.,0.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.)</td>
<td>X: (0.,1.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.)</td>
<td>X: (0.,0.,0.) Y: (1.,0.,0.) Z: (0.,-1.,0.)</td>
<td>X: (0.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,-1.)</td>
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<tr>
<td>P1: (0.,0.,0.) P2: (9.920.,0.,0.) P3: (9.923.,0.,0.)</td>
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<td>P1: (5.,0.,0.) P2: (5.,4.,0.) P3: (5.,4.,0.)</td>
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Count of Space Boundaries relating to Room 103a = 7
| Room 103b Space Boundary 1 (#4826 in Reference IFC) | "2nd Level" Physical External | Room 103b (1st Floor East Wall (#620)) | Origin: (9.92,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (5.04,0.,0.) P3: (5.04,3.,0.) P4: (0.,3.,0.) |
| Room 103b Space Boundary 2 (#4958) | "2nd Level" Physical External | Room 103b (1st Floor North Wall (#790)) | Origin: (9.92,5.04,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,3.,0.) P4: (0.,3.,0.) |
| Room 103b Space Boundary 3 (#4914) | "2nd Level" Physical Internal Type 2a | Room 103b (1st Floor Vertical Interior Wall (#1169)) | Origin: (0.,5.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (3.,0.,0.) P3: (3.,3.,0.) P4: (0.,3.,0.) |
| Room 103b Space Boundary 4 (#5070) | "2nd Level" Physical Internal Type 2b (due to 1st floor horizontal wall) | Room 103b (1st Floor Vertical Interior Wall (#1169)) | Origin: (0.,5.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (3.12,0.,0.) P3: (3.12,3.,0.) P4: (3.,3.,0.) |
| Room 103b Space Boundary 5 (#5014) | "2nd Level" Physical Internal Type 2a | Room 103b (1st Floor Vertical Interior Wall (#1169)) | Origin: (0.,5.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (3.12,0.,0.) P2: (5.04,0.,0.) P3: (5.04,3.,0.) P4: (3.12,3.,0.) |
| Room 103b Space Boundary 6 (#3884) | "2nd Level" Virtual Internal | Room 103b (1st Floor Virtual Element (#3865)) | Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,3.,0.) P4: (0.,3.,0.) |
| Room 103b Space Boundary 7 (#4786) | "2nd Level" Physical External | Room 103b (Base Slab (#1548)) | Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (5.04,0.,0.) P3: (5.04,9.92,0.) P4: (0.,9.92,0.) |
| Room 103b Space Boundary 8 (#4866) | "2nd Level" Physical Internal Type 2a | Room 103b (Floor Slab (#3001)) | Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (5.,0.,0.) P3: (5.,5.04,0.) P4: (0.,5.04,0.) |
| Room 103b Space Boundary 9 (#5118) | "2nd Level" Physical Internal Type 2a | Room 103b (Floor Slab (#3001)) | Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,5.04,0.) P4: (5.,5.04,0.) |

Count of Space Boundaries relating to Room 103b = 9
Verdict Criteria Summary for all Space Boundaries relating to Room 201

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<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
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<tbody>
<tr>
<td>Room 201 Space Boundary 1 (&quot;2nd Level&quot; Physical External)</td>
<td>Room 201 (#3639)</td>
<td>2nd Floor South Wall (#2146)</td>
<td>Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (2.,0.,0.) P3: (2.,3.,0.) P4: (0.,3.,0.)</td>
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<td>Room 201 Space Boundary 2 (&quot;2nd Level&quot; Physical External)</td>
<td>Room 201 (#3639)</td>
<td>2nd Floor North Wall (#2454)</td>
<td>Origin: (2.,9.04,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (2.,0.,0.) P3: (2.,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td>Room 201 Space Boundary 3 (&quot;2nd Level&quot; Physical External)</td>
<td>Room 201 (#3639)</td>
<td>2nd Floor West Wall (#2624)</td>
<td>Origin: (0.,9.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td>Room 201 Space Boundary 4 (&quot;2nd Level&quot; Physical Internal Type 2a)</td>
<td>Room 201 (#3639)</td>
<td>2nd Floor Interior Wall (#2818)</td>
<td>Origin: (2.,0.,0.) X: (0.,1.,0.) Y: (0.,1.,0.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 201 Space Boundary 5 (&quot;2nd Level&quot; Physical Internal Type 2a)</td>
<td>Room 201 (#3639)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (5.92,0.,0.) P3: (5.92,2.,0.) P4: (0.,2.,0.)</td>
</tr>
<tr>
<td>Room 201 Space Boundary 6 (&quot;2nd Level&quot; Physical Internal Type 2b (due to 1st floor interior wall))</td>
<td>Room 201 (#3639)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (5.92,0.,0.) P2: (6.04,0.,0.) P3: (6.04,2.,0.) P4: (5.92,2.,0.)</td>
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<tr>
<td>Room 201 Space Boundary 7 (&quot;2nd Level&quot; Physical Internal Type 2a)</td>
<td>Room 201 (#3639)</td>
<td>Floor Slab (#3001)</td>
<td>Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (6.04,0.,0.) P2: (9.04,0.,0.) P3: (9.04,2.,0.) P4: (6.04,2.,0.)</td>
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<td>Room 201 Space Boundary 8 (&quot;2nd Level&quot; Physical External)</td>
<td>Room 201 (#3639)</td>
<td>Roof Slab (#3142)</td>
<td>Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (0.,0.,0.) P2: (2.,0.,0.) P3: (2.,9.04,0.) P4: (0.,9.04,0.)</td>
</tr>
</tbody>
</table>

Count of Space Boundaries relating to Room 201 = 8
Verdict Criteria Summary for all Space Boundaries relating to Room 202a

<table>
<thead>
<tr>
<th>Attributes: Name</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 202a Space Boundary 1 (#5762 in Reference IFC)</td>
<td>“2nd Level” Physical External</td>
<td>Room 202a (#3698)</td>
<td>2nd Floor South Wall (#2146) Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (7.,0.,0.) P3: (7.,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 2 (#5942)</td>
<td>“2nd Level” Physical External</td>
<td>Room 202a (#3698)</td>
<td>2nd Floor North Wall (#2454) Origin: (7.,0.,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (7.,0.,0.) P3: (7.,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 3 (#5898)</td>
<td>“2nd Level” Physical Internal Type 2a</td>
<td>Room 202a (#3698)</td>
<td>2nd Floor Interior Wall (#2818) Origin: (0.,9.04,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (7.,0.,0.) P3: (7.,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 4 (#4001)</td>
<td>“2nd Level” Virtual Internal</td>
<td>Room 202a (#3698)</td>
<td>2nd Floor Virtual Element (#3982) Origin: (7.,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 5 (#5810)</td>
<td>“2nd Level” Physical Internal Type 2a</td>
<td>Room 202a (#3698)</td>
<td>Floor Slab (#3001) Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,1.88,0.) P4: (6.04,1.88,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 6 (#5982)</td>
<td>“2nd Level” Physical Internal Type 2a</td>
<td>Room 202a (#3698)</td>
<td>Floor Slab (#3001) Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (5.92,0.,0.) P3: (5.92,1.88,0.) P4: (0.,1.88,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 7 (#6030)</td>
<td>“2nd Level” Physical Internal Type 2a</td>
<td>Room 202a (#3698)</td>
<td>Floor Slab (#3001) Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (4.,2.,0.) P2: (9.04,2.,0.) P3: (9.04,7.,0.) P4: (4.,7.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 8 (#6078)</td>
<td>“2nd Level” Physical Internal Type 2a</td>
<td>Room 202a (#3698)</td>
<td>Floor Slab (#3001) Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (4.,2.,0.) P3: (4.,7.,0.) P4: (0.,7.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 9 (#6142)</td>
<td>“2nd Level” Physical Internal Type 2b (due to 1st floor interior walls)</td>
<td>Room 202a (#3698)</td>
<td>Floor Slab (#3001) Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (5.92,1.88,0.) P3: (6.04,1.88,0.) P4: (5.92,0.,0.)</td>
</tr>
<tr>
<td>Room 202a Space Boundary 10 (#5850)</td>
<td>“2nd Level” Physical External</td>
<td>Room 202a (#3698)</td>
<td>Roof Slab (#3142) Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (7.,0.,0.) P3: (7.,9.04,0.) P4: (0.,9.04,0.)</td>
</tr>
</tbody>
</table>

Count of Space Boundaries relating to Room 201 = 10
## Verdict Criteria Summary for all Space Boundaries relating to Room 202b

<table>
<thead>
<tr>
<th>Attributes: Name</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 202b Space Boundary 1 (#6182 in Reference IFC)</td>
<td>2nd Floor South Wall (#2146)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 2 (#6270)</td>
<td>2nd Floor East Wall (#2284)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (4.92,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 3 (#6354)</td>
<td>2nd Floor North Wall (#2454)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (4.92,9.04,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 4 (#4002)</td>
<td>2nd Floor Virtual Element (#3982)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (0.,9.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 5 (#6394)</td>
<td>Floor Slab (#3001)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (4.,0.,0.) P3: (4.,4.92,0.) P4: (0.,4.92,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 6 (#6230)</td>
<td>Floor Slab (#3001)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (4.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,4.92,0.) P4: (4.,4.92,0.)</td>
</tr>
<tr>
<td>Room 202b Space Boundary 7 (#6310)</td>
<td>Roof Slab (#3142)</td>
<td>Room 202b (#3757)</td>
<td>Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,9.04,0.) P4: (0.,9.04,0.)</td>
</tr>
</tbody>
</table>

Count of Space Boundaries relating to Room 201 = 7

Total Space Boundary Count = 58
7.4 **BPEA Test Case 3**

**BPEA Test Case 3**

Test Case Title: Two Stories Building with Doors, Windows, and Columns

Date of Last Edit: 10/08/2009

**Summary Description:** Test Case 3 consists of a two-stories building with internal walls as well as columns, doors and windows, as shown on Figure A4. The floor plan of Test Case 3 is similar to that of Test Case 2, except that the 2nd floor internal walls have been removed, and the air wall in 1st floor has been replaced by a regular wall. The building elements included in this test case are: 8 exterior walls (4 for each floor), 3 interior walls (all on 1st floor), 3 doors (2 exterior and 1 interior, all on 1st floor), 2 windows (all on 1st floor), 2 columns (one freestanding and one embedded to the wall, both go through 1st and 2nd floor), 1 base slab, 1 floor slab, and 1 roof slab.

**Test Objectives:**
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets
- Check for accurate counts of spaces and space boundaries
- Check space boundary attributes, reference to space and building elements, and connection geometry.

![Figure A4: Two Stories Building with Doors, Windows, and Columns](image-url)
### Detailed Description:

**Project Name:** BPEA Test Case 3  
**Site Location:** Washington D.C. (38˚55’ Latitude, -77˚0’ Longitude)  
**Site Elevation = 0 m**

**Building Name:** TC3  
**Building Global Coordinates:** 38˚55’ Latitude, -77˚0’ Longitude  
**Building Orientation:** 30˚ from true north  
**Building Elevation from Sea Level = 0 m**

- **Total Number of Building Stories = 2**
- **Name of 1st Building Story:** “1st Floor”  
- **Elevation (relative to building datum) = 0 m**
- **Name of 2nd Building Story:** “2nd Floor”  
- **Elevation (relative to building datum) = 3.61 m**

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (1st floor east)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (15, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall (1st floor west)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (0, 10, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall (1st floor south)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 0)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Exterior Wall (1st floor north)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 0)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>5. Exterior Wall (2nd floor east)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (15, 0, 3.61)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>6. Exterior Wall (2nd floor west)</td>
<td>Length: 10 m Height: 3 m Thickness: 0.48 m Origin: (0, 10, 3.61)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls  
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Exterior Wall (2\textsuperscript{nd} floor south)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 3.61)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>8. Exterior Wall (2\textsuperscript{nd} floor north)</td>
<td>Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 3.61)</td>
<td>WA26</td>
<td>12-in LW CMU Fill insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>9. Interior Wall (1\textsuperscript{st} floor hori.)</td>
<td>Length: 4 m Height: 3 m Thickness: 0.12 m Origin: (0, 6, 0)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>10. Interior Wall (1\textsuperscript{st} floor vert.)</td>
<td>Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (5, 0, 0)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>11. Interior Wall (1\textsuperscript{st} floor hori.)</td>
<td>Length: 9.9 m Height: 3 m Thickness: 0.12 m Origin: (4.6, 4.6, 0)</td>
<td>WA36</td>
<td>2 Gypsum boards Wall air space</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>12. Base Slab</td>
<td>15 m by 10 m Thickness: 0.256 m Origin: (0, 0, -0.256) X-axis: (1, 0, 0)</td>
<td>FA5</td>
<td>6-in HW concrete 4-in Gravel</td>
<td>A1030 Slab-on-grade</td>
</tr>
<tr>
<td>13. Floor Slab (between 1\textsuperscript{st} and 2\textsuperscript{nd})</td>
<td>15 m by 10 m Thickness: 0.61 m Origin: (0, 0, 3) X-axis: (1, 0, 0)</td>
<td>FA2</td>
<td>Acoustical tile Air wall resistance 6-in HW concrete</td>
<td>B1010 Floor Construction</td>
</tr>
<tr>
<td>14. Roof Slab</td>
<td>15 m by 10 m Thickness: 0.2 m Origin: (0, 0, 6.61) X-axis: (1, 0, 0)</td>
<td>RA14</td>
<td>R-15 insulation 4-in LW concrete</td>
<td>B1020 Roof Construction</td>
</tr>
<tr>
<td>15. Exterior Door (south wall)</td>
<td>Width: 1.5 m Height: 2.5 m Sill to base: 0 m Origin: (6.75, 0, 0)</td>
<td>D3</td>
<td>Single door</td>
<td>D2030 Exterior Doors</td>
</tr>
<tr>
<td>16. Exterior Door (east wall)</td>
<td>Width: 1 m Height: 2.5 m Sill to base: 0 m Origin: (15, 7, 0)</td>
<td>D3</td>
<td>Single door</td>
<td>D2030 Exterior Doors</td>
</tr>
<tr>
<td>Building Elements</td>
<td>Dimension and Origin in World Coordinate Sys.</td>
<td>Construction Type (ASHRAE)</td>
<td>Description (ASHRAE)</td>
<td>UniFormat Classification</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>--------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>17. Interior Door (1st floor hori. wall)</td>
<td>Width: 1 m Height: 2.5 m Sill to base: 0 m Origin: (9, 4.48, 0)</td>
<td>D1</td>
<td>Single door</td>
<td>C1010 Interior Doors</td>
</tr>
<tr>
<td>18. Exterior Window (south wall)</td>
<td>Width: 3 m Height: 2 m Sill to base: 0 m Origin: (9.9, 0, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>19. Exterior Window (east wall)</td>
<td>Width: 1.5 m Height: 1.5 m Sill to base: 0.5 m Origin: (15, 1.6, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>20. Door Opening (south wall door)</td>
<td>Width: 1.5 m Height: 2.5 m Thickness: 0.41 m Origin: (7.5, 0, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Door Opening (east wall door)</td>
<td>Width: 1 m Height: 2.5 m Thickness: 0.48 m Origin: (15, 7.5, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Door Opening (interior door)</td>
<td>Width: 1 m Height: 2.5 m Thickness: 0.12 m Origin: (9.56, 4.48, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Window Opening (south wall window)</td>
<td>Width: 3 m Height: 2 m Thickness: 0.41 m Origin: (11.4, 0, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Window Opening (east wall window)</td>
<td>Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (15, 2.35, 0.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Embedded Rectangular Column</td>
<td>0.76 m by 0.76 m Height: 6.61 m Origin: (0.1, 5.41, 0)</td>
<td>C3</td>
<td>30-in. by 30-in. rectangular concrete column</td>
<td>B1020 Roof Construction</td>
</tr>
<tr>
<td>26. Freestanding Circular Column</td>
<td>0.5 m diameter Height: 6.61 m Origin: (2, 2, 0)</td>
<td>C4</td>
<td>20-in diameter concrete round column</td>
<td>B1020 Roof Construction</td>
</tr>
<tr>
<td>Building Elements</td>
<td>Dimension and Origin in World Coordinate Sys.</td>
<td>Construction Type (ASHRAE)</td>
<td>Description (ASHRAE)</td>
<td>UniFormat Classification</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td>---------------------</td>
<td>-------------------------</td>
</tr>
</tbody>
</table>
| 27. Space (Room 101) | Length: 4 m  
Width: 3 m  
Height: 3 m  
Origin: $(0.48, 6.6, 0)$ | | | |
| 28. Space (Room 102) | Length: 4 m  
Width: 6 m  
Height: 3 m  
Origin: $(0.48, 0.48, 0)$ | | | |
| 29. Space (Room 103a) | Length: 9.9 m  
Width: 4 m  
Height: 3 m  
Origin: $(4.6, 0.48, 0)$ | | | |
| 30. Space (Room 103b) | Length: 9.9 m  
Width: 5 m  
Height: 3 m  
Origin: $(4.6, 4.6, 0)$ | | | |
| 31. Space (Room 201) | Length: 14 m  
Width: 9.1 m  
Height: 3 m  
Origin: $(0.48, 0.48, 3.61)$ | | | |

All spaces have X-axis = $(1,0,0)$

When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.

**Screenshots of the building model in different IFC Viewers**

![IFcStoreyView](image)
Solibri Model Checker

DDS-CAD Viewer
Testing Details for BPEA Test Case 3

<table>
<thead>
<tr>
<th>Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Check that all building elements exist</strong></td>
</tr>
<tr>
<td>11 IfcWallStandardCase</td>
</tr>
<tr>
<td>5 IfcOpeningElement</td>
</tr>
<tr>
<td>2 IfcWindow</td>
</tr>
<tr>
<td>2 IfcColumn</td>
</tr>
<tr>
<td>3 IfcSlab</td>
</tr>
<tr>
<td>3 IfcDoor</td>
</tr>
<tr>
<td>5 IfcSpace</td>
</tr>
</tbody>
</table>

**Project**

- **Project identifier is required**
  - IfcProject.LongName = "BPEA Test Case 3"

Sample IFC Code¹:

```
#54= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 3',$,'BPEA Test Case 2',$,(#51,#110,#271),#26);
```

- **Correct unit assignment**
  - Length measurement is in "Meter"

Sample IFC Code:

```
#14= IFCSIUNIT(*,.LENGTHUNIT.,$,METRE.);
```

**Site**

- **Site location is specified**
  - IfcSite.LongName = "Washington D.C."
- **Global coordinates (latitude and longitude) are required**
  - IfcSite.RefLatitude = (38.55,0)
  - IfcSite.RefLongitude = (-77,0,0)
- **Site elevation (relative to sea level) is required**
  - IfcSite.RefElevation = 0 (m.)
- **Coordinate of site origin is correctly specified**
  - Coordinate of site origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code²:

```
#64= IFCSITE(GUID,#13,'Default Site','Washington D.C.',$,#61,$,'Washington D.C.',.ELEMENT.,(38,55,0),(-77,0,0),0.,$,$);
#61= IFCLocalPlacement($,#44);
#44= IFCAxis2Placement3D(#40,#36,#28);
#40= IFCCartesianPoint((0.,0.,0.,));
```

---

¹ One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as '0bY52t0r7xHf8Ow0sY$t_'. In the examples, the GUID is shortened to the string 'GUID' to save space and improve readability.

² In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

Building
- Building identifier is required
  ___ IfcBuilding.LongName = "TC3"
- Elevation (base elevation of ground level floor above sea level) is required
  ___ IfcBuilding.ElevationOfRefHeight = 0 (m.)
- Coordinate of building origin is correctly specified
  ___ Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
```
#77= IFCBUILDING(GUID,#13,'Default Building','TC3',$,#74,$,'TC3',.ELEMENT.,
  0.,$,$);
#74= IFCLocalPlacement(#61,#44);
 #61= IFCLocalPlacement($,#44);
 #44= IFCAxis2Placement3D(#40,#36,#28);
 #40= IFCCartesianPoint((0.,0.,0.));
```

- Number of stories is specified
  ___ Pset_BuildingCommon.NumberOfStoreys = 2

Sample IFC Code:
```
#9207= IFC_PROPERTY_SINGLEVALUE('NumberOfStoreys',$,IFCINTEGER(2),$);
```

- Building orientation (the degrees of clockwise from true north) is required
  ___ IfcGeometricRepresentationContext.TrueNorth = (-0.5,0.866)

Sample IFC Code:
```
#51= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan','Design',3,1.0000000E-5,
  #44,#47);
 #47= IFC_DIRECTION((-0.5,0.866));
```

Building Stories
- Identification is required
  ___ IfcBuildingStorey.Name = "1st Floor", IfcBuildingStorey.Name = "2nd Floor"
- Elevation (relative to building datum) is required
  ___ IfcBuildingStorey.Elevation = 0, IfcBuildingStorey.Elevation = 3.61 (m.)
- Coordinate of building story origin is correctly specified
  ___ Coordinate of building story origin is the origin of world coordinate system, (0.,0.,0.)
  ___ Coordinate of building story origin (2nd floor) is (0.,0.,3.61)

Sample IFC Code:
```
#93= IFCBUILDINGSTOREY(GUID,#13,'1st Floor',$,$,#90,$,$,.ELEMENT.,
  0.); #90= IFCLocalPlacement(#74,#87);
 #74= IFCLocalPlacement(#61,#44);
 #61= IFCLocalPlacement($,#44);
 #44= IFCAxis2Placement3D(#40,#36,#28);
 #40= IFCCartesianPoint((0.,0.,0.));
```
```
#5666= IFCBUILDINGSTOREY(GUID,#13,'2nd Floor',$,$,#5663,$,$,.ELEMENT.,3.61); 
#5663= IFCLocalPlacement(#74,#5660);
 #74= IFCLocalPlacement(#61,#44);
 #5660= IFCAxis2Placement3D(#5656,#36,#28);
 #5656= IFCCartesianPoint((0.,0.,3.61));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Walls (West Wall)
- Check wall dimension and geometry
  __ Origin\(^2\) = (0.,10.,0.)
  __ XYZ directions\(^2\): X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)
  __ IfcShapeRepresentation.RepresentationIdentifier = “Body”
  __ IfcShapeRepresentation.RepresentationType = “SweptSolid”
  __ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  __ IfcExtrudedAreaSolid.Depth = 3 (m.)
  __ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
  __ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  __ IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
  __ 4 Cartesian points for the swept area\(^3\) = (0.,0.), (10.,0.), (9.52,0.48), (0.48,0.48)

- Check wall properties
  Check wall construction type
    __ Pset_WallCommon.Reference = “WA34” OR IfcWall.Name = “WA34”
  Check Uniformat classification
    __ IfcWall.Description = “B2010 Exterior Wall”
  Check exterior or interior is declared
    __ Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code\(^4\):
```
#3576 = IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',$
    $,#3573,#3646,$);
#3573 = IFCLOCALPLACEMENT(#90,#3570);
  #3570 = IFCCAXIS2PLACEMENT3D(#3566,#36,#3562);
#3566 = IFCCARTESIANPOINT((0.,10.,0.));
#36 = IFCDIRECTION((0.,0.,1.));
#3562 = IFCDIRECTION((0.,-1.,0.));
#3646 = IFCPRODUCTDEFINITIONSHAPE($,$,(#3637));
#3637 = IFCEXTRUDEDAREASOLID(#3633,#3634,#36,#3);
#3633 = IFCARBITRARYCLOSEDPROFILEDEF(AREA.,$,#3629);
  #3629 = IFCPOLYLINE((#3613,#3617,#3621,#3625,#3613));
#3613 = IFCCARTESIANPOINT((0.07,0.));
#3621 = IFCCARTESIANPOINT((9.93,0.));
#3617 = IFCCARTESIANPOINT((9.52,0.48));
#3625 = IFCCARTESIANPOINT((0.48,0.48));
#3634 = IFCCAXIS2PLACEMENT3D(#40,#36,#36);
  #40 = IFCCARTESIANPOINT((0.,0.,0.));
#36 = IFCDIRECTION((0.,0.,1.));
#28 = IFCDIRECTION((1.,0.,0.));
```

\(^1\) The intersection between walls can affect the geometry, i.e., the placement of the Cartesian points of the swept area.

\(^2\) The origin and the direction of the wall (and other building elements) are indicated by IfcWall (or IfcWallStandardCase).IfcLocalPlacement.Position. The XYZ directions are the axes of the local coordinate system (LCS) in reference to the world coordinate system.

\(^3\) These are points in the local coordinate system.

\(^4\) The position and orientation in #3570 are related to the wall. The position and orientation in #3634 are related to the extrusion.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

Walls (All Walls)

- **Check material association (for east and west walls)**
  - IfcMaterialLayerSet.LayerSetName = "WA34"
  - IfcMaterialLayer.LayerThickness = 0.001 (m.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 0.3048 (m.)
  - IfcMaterial.Name = "12 in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.15875 (m.)
  - IfcMaterial.Name = "R-19 batt insulation"
  - IfcMaterialLayer.LayerThickness = 0.015875 (m.)
  - IfcMaterial.Name = "Gyp board"
  - IfcMaterialLayer.LayerThickness = 0.001 (m.)
  - IfcMaterial.Name = "Inside surface resistance"

Sample IFC Code:
```
#2035= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#1961),#1950);
#1950= IFCMATERIALLAYERSETUSAGE(#1948,.AXIS2.,.NEGATIVE.,0.48);
#1948= IFCMATERIALLAYERSET((#1718,#1860,#1906,#1941,#1946),' Wall Type 34_WA34 Precast and CIP Concrete Walls');
  #1718= IFCMATERIALLAYER(#1715,0.0001,.U.);
    #1715= IFCMATERIAL('F01 Outside Surface Resistance');
  #1860= IFCMATERIALLAYER(#1720,0.3048,.U.);
    #1720= IFCMATERIAL(' M16 | 12 in. Heavyweight Concrete');
  #1906= IFCMATERIALLAYER(#1862,0.15875,.U.);
    #1862= IFCMATERIAL(' I05 | R-19, 6-1/4 in. Batt Insulation');
  #1941= IFCMATERIALLAYER(#1908,0.015875,.U.);
    #1908= IFCMATERIAL(' G01 | 5/8 in. Gyp Board');
  #1946= IFCMATERIALLAYER(#1943,0.0001,.U.);
    #1943= IFCMATERIAL('F02 Inside Vertical Surface Resistance');
```

- **Check material association (for north and south walls)**
  - IfcMaterialLayerSet.LayerSetName = "WA26"
  - IfcMaterialLayer.LayerThickness = 0.3048 (m.)
  - IfcMaterial.Name = "Block masonry"
  - IfcMaterialLayer.LayerThickness = 0.092075 (m.)
  - IfcMaterial.Name = "Insulation batt"
  - IfcMaterialLayer.LayerThickness = 0.015875 (m.)
  - IfcMaterial.Name = "Gypsum board"

Sample IFC Code:
```
#317= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#236),#229);
#229= IFCMATERIALLAYERSETUSAGE(#227,.AXIS2.,.NEGATIVE.,0.48);
  #227= IFCMATERIALLAYERSET((#144,#190,#225),' Wall Type 26 WA26 Concrete Block Walls');
    #144= IFCMATERIALLAYER(#103,0.3048,.U.);
      #103= IFCMATERIAL('04 Block Masonry');
    #190= IFCMATERIALLAYER(#146,0.092075,.U.);
      #146= IFCMATERIAL('07 Insulation Batt ');
    #225= IFCMATERIALLAYER(#192,0.015875,.U.);
      #192= IFCMATERIAL('09 Gypsum Board');
```
<table>
<thead>
<tr>
<th>Verdict Criteria Summary for 1st Floor Exterior Walls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall dimension and geometry</strong></td>
</tr>
<tr>
<td><strong>Origin of LCS</strong></td>
</tr>
<tr>
<td><strong>XYZ directions of LCS</strong></td>
</tr>
<tr>
<td><strong>Shape representation</strong></td>
</tr>
<tr>
<td><strong>Extrusion:</strong></td>
</tr>
<tr>
<td><strong>Profile type</strong></td>
</tr>
<tr>
<td><strong>Position</strong></td>
</tr>
<tr>
<td><strong>Depth</strong></td>
</tr>
<tr>
<td><strong>Direction</strong></td>
</tr>
<tr>
<td><strong>Cartesian points for the swept area</strong></td>
</tr>
<tr>
<td><strong>from origin of LCS</strong></td>
</tr>
<tr>
<td><strong>Body:</strong> Swept Solid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wall properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction type</strong></td>
</tr>
<tr>
<td><strong>UniFormat classification</strong></td>
</tr>
<tr>
<td><strong>Exterior / Interior</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wall material association</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Layer name</strong></td>
</tr>
<tr>
<td><strong>Material layer and thickness</strong></td>
</tr>
<tr>
<td>- Block Masonry Thickness: 0.3048 m</td>
</tr>
<tr>
<td>- Insulation Batt Thickness: 0.092075 m</td>
</tr>
<tr>
<td>- Gypsum Board Thickness: 0.015875 m</td>
</tr>
<tr>
<td>- Inside Surface Resistance 0.0001 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corresponding code line number in reference IFC file</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3406 (dimension and geometry)</td>
</tr>
<tr>
<td>#3480 (materials)</td>
</tr>
<tr>
<td>#3544 (properties)</td>
</tr>
<tr>
<td>Wall dimension and geometry</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Origin of LCS</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Shape representation</td>
</tr>
<tr>
<td>Extrusion:</td>
</tr>
<tr>
<td>Profile type</td>
</tr>
<tr>
<td>Position</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Wall properties</td>
</tr>
<tr>
<td>Construction type</td>
</tr>
<tr>
<td>UniFormat classification</td>
</tr>
<tr>
<td>Exterior / Interior</td>
</tr>
<tr>
<td>Wall material association</td>
</tr>
<tr>
<td>Layer name</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Corresponding code line number in reference IFC file</td>
</tr>
</tbody>
</table>
### Verdict Criteria Summary for all Interior Walls

<table>
<thead>
<tr>
<th>Wall dimension and geometry</th>
<th>1st Floor Left Horizontal Wall</th>
<th>1st Floor Right Horizontal Wall</th>
<th>1st Floor Vertical Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of LCS</td>
<td>(0.,6.46,0.)</td>
<td>(4.54,4.54,0.)</td>
<td>(4.54,0.,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
<td>X: (1.,0.,0.)</td>
<td>X: (0.,1.,0.)</td>
<td>X: (0.,1.,0.)</td>
</tr>
<tr>
<td></td>
<td>Y: (0.,1.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
</tr>
<tr>
<td></td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Shape representation</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td>Extrusion:</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Profile type</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
</tr>
<tr>
<td>Position</td>
<td>3 m.</td>
<td>3 m.</td>
<td>3 m.</td>
</tr>
<tr>
<td>Depth</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
</tr>
<tr>
<td>Direction</td>
<td>(0.48,0.06), (4.48,0.06), (0.48,0.06)</td>
<td>(0.06,-0.06), (9.98,-0.06), (9.98,0.06), (0.06,0.06)</td>
<td>(0.48,-0.06), (9.52,-0.06), (9.52,0.06), (0.48,0.06)</td>
</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
<td>(0.48,0.06), (4.48,0.06), (0.48,0.06)</td>
<td>(0.06,-0.06), (9.98,-0.06), (9.98,0.06), (0.06,0.06)</td>
<td>(0.48,-0.06), (9.52,-0.06), (9.52,0.06), (0.48,0.06)</td>
</tr>
</tbody>
</table>

### Wall properties

<table>
<thead>
<tr>
<th>Construction type</th>
<th>WA36</th>
<th>WA36</th>
<th>WA36</th>
</tr>
</thead>
<tbody>
<tr>
<td>UniFormat classification</td>
<td>C1010 Interior Fixed Partitions</td>
<td>C1010 Interior Fixed Partitions</td>
<td>C1010 Interior Fixed Partitions</td>
</tr>
<tr>
<td>Exterior / Interior</td>
<td>Interior</td>
<td>Interior</td>
<td>Interior</td>
</tr>
</tbody>
</table>

### Wall material association

<table>
<thead>
<tr>
<th>Layer name</th>
<th>WA36</th>
<th>WA36</th>
<th>WA36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material layer and thickness</td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
</tr>
<tr>
<td></td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
</tr>
<tr>
<td></td>
<td>- Wall Air Space Resistance 0.092075 m</td>
<td>- Wall Air Space Resistance 0.092075 m</td>
<td>- Wall Air Space Resistance 0.092075 m</td>
</tr>
<tr>
<td></td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
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<tr>
<td></td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
</tr>
</tbody>
</table>

### Corresponding code line number in reference IFC file

<table>
<thead>
<tr>
<th>WA36 (dimension and geometry)</th>
<th>#3981</th>
<th>#4175</th>
<th>#3785</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA36 (materials)</td>
<td>#4055</td>
<td>#4249</td>
<td>#3859</td>
</tr>
<tr>
<td>WA36 (properties)</td>
<td>#4147</td>
<td>#4765</td>
<td>#3951</td>
</tr>
<tr>
<td>Slab dimension and geometry</td>
<td>Base slab</td>
<td>Floor slab</td>
<td>Roof slab</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Origin of LCS</td>
<td>(0.,0.,-0.256)</td>
<td>(0.,0.,3.)</td>
<td>(0.,0.,6.61)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
<td>X: (1.,0.,0.)</td>
<td>X: (1.,0.,0.)</td>
<td>X: (1.,0.,0.)</td>
</tr>
<tr>
<td></td>
<td>Y: (0.,1.,0.)</td>
<td>Y: (0.,1.,0.)</td>
<td>Y: (0.,1.,0.)</td>
</tr>
<tr>
<td></td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Shape representation</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td>Extrusion:</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Profile type</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
</tr>
<tr>
<td>Position</td>
<td>0.256 m.</td>
<td>0.61 m.</td>
<td>0.2 m.</td>
</tr>
<tr>
<td>Depth</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
</tr>
<tr>
<td>Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
<td>(0.,0.,(15.,0), (15.,10.), (0.,10.), (0.,0.), (15.,0), (15.,10.), (0.,10.).)</td>
<td>(0.,0.,(15.,0), (15.,10.), (0.,10.), (0.,0.), (15.,0), (15.,10.), (0.,10.).)</td>
<td></td>
</tr>
<tr>
<td>Slab properties</td>
<td>FA5</td>
<td>FA2</td>
<td>RA14</td>
</tr>
<tr>
<td>Construction type</td>
<td>A1030 Slabs-On-Grade</td>
<td>B1010 Floor Construction</td>
<td>B1020 Roof Construction</td>
</tr>
<tr>
<td>UniFormat classification</td>
<td>Exterior</td>
<td>Interior</td>
<td>Exterior</td>
</tr>
<tr>
<td>Exterior / Interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slab material association</td>
<td>FA5</td>
<td>FA2</td>
<td>RA14</td>
</tr>
<tr>
<td>Layer name</td>
<td>- 6-in Heavyweight Concrete 0.1524 m</td>
<td>- 6-in Heavyweight Concrete 0.1524 m</td>
<td>- Outside Surface Resistance Thickness: 0.0001 m</td>
</tr>
<tr>
<td>Material layer and thickness</td>
<td>- Vapor Barrier 0.002 m</td>
<td>- Ceiling Air Space Resistance 0.441325 m</td>
<td>- Built-up Roofing Thickness: 0.0095 m</td>
</tr>
<tr>
<td></td>
<td>- 4-in Gravel 0.1016 m</td>
<td>- Acoustic Tile 0.015875 m</td>
<td>- Fiberboard Sheathing Thickness: 0.0127 m</td>
</tr>
<tr>
<td>Corresponding code line number in reference IFC file</td>
<td>#5085 (dimension and geometry) #5384 (materials) #5407 (properties)</td>
<td>#6344 (dimension and geometry) #6458 (materials) #6481 (properties)</td>
<td>#6483 (dimension and geometry) #6906 (materials) #6929 (properties)</td>
</tr>
</tbody>
</table>
# Verdict Criteria Summary for all Openings, Doors, and Windows

<table>
<thead>
<tr>
<th>Opening dimen. and geometry</th>
<th>South wall door opening</th>
<th>East wall door opening</th>
<th>Interior wall door opening</th>
<th>South wall window opening</th>
<th>East wall window opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin of LCS from the LCS of the wall</td>
<td>(7.5,0.07,0.)</td>
<td>(7.5,0.0)</td>
<td>(5.0,-0.07,0.)</td>
<td>(11.5,0.07,0.)</td>
<td>(2.5,0.,0.5)</td>
</tr>
<tr>
<td>XYZ directions of LCS relative to XYZ of LCS of the wall</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td></td>
</tr>
<tr>
<td>Extrusion: Profile type</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
</tr>
<tr>
<td>Position from LCS</td>
<td>0.41 m.</td>
<td>0.48 m.</td>
<td>0.12 m.</td>
<td>0.41 m.</td>
<td>0.48 m.</td>
</tr>
<tr>
<td>Depth</td>
<td>(0.,1.,0.)</td>
<td>(0.,1.,0.)</td>
<td>(0.,1.,0.)</td>
<td>(0.,1.,0.)</td>
<td>(0.,1.,0.)</td>
</tr>
<tr>
<td>Direction in LCS</td>
<td>Rectangle Profile</td>
<td>Center from LCS</td>
<td>1.5, 2.5</td>
<td>1.5, 1.5</td>
<td></td>
</tr>
<tr>
<td>XDim, YDim</td>
<td>(0.,1.25)</td>
<td>(0.,1.25)</td>
<td>(0.,1.)</td>
<td>(0.,1.)</td>
<td>(0.,0.75)</td>
</tr>
<tr>
<td>Code line number in reference IFC file</td>
<td>#361</td>
<td>#2079</td>
<td>#4293</td>
<td>#801</td>
<td>#2513</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Door / Window dimension and geometry</th>
<th>South wall door</th>
<th>East wall door</th>
<th>Interior wall door</th>
<th>South wall window</th>
<th>East wall window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape representation</td>
<td>Body: Brep/Swept Solid/Bounding Box</td>
<td>Body: Brep/Swept Solid/Bounding Box</td>
<td>Body: Brep/Swept Solid/Bounding Box</td>
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<td>Overall Height</td>
<td>2.5 m</td>
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<td>2 m</td>
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<td>Overall Width</td>
<td>1.5 m</td>
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<th>South wall door</th>
<th>East wall door</th>
<th>Interior wall door</th>
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<th>East wall window</th>
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<td>D1</td>
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<td>Interior</td>
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<td>#705 #746</td>
<td>#2419 #2452</td>
<td>#4633 #4666</td>
<td>#1567 #1608</td>
<td>#3277 #3310</td>
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<td>Round column</td>
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<td>Verdict Criteria Summary for all Spaces</td>
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<td><strong>Origin of LCS</strong></td>
<td><strong>XYZ Direction of LCS</strong></td>
<td><strong>Shape Repr.</strong></td>
<td><strong>Extrusion:</strong> Profile type, Position, Depth, Direction</td>
<td><strong>Cartesian points of swept area (from origin of LCS)</strong></td>
<td><strong>Space Properties:</strong> Longname, Ext. / Int.</td>
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<td>Room 101 (#5522 in Reference IFC file)</td>
<td>(0.48,6.53,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<tr>
<td>Room 102 (#5458)</td>
<td>(0.48,0.48,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<td>Room 103 (#5640)</td>
<td>(4.6,0.48,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<td>Room 104 (#5581)</td>
<td>(4.6,4.6,0.)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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<td>Room 201 (#6978)</td>
<td>(0.48,0.48,3.61)</td>
<td>X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)</td>
<td>Body: Swept Solid</td>
<td>Area (0.,0.,0.) 3 m. (0.,0.,1.)</td>
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Verdict Criteria Summary for all Space Boundaries relating to Room 101

| Room 101 Space Boundary 1  
#7705 in Reference IFC | “2nd Level” Physical External | Room 101 (##5522) | 1st Floor North Wall (##3406) | Origin: (4.,3.,0.)  
X: (-1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,1.,0.)  
P1: (0.,0.,0.)  
P2: (4.,0.,0.)  
P3: (4.,3.,0.)  
P4: (0.,3.,0.) |
| --- | --- | --- | --- | --- |
| Room 101 Space Boundary 2  
#7661 | “2nd Level” Physical External | Room 101 (##5522) | 1st Floor West Wall (##3576) | Origin: (0.,3.,0.)  
X: (0.,-1.,0.)  
Y: (0.,0.,1.)  
Z: (-1.,0.,0.)  
P1: (0.,0.,0.)  
P2: (3.,0.,0.)  
P3: (3.,3.,0.)  
P4: (0.,3.,0.) |
| Room 101 Space Boundary 3  
#7573 | “2nd Level” Physical Internal Type 2a | Room 101 (##5522) | 1st Floor Vertical Interior Wall (##3785) | Origin: (4.,0.,0.)  
X: (0.,1.,0.)  
Y: (0.,0.,1.)  
Z: (1.,0.,0.)  
P1: (0.,0.,0.)  
P2: (3.,0.,0.)  
P3: (3.,3.,0.)  
P4: (0.,3.,0.) |
| Room 101 Space Boundary 4  
#7493 | “2nd Level” Physical Internal Type 2a | Room 101 (##5522) | 1st Floor Horizontal Interior Wall (##3981) | Origin: (0.,0.,0.)  
X: (1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,-1.,0.)  
P1: (0.,0.,0.)  
P2: (4.,0.,0.)  
P3: (4.,3.,0.)  
P4: (0.,3.,0.) |
| Room 101 Space Boundary 5  
#7533 | “2nd Level” Physical External | Room 101 (##5522) | Base Slab (##5085) | Origin: (0.,0.,0.)  
X: (0.,1.,0.)  
Y: (1.,0.,0.)  
Z: (0.,0.,-1.)  
P1: (0.,0.,0.)  
P2: (3.,0.,0.)  
P3: (3.,4.,0.)  
P4: (0.,4.,0.) |
| Room 101 Space Boundary 6  
#7613 | “2nd Level” Physical Internal Type 2a | Room 101 (##5522) | Floor Slab (##6344) | Origin: (0.,0.,3.)  
X: (1.,0.,0.)  
Y: (0.,1.,0.)  
Z: (0.,0.,1.)  
P1: (0.,0.,0.)  
P2: (4.,0.,0.)  
P3: (4.,3.,0.)  
P4: (0.,3.,0.) |

Count of Space Boundaries relating to Room 101 = 6
### Verdict Criteria Summary for all Space Boundaries relating to Room 102

| Room 102 Space Boundary 1 (#7033 in Reference IFC) | "2nd Level" Physical External | Room 102 (#5458) | 1st Floor South Wall (#236) | Origin: (0.,0.,0.)  X: (1.,0.,0.)  Y: (0.,0.,1.)  Z: (0.,-1.,0.)  P1: (0.,0.,0.)  P2: (4.,0.,0.)  P3: (4.,3.,0.)  P4: (0.,3.,0.) |
| Room 102 Space Boundary 2 (#7309) | "2nd Level" Physical External | Room 102 (#5458) | 1st Floor West Wall (#3576) | Origin: (0.,5.92.,0.)  X: (0.,-1.,0.)  Y: (0.,0.,1.)  Z: (0.,-1.,0.)  P1: (0.,0.,0.)  P2: (1.02,0.,0.)  P3: (1.02,3.,0.)  P4: (0.,3.,0.) |
| Room 102 Space Boundary 3 (#7365) | "2nd Level" Physical External | Room 102 (#5458) | 1st Floor West Wall (#3576) | Origin: (0.,5.92.,0.)  X: (0.,-1.,0.)  Y: (0.,0.,1.)  Z: (0.,-1.,0.)  P1: (1.78,0.,0.)  P2: (5.92,0.,0.)  P3: (5.92,3.,0.)  P4: (1.78,3.,0.) |
| Room 102 Space Boundary 4 (#7405) | "2nd Level" Physical Internal Type 2a | Room 102 (#5458) | 1st Floor Vertical Interior Wall (#3785) | Origin: (4.,0.,0.)  X: (0.,1.,0.)  Y: (0.,0.,1.)  Z: (1.,0.,0.)  P1: (0.,0.,0.)  P2: (4.,0.,0.)  P3: (4.,3.,0.)  P4: (0.,3.,0.) |
| Room 102 Space Boundary 5 (#7453) | "3rd Level" Physical Internal Type 2b (1st floor hori. right wall) | Room 102 (#5458) | 1st Floor Vertical Interior Wall (#3785) | Origin: (4.,0.,0.)  X: (0.,1.,0.)  Y: (0.,0.,1.)  Z: (1.,0.,0.)  P1: (4.,0.,0.)  P2: (4.12,0.,0.)  P3: (4.12,3.,0.)  P4: (4.,3.,0.) |
| Room 102 Space Boundary 6 (#7121) | "2nd Level" Physical Internal Type 2a | Room 102 (#5458) | 1st Floor Vertical Interior Wall (#3785) | Origin: (4.,0.,0.)  X: (0.,1.,0.)  Y: (0.,0.,1.)  Z: (1.,0.,0.)  P1: (4.,0.,0.)  P2: (5.92,0.,0.)  P3: (5.92,3.,0.)  P4: (4.12,3.,0.) |
| Room 102 Space Boundary 7 (#7261) | "2nd Level" Physical Internal Type 2a | Room 102 (#5458) | 1st Floor Horizontal Interior Wall (#3981) | Origin: (4.,5.92.,0.)  X: (-1.,0.,0.)  Y: (0.,0.,1.)  Z: (0.,-1.,0.)  P1: (1.02,0.,0.)  P2: (1.78,0.,0.)  P3: (1.02,3.,0.)  P4: (1.78,3.,0.) |
| Room 102 Space Boundary 8 (#7217) | "2nd Level" Physical External | Room 102 (#5458) | Embedded Rectangular Column (#4775) | Origin: (0.,5.92.,0.)  X: (0.,-1.,0.)  Y: (0.,0.,1.)  Z: (0.,-1.,0.)  P1: (1.02,0.,0.)  P2: (1.78,0.,0.)  P3: (1.02,3.,0.)  P4: (1.78,3.,0.) |
| Room 102 Space Boundary 9 (#7073) | "2nd Level" Physical External | Room 102 (#5458) | Base Slab (#5085) | Origin: (0.,0.,0.)  X: (0.,1.,0.)  Y: (1.,0.,0.)  Z: (0.,0.,1.)  P1: (0.,0.,0.)  P2: (5.92,0.,0.)  P3: (5.92,4.,0.)  P4: (0.,4.,0.) |
| Room 102 Space Boundary 10 (#7161) | "2nd Level" Physical Internal Type 2a | Room 102 (#5458) | Floor Slab (#6344) | Origin: (0.,0.,3.)  X: (1.,0.,0.)  Y: (0.,0.,1.)  Z: (0.,0.,1.)  P1: (0.,0.,0.)  P2: (4.,0.,0.)  P3: (4.5,92.0,)  P4: (0.5,92.0,) |

Count of Space Boundaries relating to Room 102 = 10
| Room 103 Space Boundary 1 | "2nd Level" Physical External | Room 103 (#5640) | 1st Floor South Wall (#236) | Origin: (0.,0.,0.)  
X: (1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,-1.,0.)  
P1: (0.,0.,0.)  
P2: (9.92,0.,0.)  
P3: (9.92,3.,0.)  
P4: (0.,3.,0.) |
| Room 103 Space Boundary 2 | "2nd Level" Physical External | Room 103 (#5640) | 1st Floor East Wall (#1961) | Origin: (9.92,0.,0.)  
X: (0.,1.,0.)  
Y: (0.,0.,1.)  
Z: (1.,0.,0.)  
P1: (0.,0.,0.)  
P2: (4.,0.,0.)  
P3: (4.,3.,0.)  
P4: (0.,3.,0.) |
| Room 103 Space Boundary 3 | "2nd Level" Physical Internal Type 2a | Room 103 (#5640) | 1st Floor Vertical Interior Wall (#3785) | Origin: (0.,4.,0.)  
X: (0.,-1.,0.)  
Y: (0.,0.,1.)  
Z: (-1.,0.,0.)  
P1: (0.,0.,0.)  
P2: (2.15,0.,0.)  
P3: (2.15,2.5,0.)  
P4: (0.,3.,0.) |
| Room 103 Space Boundary 4 | "2nd Level" Physical Internal Type 2a | Room 103 (#5640) | 1st Floor Horizontal Interior Wall (#4175) | Origin: (9.92,4.,0.)  
X: (-1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,1.,0.)  
P1: (0.,0.,0.)  
P2: (4.48,0.,0.)  
P3: (4.48,2.,0.)  
P4: (0.,3.,0.) |
| Room 103 Space Boundary 5 | "2nd Level" Physical External | Room 103 (#5640) | 1st Floor South Wall Ext. Door (#705) | Origin: (0.,0.,0.)  
X: (1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,-1.,0.)  
P1: (2.15,0.,0.)  
P2: (3.65,0.,0.)  
P3: (3.65,2.5,0.)  
P4: (2.15,2.5,0.) |
| Room 103 Space Boundary 6 | "2nd Level" Physical External | Room 103 (#5640) | 1st Floor South Wall Window (#1567) | Origin: (0.,0.,0.)  
X: (1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,-1.,0.)  
P1: (5.4,0.,0.)  
P2: (8.4,0.,0.)  
P3: (8.4,2.0.)  
P4: (5.4,2.0.) |
| Room 103 Space Boundary 7 | "2nd Level" Physical External | Room 103 (#5640) | 1st Floor East Wall Window (#3277) | Origin: (9.92,0.,0.)  
X: (0.,1.,0.)  
Y: (0.,0.,1.)  
Z: (1.,0.,0.)  
P1: (1.27,0.5,0.)  
P2: (2.77,0.5,0.)  
P3: (2.77,2.,0.)  
P4: (1.27,2.,0.) |
| Room 103 Space Boundary 8 | "2nd Level" Physical Internal Type 2a | Room 103 (#5640) | 1st Floor Interior Door (#4633) | Origin: (9.92,4.,0.)  
X: (-1.,0.,0.)  
Y: (0.,0.,1.)  
Z: (0.,1.,0.)  
P1: (4.48,0.,0.)  
P2: (5.48,0.,0.)  
P3: (5.48,2.,0.)  
P4: (4.48,2.,0.) |
| Room 103 Space Boundary 9 | "2nd Level" Physical External | Room 103 (#5640) | Base Slab (#5085) | Origin: (0.,0.,0.)  
X: (0.,1.,0.)  
Y: (1.,0.,0.)  
Z: (0.,-1.,0.)  
P1: (0.,0.,0.)  
P2: (4.,0.,0.)  
P3: (4.,9.92,0.)  
P4: (0.,9.92,0.) |
| Room 103 Space Boundary 10 | "2nd Level" Physical Internal Type 2a | Room 103 (#5640) | Floor Slab (#6344) | Origin: (0.,0.,0.)  
X: (1.,0.,0.)  
Y: (0.,1.,0.)  
Z: (0.,0.,1.)  
P1: (0.,0.,0.)  
P2: (9.92,0.,0.)  
P3: (9.92,4.,0.)  
P4: (0.,4.,0.) |

Count of Space Boundaries relating to Room 103 = 10
## Verdict Criteria Summary for all Space Boundaries relating to Room 104

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<th>Attributes:</th>
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<th>Related Building Element</th>
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<td>Name</td>
<td>Physical/Virtual Ext. / Int.</td>
<td>1st Floor East Wall (#1961)</td>
<td>(9.92,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,3.,0.) P4: (0.,3.,0.)</td>
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<td>Room 104 Space Boundary 1 (7825 in Reference IFC)</td>
<td>Room 104 (5581)</td>
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<tr>
<td>Room 104 Space Boundary 2 (7965)</td>
<td>Room 104 (5581)</td>
<td>1st Floor North Wall (#3406)</td>
<td>(9.92,4.92,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,3.,0.) P4: (0.,3.,0.)</td>
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<tr>
<td>Room 104 Space Boundary 3 (8109)</td>
<td>Room 104 (5581)</td>
<td>1st Floor Vertical Interior Wall (#3785)</td>
<td>(0.,4.92,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (0.,0.,0.) P2: (3.,0.,0.) P3: (3.,3.,0.) P4: (3.,3.,0.)</td>
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<td>Room 104 Space Boundary 4 (7921)</td>
<td>Room 104 (5581)</td>
<td>1st Floor Vertical Interior Wall (#3785)</td>
<td>(0.,4.92,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (3.12,0.,0.) P2: (4.92,0.,0.) P3: (4.92,3.,0.) P4: (3.,3.,0.)</td>
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<td>Room 104 (5581)</td>
<td>1st Floor Vertical Interior Wall (#3785)</td>
<td>(0.,4.92,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (3.12,0.,0.) P2: (3.,0.,0.) P3: (3.,3.,0.) P4: (3.,3.,0.)</td>
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<td></td>
<td>2nd Level Physical Internal Type 2a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room 104 Space Boundary 6 (7745)</td>
<td>Room 104 (5581)</td>
<td>1st Floor Horizontal Interior Wall (#4175)</td>
<td>(9.92,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,3.,0.) P4: (0.,3.,0.)</td>
</tr>
<tr>
<td></td>
<td>2nd Level Physical Internal Type 2a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room 104 Space Boundary 7 (8013)</td>
<td>Room 104 (5581)</td>
<td>1st Floor East Wall Ext. Door (#2419)</td>
<td>(2.4,0.,0.) X: (3.4,2.5,0.) P2: (3.4,0.,0.) P3: (3.4,2.5,0.) P4: (2.4,2.5,0.)</td>
</tr>
<tr>
<td></td>
<td>2nd Level Physical External</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room 104 Space Boundary 8 (8061)</td>
<td>Room 104 (5581)</td>
<td>1st Floor Interior Door (#4633)</td>
<td>(0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (4.44,0.,0.) P2: (5.44,0.,0.) P3: (5.44,2.,0.) P4: (4.44,2.,0.)</td>
</tr>
<tr>
<td></td>
<td>2nd Level Physical Internal Type 2a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room 104 Space Boundary 9 (7785)</td>
<td>Room 104 (5581)</td>
<td>Base Slab (#5085)</td>
<td>(0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,9.92,0.) P4: (0.,9.92,0.)</td>
</tr>
<tr>
<td></td>
<td>2nd Level Physical External</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room 104 Space Boundary 10 (7865)</td>
<td>Room 104 (5581)</td>
<td>Floor Slab (#6344)</td>
<td>(0.,0.,3.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (9.92,4.92,0.) P4: (0.,4.92,0.)</td>
</tr>
</tbody>
</table>

Count of Space Boundaries relating to Room 104 = 10
<p>| Room 201 Space Boundary 1 (#8653 in Reference IFC) | 2nd Level Physical External | Room 201 (#6978) | 2nd Floor South Wall (#5683) | Origin: (0.,0.,0.) X: (1.,0.,0.) Y: (0.,0.,1.) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (14.04,0.,0.) P3: (14.04,3.,0.) P4: (0.,3.,0.) |
| Room 201 Space Boundary 2 (#8873) | 2nd Level Physical External | Room 201 (#6978) | 2nd Floor North Wall (#5991) | Origin: (14.04,9.04,0.) X: (-1.,0.,0.) Y: (0.,0.,1.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (14.04,0.,0.) P3: (14.04,3.,0.) P4: (0.,3.,0.) |
| Room 201 Space Boundary 3 (#8921) | 2nd Level Physical External | Room 201 (#6978) | 2nd Floor West Wall (#6161) | Origin: (0.,9.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (4.14,0.,0.) P3: (4.14,3.,0.) P4: (0.,3.,0.) |
| Room 201 Space Boundary 4 (#8977) | 2nd Level Physical External | Room 201 (#6978) | 2nd Floor West Wall (#6161) | Origin: (0.,9.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (4.9,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (4.9,3.,0.) |
| Room 201 Space Boundary 5 (#8733) | 2nd Level Physical External | Room 201 (#6978) | 2nd Floor East Wall (#5821) | Origin: (14.04,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (0.,0.,0.) P2: (9.04,0.,0.) P3: (9.04,3.,0.) P4: (0.,3.,0.) |
| Room 201 Space Boundary 6 (#8829) | 2nd Level Physical External | Room 201 (#6978) | Embedded Rectangular Column (#4775) | Origin: (0.,9.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (4.14,0.,0.) P2: (4.9,0.,0.) P3: (4.9,3.,0.) P4: (4.14,3.,0.) |
| Room 201 Space Boundary 7 (#8693) | 2nd Level Physical Internal Type 2a | Room 201 (#6978) | Floor Slab (#6344) | Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (5.92,0.,0.) P3: (5.92,4.,0.) P4: (0.,4.,0.) |
| Room 201 Space Boundary 8 (#9025) | 2nd Level Physical Internal Type 2a | Room 201 (#6978) | Floor Slab (#6344) | Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (6.04,0.,0.) P2: (9.04,0.,0.) P3: (9.04,4.,0.) P4: (6.04,4.,0.) |
| Room 201 Space Boundary 9 (#9121) | 2nd Level Physical Internal Type 2a | Room 201 (#6978) | Floor Slab (#6344) | Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,4.12,0.) P2: (4.,4.12,0.) P3: (4.,14.04,0.) P4: (0.,14.04,0.) |</p>
<table>
<thead>
<tr>
<th>Attributes:</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry:</th>
<th>Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Physical/Virtual Ext. / Int.</td>
<td>Room 201 (#6978)</td>
<td>Room 201 Floor Slab (#6344)</td>
<td>Room 201 Space Boundary 10 (#9073) &quot;2nd Level&quot; Physical Internal Type 2a</td>
</tr>
<tr>
<td>Origin</td>
<td>(0.,0.,0.)</td>
<td>X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.)</td>
<td>P1: (4.12,4.12,0.) P2: (9.04,4.12,0.) P3: (9.04,14.04,0.) P4: (4.12,14.04,0.)</td>
<td></td>
</tr>
<tr>
<td>Points</td>
<td>P1: (4.12,4.12,0.)</td>
<td>P2: (9.04,4.12,0.)</td>
<td>P3: (9.04,14.04,0.)</td>
<td>P4: (4.12,14.04,0.)</td>
</tr>
</tbody>
</table>

| Name        | Physical/Virtual Ext. / Int. | Room 201 (#6978) | Room 201 Floor Slab (#6344) | Room 201 Space Boundary 11 (#9201) "3rd Level" Physical Internal Type 2b (due to 1st Floor Interior Walls) |
| Origin      | (0.4.,0.)    | X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) | P1: (0.,4.,0.) P2: (5.92,4.,0.) P3: (5.92,0.,0.) P4: (6.04,0.,0.) |
| Points      | P5: (6.04,4.,0.) | P6: (9.04,4.,0.) | P7: (9.04,4.12,0.) | P8: (4.12,4.12,0.) |
| Origin      | (4.12,14.04,0.) | P9: (4.12,14.04,0.) | P10: (4.14.04,0.) | P11: (4.4.,12.0.) P12: (0.,4.12,0.) |

| Name        | Physical/Virtual Ext. / Int. | Room 201 (#6978) | Room 201 Floor Slab (#6483) | Room 201 Space Boundary 12 (#8773) "2nd Level" Physical External |
| Origin      | (0.,0.,3.) | X: (0.,1.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) | P1: (0.,0.,0.) P2: (14.04,0.,0.) P3: (14.04,9.04,0.) P4: (0.,9.04,0.) |

Count of Space Boundaries relating to Room 201 = 12

Total Space Boundary Count = 48
### 7.5 BPEA Test Case 4

BPEA Test Case 4

Test Case Title: One Story Non-Rectangular Building with Curtain Wall and Shading Devices

Date of Last Edit: 10/10/2009

**Summary Description:** Test Case 4 consists of a one-story building with non-rectangular floor plan and has curtain wall and shading devices, as shown on Figure A5. The south wall of the building is not orthogonal to the east and west walls, producing the non-rectangular floor plan. The building elements included in this test case are: 4 exterior walls (3 regular walls and 1 curtain wall base wall), 1 door, 1 regular windows, 7 curtain wall windows, 3 shading device slabs (1 for the entire curtain wall windows, 1 for the regular window, and 1 for the door), 1 base slab, and 1 roof slab.

**Test Objectives:**
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets
- Check for accurate counts of spaces and space boundaries
- Check space boundary attributes, reference to space and building elements, and connection geometry.

![Figure A5: One Story Non-rectangular Building with Curtain Wall and Shading Devices](image)
Detailed Description:

**Project Name: BPEA Test Case 4**

Site Location: Washington D.C. (38˚55' Latitude, -77˚0' Longitude)
Site Elevation = 0 m

Building Name: TC4
Building Global Coordinates: 38˚55' Latitude, -77˚0' Longitude
Building Orientation: 30˚ from true north
Building Elevation from Sea Level = 0 m

Total Number of Building Stories = 1
Name of 1st Building Story: “1st Floor”
Elevation (relative to building datum) = 0 m

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (1st floor east)</td>
<td>Length: 5 m Height: 3.5 m Thickness: 0.48 m Origin: (15, 5, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall (1st floor west)</td>
<td>Length: 10 m Height: 3.5 m Thickness: 0.48 m Origin: (0, 10, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall (1st floor south)</td>
<td>Length: 15.8 m Height: 3.5 m Thickness: 0.48 m Origin: (0, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Curtain Wall Base (1st floor north)</td>
<td>Length: 15 m Height: 3.5 m Thickness: 0.165 m Origin: (15, 10, 0)</td>
<td>WA41</td>
<td>Spandrel glass R-19 insulation</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>5. Base Slab</td>
<td>15 m by 10 m Thickness: 0.256 m Origin: (0, 0, -0.256) X-axis (0.95, 0.32, 0)</td>
<td>FA5</td>
<td>6-in HW concrete 4-in Gravel</td>
<td>A1030 Slab-on-grade</td>
</tr>
<tr>
<td>6. Roof Slab</td>
<td>15 m by 10 m Thickness: 0.2 m Origin: (0, 0, 3) X-axis (0.95, 0.32, 0)</td>
<td>RA14</td>
<td>R-15 insulation 4-in LW concrete</td>
<td>B1020 Roof Construction</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Exterior Door (west wall)</td>
<td>Width: 1.5 m  Height: 2 m  Sill to base: 0 m  Origin: (4.25, 0, 0)</td>
<td>D3</td>
<td>Double door</td>
<td>D2030 Exterior Doors</td>
</tr>
<tr>
<td>8. Exterior Window (west wall)</td>
<td>Width: 1.5 m  Height: 1.5 m  Sill to base: 0.5 m  Origin: (7.5, 0, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>9. Curtain Wall Window 1 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (2.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>10. Curtain Wall Window 2 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (4.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>11. Curtain Wall Window 3 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (6.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>12. Curtain Wall Window 4 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (8.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>13. Curtain Wall Window 5 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (10.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>14. Curtain Wall Window 6 (north wall)</td>
<td>Width: 2 m  Height: 2.5 m  Sill to base: 0 m  Origin: (12.48, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>15. Curtain Wall Window 7 (north wall)</td>
<td>Width: 2.04 m  Height: 2.5 m  Sill to base: 0 m  Origin: (14.52, 10, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>16. Door Opening (west wall door)</td>
<td>Width: 1.5 m  Height: 2 m  Thickness: 0.48 m  Origin: (0, 3.5, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Elements</td>
<td>Dimension and Origin in World Coordinate Sys.</td>
<td>Construction Type (ASHRAE)</td>
<td>Description (ASHRAE)</td>
<td>UniFormat Classification</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>--------------------------</td>
</tr>
</tbody>
</table>
| 23. Window Opening (west wall window) | Width: 1.5 m  
Height: 1.5 m  
Thick: 0.48 m  
Origin: (0, 6.75, 0.5) | | | |
| 24. Window Opening (curtain wall window 1) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (1.48, 10, 0) | | | |
| 25. Window Opening (curtain wall window 2) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (3.48, 10, 0) | | | |
| 26. Window Opening (curtain wall window 3) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (5.48, 10, 0) | | | |
| 27. Window Opening (curtain wall window 4) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (7.48, 10, 0) | | | |
| 28. Window Opening (curtain wall window 5) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (9.48, 10, 0) | | | |
| 29. Window Opening (curtain wall window 6) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (11.48, 10, 0) | | | |
| 30. Window Opening (curtain wall window 7) | Width: 2 m  
Height: 2.5 m  
Thick: 0.165 m  
Origin: (13.5, 10, 0) | | | |
| 31. Shading Device Slab (west wall door) | 0.8 m by 1.5 m  
Thick: 0.054 m  
Origin: (0, 2.75, 2)  
X-axis (-1, 0, 0) | FA4 | Metal surface 2-in lightweight concrete | B2010 Exterior Protection Devices for Openings |
| 32. Shading Device Slab (west wall window) | 0.8 m by 1.5 m  
Thick: 0.054 m  
Origin: (0, 6, 2)  
X-axis (-1, 0, 0) | FA4 | Metal surface 2-in lightweight concrete | B2010 Exterior Protection Devices for Openings |
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>33. Shading Device Slab (entire curtain wall windows)</td>
<td>15 m by 1 m Thickness: 0.054 m Origin: (0, 10, 2.5) X-axis (1, 0, 0)</td>
<td>FA4</td>
<td>Metal surface 2-in lightweight concrete</td>
<td>B2010 Exterior Protection Devices for Openings</td>
</tr>
<tr>
<td>34. Space (Room)</td>
<td>Height: 3. m Origin: (0.48, 0.67, 0) 4 corner points: (0.48, 0.67), (14.52, 5.346), (14.52, 9.835), (0.48, 9.835) X-axis: (0.95,0.32,0.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.

**Screenshots of the building model in different IFC Viewers**

![IfcStoreyView](image-url)
Solibri Model Checker

DDS-CAD Viewer
Testing Details for BPEA Test Case 4

Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

- Check that all building elements exist
  - 4 IfcWallStandardCase
  - 9 IfcOpeningElement
  - 8 IfcWindow
  - 5 IfcSlab (including 3 shading device slabs)
  - 1 IfcDoor
  - 1 IfcSpace

Project
- Project identifier is required
  - IfcProject.LongName = “BPEA Test Case 4”

Sample IFC Code:\(^1\):
#54= IFCPROJECT(GUID,#13,'Default Project', 'BPEA Test Case 4', $,'BPEA Test Case 4', $,(#51,#110,#394),#26);

- Correct unit assignment
  - Length measurement is in “Meter”

Sample IFC Code:
#14= IFCSIUNIT(*,.LENGTHUNIT.,$,.METRE.);

Site
- Site location is specified
  - IfcSite.LongName = “Washington D.C.”

Sample IFC Code:\(^2\):
#64= IFCSITE(GUID,#13,'Default Site', 'Washington D.C.', $,#61,$,'Washington D.C.', .ELEMENT., (38,55,0), (-77,0,0), 0.,$,$);
#61= IFCLocalPlacement($,#44);
#44= IFCAxis2Placement3D(#40,#36,#28);
#40= IFCCartesianPoint((0.,0.,0.));

1. One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as '0bY5z0t7xHf0xW0sY$'t'. In the examples, the GUID is shortened to the string 'GUID' to save space and improve readability.
2. In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

**Building**
- **Building identifier is required**
  
  IfcBuilding.LongName = “TC4”

- **Elevation (base elevation of ground level floor above sea level) is required**
  
  IfcBuilding.ElevationOfRefHeight = 0 (m.)

- **Coordinate of building origin is correctly specified**
  
  Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:

```latex
#77= IFCBUILDING(GUID,#13,'Default Building','TC4',$,#74,$,'TC4',.ELEMENT.,0.,$,$); 
   #74= IFCLocalPlacement(#61,#44); 
   #61= IFCLocalPlacement($,#44); 
   #44= IFCAxis2Placement3D(#40,#36,#28); 
   #40= IFCCartesianPoint((0.,0.,0.));
```

- **Number of stories is specified**
  
  Pset_BuildingCommon.NumberOfStoreys = 1

Sample IFC Code:

```latex
#7739= IFCPropertySingleValue('NumberOfStoreys',$,IFCINTEGER(1),$);
```

- **Building orientation (the degrees of clockwise from true north) is required**

Sample IFC Code:

```latex
#51= IFCGeometricRepresentationContext('Plan','Design',3,1.0000000E-5,$,#44,#47); 
   #47= IFCDirection((-0.5,0.866));
```

**Building Stories**
- **Identification is required**

IfcBuildingStorey.Name = "1st Floor"

- **Elevation (relative to building datum) is required**

IfcBuildingStorey.Elevation = 0

- **Coordinate of building story origin is correctly specified**

Coordinate of building story origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:

```latex
#93= IFCBUILDINGSTOREY(GUID,#13,'1st Floor',$,$,#90,$,$,.ELEMENT.,0.); 
   #90= IFCLocalPlacement(#74,#87); 
   #74= IFCLocalPlacement(#61,#44); 
   #61= IFCLocalPlacement($,#44); 
   #44= IFCAxis2Placement3D(#40,#36,#28); 
   #87= IFCAxis2Placement3D(#40,#36,#28); 
   #40= IFCCartesianPoint((0.,0.,0.));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Walls (West Wall)

- **Check wall dimension and geometry**: Origin = (0.,10.,0.), XYZ directions: X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)
- IfcShapeRepresentation.RepresentationIdentifier = "Body"
- IfcShapeRepresentation.RepresentationType = "SweptSolid"
- IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
- IfcExtrudedAreaSolid.Depth = 3 (m.)
- IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
- IfcExtrudedAreaSolid.Position = (0.,0.,0.)
- IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
- 4 Cartesian points for the swept area = (0.,0.), (10.,0.), (9.52,0.48), (0.48,0.48)

- **Check wall properties**
  - Check wall construction type: Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - Check Uniformat classification: IfcWall.Description = "B2010 Exterior Wall"
  - Check exterior or interior is declared: Pset_WallCommon.IsExternal = IfcBoolean(T)

Sample IFC Code:
```
#4037= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',
$,#4034,#4107,$);
#4034= IFCLOCALPLACEMENT(#90,#4031);
  #4031= IFCAxis2Placement3D(#4027,#36,#4023);
    #4027= IFCCartesianPoint((0.,10.,0.));
    #36= IFCDirection((0.,0.,1.));
    #4023= IFCDirection((0.,-1.,0.));
  #4107= IFCProductDefinitionShape($,$,#4068,#4101);
    #4101= IFCSShapeRepresentation(#394,'Body','SweptSolid',(#4098));
    #4098= IFCEXtrudedAreaSolid(#4094,#4095,#36,3.5);
    #4094= IFCArbitraryClosedProfileDef(.AREA.,$,#4090);
    #4090= IFCPolyline((#4074,#4078,#4082,#4086,#4074));
    #4074= IFCCartesianPoint((0.,0.));
    #4078= IFCCartesianPoint((10.,0.));
    #4082= IFCCartesianPoint(9.33,0.48));
    #4086= IFCCartesianPoint(0.17,0.48));
  #4095= IFCAxis2Placement3D(#40,#36,#28);
    #40= IFCCartesianPoint((0.,0.,0.));
    #36= IFCDirection((0.,0.,1.));
    #28= IFCDirection((1.,0.,0.));
#5595= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,#4037),#5569);
#5569= IFCPROPERTYSET(GUID,#5573,'Pset_WallCommon',$,#5575,#5579);
#5575= IFCPROPERTYSYINGLEVALUE('Reference',$,'IFCIDENTIFIER('WA34'),$);
#5579= IFCPROPERTYSYINGLEVALUE('IsExternal',$,'IFCBOOLEAN(.T.),$);
```

---

1 The intersection between walls can affect the geometry, i.e., the placement of the Cartesian points of the swept area.
2 The origin and the direction of the wall (and other building elements) are indicated by IfcWall (or IfcWallStandardCase).IfcLocalPlacement.Position. The XYZ directions are the axes of the local coordinate system (LCS) in reference to the world coordinate system.
3 These are points in the local coordinate system.
4 The position and orientation in #4031 are related to the wall. The position and orientation in #4095 are related to the extrusion.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Walls (All Walls)
  - Check material association (East, West, and South Walls)
    __ IfcMaterialLayerSet.LayerSetName = "WA34"
    __ IfcMaterialLayer.LayerThickness = 0.0001 (m.)
    __ IfcMaterial.Name = "Outside surface resistance"
    __ IfcMaterialLayer.LayerThickness = 0.3048 (m.)
    __ IfcMaterial.Name = "12 in. heavyweight concrete"
    __ IfcMaterialLayer.LayerThickness = 0.15875 (m.)
    __ IfcMaterial.Name = "R-19 batt insulation"
    __ IfcMaterialLayer.LayerThickness = 0.015875 (m.)
    __ IfcMaterial.Name = "Gyp board"
    __ IfcMaterialLayer.LayerThickness = 0.0001 (m.)
    __ IfcMaterial.Name = "Inside surface resistance"

Sample IFC Code:
#440= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#359),#348);
#348= IFCMATERIALLAYERSETUSAGE(#346,.AXIS2.,.POSITIVE.,0.);
#346= IFCMATERIALLAYERSET((#116,#258,#304,#339,#344),' Wall Type 34 WA34 Precast and CIP Concrete Walls');
  #116= IFCMATERIALLAYER(#103,0.0001,.U.);
  #103= IFCMATERIAL('F01 Outside Surface Resistance');
  #258= IFCMATERIALLAYER(#118,0.3048,.U.);
  #118= IFCMATERIAL(' M16 12 in. Heavyweight Concrete');
  #304= IFCMATERIALLAYER(#260,0.15875,.U.);
  #260= IFCMATERIAL(' I05 R-19, 6-1/4 in. Batt Insulation');
  #339= IFCMATERIALLAYER(#306,0.015875,.U.);
  #306= IFCMATERIAL(' G01 5/8 in. Gyp Board');
  #344= IFCMATERIALLAYER(#341,0.0001,.U.);
  #341= IFCMATERIAL('F02 Inside Vertical Surface Resistance');

  - Check material association (North Wall)
    __ IfcMaterialLayerSet.LayerSetName = "WA41"
    __ IfcMaterialLayer.LayerThickness = 0.0064 (m.)
    __ IfcMaterial.Name = "Opaque spandrel glass"
    __ IfcMaterialLayer.LayerThickness = 0.15875 (m.)
    __ IfcMaterial.Name = "R-19 batt insulation"

#806= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#732),#717);
#717= IFCMATERIALLAYERSETUSAGE(#715,.AXIS2.,.POSITIVE.,0.);
#715= IFCMATERIALLAYERSET(#711,#713),' Wall Type 41 WA41 Curtain Wall Base Wall');
  #711= IFCMATERIALLAYER(#663,0.0064,.U.);
  #663= IFCMATERIAL(' F09 Opaque spandrel glass');
  #713= IFCMATERIALLAYER(#260,0.15875,.U.);
  #260= IFCMATERIAL(' I05 R-19, 6-1/4 in. Batt Insulation');
# Verdict Criteria Summary for 1st Floor Exterior Walls

<table>
<thead>
<tr>
<th></th>
<th>North Wall</th>
<th>East Wall</th>
<th>South Wall</th>
<th>West Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall dimension and geometry</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of LCS</td>
<td>(15.,10.,0.)</td>
<td>(15.,5.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,10.,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
<td>X: (-1.,0.,0.)</td>
<td>X: (0.,1.,0.)</td>
<td>X: (0.95,0.32,0.)</td>
<td>X: (0.,-1.,0.)</td>
</tr>
<tr>
<td></td>
<td>Y: (0.,-1.,0.)</td>
<td>Y: (-1.,0.,0.)</td>
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<td>Y: (1.,0.,0.)</td>
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<tr>
<td></td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
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<td>Z: (0.,0.,1.)</td>
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<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
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<tr>
<td><strong>Extrusion:</strong></td>
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<td></td>
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<tr>
<td>Profile type</td>
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<td></td>
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<tr>
<td>Position</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td>Depth</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
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<tr>
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<td>3.5 m,</td>
<td>3.5 m,</td>
<td>3.5 m,</td>
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<tr>
<td></td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
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<tr>
<td><strong>Cartesian points for the swept area (from origin of LCS)</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.,0.),</td>
<td>(0.,0.),</td>
<td>(0.,0.),</td>
<td>(0.,0.),</td>
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<tr>
<td></td>
<td>(15.,0.)</td>
<td>(5.,0.),</td>
<td>(15.81,0.),</td>
<td>(10.,0.),</td>
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<tr>
<td></td>
<td>(14.52,0.165),</td>
<td>(4.83,0.48),</td>
<td>(15.47,0.48),</td>
<td>(9.33,0.48),</td>
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<td></td>
<td>(0.48,0.165)</td>
<td>(0.35,0.48)</td>
<td>(0.67,0.48)</td>
<td>(0.165,0.48)</td>
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<td><strong>Wall properties</strong></td>
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<td>Construction type</td>
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<td>WA34</td>
<td>WA34</td>
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<td>Exterior</td>
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<tr>
<td><strong>Wall material association</strong></td>
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<tr>
<td>Layer name</td>
<td>WA41</td>
<td>WA34</td>
<td>WA34</td>
<td>WA34</td>
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<tr>
<td>Material layer and thickness</td>
<td>- Opaque Spandrel Glass Thickness: 0.0064 m</td>
<td>- Outside Surface Resistance 0.0001 m</td>
<td>- Outside Surface Resistance 0.0001 m</td>
<td>- Outside Surface Resistance 0.0001 m</td>
</tr>
<tr>
<td></td>
<td>- R-19 Batt Insulation Thickness: 0.15875 m</td>
<td>- 12-in HW Concrete 0.3048 m</td>
<td>- 12-in HW Concrete 0.3048 m</td>
<td>- 12-in HW Concrete 0.3048 m</td>
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<tr>
<td></td>
<td>- R-19 Batt Insulation Thickness: 0.15875 m</td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
<td>- Gypsum Board 0.015875 m</td>
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<tr>
<td></td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
<td>- Inside Surface Resistance 0.0001 m</td>
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<tr>
<td>Corresponding code line number in reference IFC file</td>
<td>#732 (dimension and geometry) #806 (materials) #4005 (properties)</td>
<td>#508 (dimension and geometry) #582 (materials) #646 (properties)</td>
<td>#359 (dimension and geometry) #440 (materials) #478 (properties)</td>
<td>#4037 (dimension and geometry) #4111 (materials) #5595 (properties)</td>
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### Verdict Criteria Summary for all Slabs

<table>
<thead>
<tr>
<th>Slab dimension and geometry</th>
<th>Base Slab</th>
<th>Roof Slab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin of LCS</strong></td>
<td>(0.,0.,-0.256)</td>
<td>(0.,0.,3.)</td>
</tr>
<tr>
<td><strong>XYZ directions of LCS</strong></td>
<td>X: (0.95,0.32,0.)</td>
<td>X: (0.95,0.32,0.)</td>
</tr>
<tr>
<td></td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td><strong>Shape representation</strong></td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td><strong>Extrusion:</strong></td>
<td>Area</td>
<td>Area</td>
</tr>
<tr>
<td><strong>Profile type</strong></td>
<td>(0.,0.,0.)</td>
<td>(0.,0.,0.)</td>
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<tr>
<td><strong>Position</strong></td>
<td>0.256 m.</td>
<td>0.2 m.</td>
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<tr>
<td><strong>Depth</strong></td>
<td>(0.,0.,1.)</td>
<td>(0.,0.,1.)</td>
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<tr>
<td><strong>Direction</strong></td>
<td>(0.,0.), (15.81,0.), (17.39,4.74), (3.16,9.49)</td>
<td>(0.,0.), (15.81,0.), (17.39,4.74), (3.16,9.49)</td>
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<tr>
<td><strong>Cartesian points for the swept area (from origin of LCS)</strong></td>
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<table>
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<tr>
<th>Slab properties</th>
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<td><strong>Construction type</strong></td>
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<td><strong>UniFormat classification</strong></td>
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<td><strong>Exterior / Interior</strong></td>
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<tr>
<th>Slab material association</th>
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<tbody>
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<td><strong>Layer name</strong></td>
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<td><strong>Material layer and thickness</strong></td>
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<tr>
<th>Corresponding code line number in reference IFC file</th>
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<tr>
<td>#5612 (dimension and geometry)</td>
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<tr>
<td>#5915 (materials)</td>
</tr>
<tr>
<td>#6938 (properties)</td>
</tr>
<tr>
<td>Slab dimension and geometry</td>
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<tr>
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<tr>
<td>Origin of LCS</td>
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<tr>
<td>XYZ directions of LCS</td>
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<tr>
<td></td>
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<tr>
<td>Shape representation</td>
</tr>
<tr>
<td>Extrusion:</td>
</tr>
<tr>
<td>Profile type</td>
</tr>
<tr>
<td>Position</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
</tr>
<tr>
<td>Slab properties</td>
</tr>
<tr>
<td>Construction type</td>
</tr>
<tr>
<td>Exterior / Interior</td>
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<tr>
<td>Slab material association</td>
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<tr>
<td>Layer name</td>
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<tr>
<td>Material layer and thickness</td>
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<tr>
<td>Corresponding code line number in reference IFC file</td>
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<tr>
<td>Verdict Criteria Summary for all Openings</td>
</tr>
<tr>
<td>------------------------------------------</td>
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<tr>
<td><strong>West wall</strong> door opening</td>
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<tr>
<td><strong>Opening dimen. and geometry</strong></td>
</tr>
<tr>
<td>Origin of LCS from the LCS of the wall</td>
</tr>
<tr>
<td>XYZ directions of LCS relative to XYZ</td>
</tr>
<tr>
<td>of LCS of the wall</td>
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<tr>
<td></td>
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<tr>
<td>Shape representation</td>
</tr>
<tr>
<td>Extrusion:</td>
</tr>
<tr>
<td>Profile type</td>
</tr>
<tr>
<td>Position from LCS</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Direction in LCS</td>
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<tr>
<td>Area</td>
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<tr>
<td>Rect. profile</td>
</tr>
<tr>
<td>Cartesian points / rectangle center &amp; X,Y</td>
</tr>
<tr>
<td>Dim</td>
</tr>
<tr>
<td>Code line number in reference IFC file</td>
</tr>
</tbody>
</table>

<p>| <strong>Opening dimen. and geometry</strong>          |                            |                                |                                |                                |
| Origin of LCS from the LCS of the wall  | (7.52,0.,0.)               | (5.2,0.,0.)                    | (3.52,0.,0.)                   | (1.5,0.,0.)                    |
| XYZ directions of LCS relative to XYZ    | X: (1.,0.,0.)              | X: (1.,0.,0.)                  | X: (1.,0.,0.)                  | X: (1.,0.,0.)                  |
| of LCS of the wall                      | Y: (0.,1.,0.)              | Y: (0.,1.,0.)                  | Y: (0.,1.,0.)                  | Y: (0.,1.,0.)                  |
|                                          | Z: (0.,0.,1.)              | Z: (0.,0.,1.)                  | Z: (0.,0.,1.)                  | Z: (0.,0.,1.)                  |
| Shape representation                    | Body: Swept Solid          | Body: Swept Solid              | Body: Swept Solid              | Body: Swept Solid              |
| Extrusion:                               |                            |                                |                                |                                |
| Profile type                            |                            |                                |                                |                                |
| Position from LCS                        |                            |                                |                                |                                |
| Depth                                   |                            |                                |                                |                                |
| Direction in LCS                         |                            |                                |                                |                                |
| Area                                    |                            |                                |                                |                                |
| Rect. profile                           |                            |                                |                                |                                |
| Cartesian points / rectangle center &amp; X,Y |                            |                                |                                |                                |
| Dim                                     |                            |                                |                                |                                |
| Code line number in reference IFC file   | #2728                      | #2880                          | #3014                         | #3148                          |</p>
<table>
<thead>
<tr>
<th>Door / Window dimension and geometry</th>
<th>West wall door</th>
<th>West wall window</th>
<th>Curtain wall window 1</th>
<th>Curtain wall window 2</th>
<th>Curtain wall window 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape representation</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
</tr>
<tr>
<td>Overall Height Overall Width</td>
<td>2 m 1.5 m</td>
<td>1.5 m 1.5 m</td>
<td>2.5 m 2 m</td>
<td>2.5 m 2 m</td>
<td>2.5 m 2 m</td>
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<tr>
<td>Door / Window properties</td>
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<tr>
<td>Construction type</td>
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<td>WIA2</td>
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<td>#4608 #4649</td>
<td>#5470 #5503</td>
<td>#1625 #1666</td>
<td>#2490 #2523</td>
<td>#2642 #2675</td>
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<table>
<thead>
<tr>
<th>Door / Window dimension and geometry</th>
<th>Curtain wall window 4</th>
<th>Curtain wall window 5</th>
<th>Curtain wall window 6</th>
<th>Curtain wall window 7</th>
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<tbody>
<tr>
<td>Shape representation</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
<td>Body: Brep/ Swept Solid/ Bounding Box</td>
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<tr>
<td>Overall Height Overall Width</td>
<td>2.5 m 2 m</td>
<td>2.5 m 2 m</td>
<td>2.5 m 2 m</td>
<td>2.5 m 2.04 m</td>
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<td>Construction type</td>
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<td>#2928 #2961</td>
<td>#3062 #3095</td>
<td>#3908 #3941</td>
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**Verdict Criteria Summary for all Spaces**

<table>
<thead>
<tr>
<th>Origin of LCS</th>
<th>XYZ Direction of LCS</th>
<th>Shape Repr.</th>
<th>Extrusion: Profile type, Position, Depth, Direction</th>
<th>Cartesian points of swept area (from origin of LCS)</th>
<th>Space Properties: Longname, Ext. / Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room (#6949 in Reference IFC file)</td>
<td>(0.48, 0.67, 0.)</td>
<td>X: (0.95, 0.32, 0.) Z: (0., 0., 1.)</td>
<td>Body: Swept Solid Area (0., 0., 0.) 3 m. (0., 0., 1.)</td>
<td>(0., 0.), (14.8, 0.), (16.2, 4.26), (2.9, 8.7)</td>
<td>“Room” Internal</td>
</tr>
</tbody>
</table>

Total Number of Spaces: 1

---

**Verdict Criteria Summary for all Space Boundaries relating to “Room”**

<table>
<thead>
<tr>
<th>Attributes: Name Physical/Virtual Ext. / Int.</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Space Boundary 1 (#7009 in Reference IFC)</td>
<td>“2nd Level” Physical External Room (#6949) South Wall (#359)</td>
<td>Origin: (0., 0., 0.) X: (1., 0., 0.) Y: (0., 0., 1.) Z: (0., -1., 0.) P1: (0., 0., 0.) P2: (14.8, 0., 0.) P3: (14.8, 3., 0.) P4: (0., 3., 0.)</td>
<td></td>
</tr>
<tr>
<td>Room Space Boundary 2 (#7053)</td>
<td>“2nd Level” Physical External Room (#6949) Base Slab (#5612)</td>
<td>Origin: (0., 0., 0.) X: (0.32, 0.95, 0.) Z: (0., 0., -1.) P1: (0., 0., 0.) P2: (9.17, 0., 0.) P3: (9.17, 14.04, 0.) P4: (4.68, 14.04, 0.)</td>
<td></td>
</tr>
<tr>
<td>Room Space Boundary 3 (#7101)</td>
<td>“2nd Level” Physical External Room (#6949) East Wall (#508)</td>
<td>Origin: (14.8, 0., 0.) X: (0.32, 0.95, 0.) Z: (0.95, -0.32, 0.) P1: (0., 0., 0.) P2: (4.49, 0., 0.) P3: (4.49, 3., 0.) P4: (0., 3., 0.)</td>
<td></td>
</tr>
<tr>
<td>Room Space Boundary 4 (#7141)</td>
<td>“2nd Level” Physical External Room (#6949) Roof Slab (#5942)</td>
<td>Origin: (0., 0., 3.) X: (1., 0., 0.) Y: (0., 1., 0.) Z: (0., 0., 1.) P1: (0., 0., 0.) P2: (14.8, 0., 0.) P3: (16.2, 4.26, 0.) P4: (2.9, 8.7, 0.)</td>
<td></td>
</tr>
<tr>
<td>Room Space Boundary 5 (#7189)</td>
<td>“2nd Level” Physical External Room (#6949) West Wall (#4037)</td>
<td>Origin: (2.9, 8.7, 0.) X: (-0.32, -0.95, 0.) Z: (-0.95, 0.32, 0.) P1: (0., 0., 0.) P2: (9.17, 0., 0.) P3: (9.17, 3., 0.) P4: (0., 3., 0.)</td>
<td></td>
</tr>
</tbody>
</table>

Continue to the next page
<table>
<thead>
<tr>
<th>Attributes: Name Physical/Virtual Ext. / Int.</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
</table>
| Room Space Boundary 6 (#7237) "2nd Level" Physical External | Room (#6949) | North Wall (#732) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (0.,0.,0.)  P2: (14.04,0.,0.)
P3: (14.04,3.,0.)  P4: (0.,3.,0.) |
| Room Space Boundary 7 (#7293 in Reference IFC) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 1 (#1625) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (14.04,0.,0.)  P2: (14.04,2.5,0.)
P3: (12.04,2.5,0.)  P4: (12.04,0.,0.) |
| Room Space Boundary 8 (#7349) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 2 (#2490) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (12.04,0.,0.)  P2: (12.04,2.5,0.)
P3: (10.04,2.5,0.)  P4: (10.04,0.,0.) |
| Room Space Boundary 9 (#7405) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 3 (#2642) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (10.04,0.,0.)  P2: (10.04,2.5,0.)
P3: (8.04,2.5,0.)  P4: (8.04,0.,0.) |
| Room Space Boundary 10 (#7461) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 4 (#2794) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (8.04,0.,0.)  P2: (8.04,2.5,0.)
P3: (6.04,2.5,0.)  P4: (6.04,0.,0.) |
| Room Space Boundary 11 (#7517) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 5 (#2928) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (6.04,0.,0.)  P2: (6.04,2.5,0.)
P3: (4.04,2.5,0.)  P4: (4.04,0.,0.) |
| Room Space Boundary 12 (#7573) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 6 (#3062) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (4.04,0.,0.)  P2: (4.04,2.5,0.)
P3: (2.04,2.5,0.)  P4: (2.04,0.,0.) |
| Room Space Boundary 13 (#7621) "2nd Level" Physical External | Room (#6949) | Curtain Wall Window 7 (#3908) | Origin: (16.2,4.26,0.)
X: (-0.95,0.32,0.)  Z: (0.32,0.95,0.)
P1: (2.04,0.,0.)  P2: (2.04,2.5,0.)
P3: (0.,2.5,0.)  P4: (0.,0.,0.) |
| Room Space Boundary 14 (#7677) "2nd Level" Physical External | Room (#6949) | West Wall Window (#5470) | Origin: (2.9,8.7,0.)
X: (-0.32,0.95,0.)  Z: (-0.95,0.32,0.)
P1: (3.83,0.5,0.)  P2: (2.33,0.5,0.)
P3: (2.33,2.,0.)  P4: (3.83,2.,0.) |

Continue to the next page
Verdict Criteria Summary for all Space Boundaries relating to “Room” (Continued)

<table>
<thead>
<tr>
<th>Attributes: Name</th>
<th>Physical/Virtual</th>
<th>Related Space</th>
<th>Related Building Element</th>
<th>Connection Geometry: Origin relative to LCS of Space</th>
<th>XYZ direction</th>
<th>Points defining the outer bound of the space boundary (from origin of LCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Space Boundary 15 (#7733)</td>
<td>“2nd Level” Physical External</td>
<td>Room (#6949)</td>
<td>West Wall Door (#4608)</td>
<td>Origin: (2.9,8.7,0.)</td>
<td>X: (-0.32,-0.95,0.)</td>
<td>Z: (-0.95,0.32,0.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P1: (5.58,0.,0.)</td>
<td>P2: (7.08,0.,0.)</td>
<td>P3: (7.08,2.,0.)</td>
</tr>
</tbody>
</table>

Count of Space Boundaries relating to Room = 15

Total Space Boundary Count = 15
7.6  BPEA Test Case 5

BPEA Test Case 5

Test Case Title: One Story Non-Rectangular Building with Curve Wall and Sloped Roof

Date of Last Edit: 10/25/2009

Summary Description: Test Case 5 consists of a one-story building with non-rectangular floor plan and has a semicircular curve wall and a sloped roof, as shown on Figure A6. The roof slab over the semicircle portion is flat. The building elements included in this test case are: 4 exterior walls (3 regular walls and 1 semicircular curve wall), 1 door, 2 windows, 1 base slab, and 2 roof slabs (one flat semicircular slab and one sloped rectangular slab).

Test Objectives:
- Check existence of all building elements
- Check existence of information required by BPEA IDM
- Check accuracy of dimensions of all building elements
- Check construction type and space type
- Check relevant property sets
- Check for accurate counts of spaces and space boundaries
- Check space boundary attributes, reference to space and building elements, and connection geometry.

Figure A6: One Story Non-rectangular Building with Curve Wall and Sloped Roof
Detailed Description:

**Project Name: BPEA Test Case 5**

Site Location: Washington D.C. (38°55’ Latitude, -77°0’ Longitude)
Site Elevation = 0 m

Building Name: TC5
Building Global Coordinates: 38°55’ Latitude, -77°0’ Longitude
Building Orientation: 30° from true north
Building Elevation from Sea Level = 0 m

Total Number of Building Stories = 1
Name of 1st Building Story: “1st Floor”
Elevation (relative to building datum) = 0 m

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)**</th>
<th>Description (ASHRAE)**</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exterior Wall* (semi-circular curve wall)</td>
<td>Radius: 10 m Height: 6 m Thickness: 0.48 m Origin: (10, 0, 0)</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>2. Exterior Wall (1st floor west)</td>
<td>Initial solid: Length: 20 m Height: 3 m Thickness: 0.48 m Origin: (0, 0, 0) Trimmed to Roof</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>3. Exterior Wall (1st floor south)</td>
<td>Initial solid: Length: 10 m Height: 6 m Thickness: 0.48 m Origin: (0, 0, 0) Trimmed to Roof</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
<tr>
<td>4. Exterior Wall (1st floor north)</td>
<td>Initial solid: Length: 10 m Height: 6 m Thickness: 0.48 m Origin: (0, 20, 0) Trimmed to Roof</td>
<td>WA34</td>
<td>12-in HW concrete R-19 insulation Gypsum board</td>
<td>B2010 Exterior Walls</td>
</tr>
</tbody>
</table>

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
</table>
| **5. Base Slab**       | Thickness: 0.256 m  
Origin: (0, 0, -0.256)  
X-axis (1, 0, 0)  
4 edges of the slab on the XY plane:  
1. line segment from (0,0) to (10,0)  
2. semicircle from (10,0) to (10,20) counterclockwise  
3. line segment from (10,20) to (0,20)  
4. line segment from (0,20) to (0,0) | FA5                        | 6-in HW concrete  
4-in Gravel | A1030  
Slab-on-grade |
| **6. Roof Slab**       | Thickness: 0.2 m  
Origin: (10, 0, 6)  
X-axis (0, 1, 0)  
2 edges of the slab on the XY plane:  
1. semicircle from (10,0) to (10,20) counterclockwise  
2. line segment from (10,20) to (10,0) | RA14                       | R-15 insulation  
4-in LW concrete | B1020  
Roof Construction |
| **7. Roof Slab**       | Thickness: 0.2 m  
Origin: (0, 20, 2.75)  
X-axis: (0, -1, 0)  
4 corner points of the slab:  
1. (0, 20, 2.75)  
2. (0, 0, 2.75)  
3. (10, 0, 6)  
4. (10, 20, 6) | RA14                       | R-15 insulation  
4-in LW concrete | B1020  
Roof Construction |
| **8. Exterior Door**   | Width: 1.5 m  
Height: 2.5 m  
Sill to base: 0 m  
Origin: (0, 9.25, 0) | D3                        | Double door         | D2030  
Exterior Doors |
| **9. Exterior Window** | Width: 1.5 m  
Height: 1.5 m  
Sill to base: 1 m  
Origin: (4.49, 0, 0) | WIA2                      | Double clear air window | B2020  
Exterior Windows |
<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Dimension and Origin in World Coordinate Sys.</th>
<th>Construction Type (ASHRAE)</th>
<th>Description (ASHRAE)</th>
<th>UniFormat Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Exterior Window (north wall)</td>
<td>Width: 1.5 m Height: 1.5 m Sill to base: 1 m Origin: (4.49, 20, 0)</td>
<td>WIA2</td>
<td>Double clear air window</td>
<td>B2020 Exterior Windows</td>
</tr>
<tr>
<td>11. Door Opening (west wall door)</td>
<td>Width: 1.5 m Height: 2.5 m Thickness: 0.48 m Origin: (0, 10, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Window Opening (south wall window)</td>
<td>Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (5.24, 0, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Window Opening (north wall window)</td>
<td>Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (5.24, 20, 0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Space (Room)</td>
<td>Initial solid: Thickness: 6 m Origin: (0.48, 0.48, 0.) X-axis (1, 0, 0) 4 edges of the slab on the XY plane: 1. line segment from (0,0) to (9.52,0) 2. semicircle from (9.52,0) to (9.52,19.04) counterclockwise 3. line segment from (9.52,19.04) to (0,19.04) 4. line segment from (0,19.04) to (0,0)</td>
<td></td>
<td>Trimmed to Roof</td>
<td></td>
</tr>
</tbody>
</table>

When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.
Screenshots of the building model in different IFC Viewers

IfcStoreyView
Solibri Model Checker

DDS-CAD Viewer
Testing Details for BPEA Test Case 5

Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

- Check that all building elements exist
  - 4 IfcWallStandardCase
  - 3 IfcSlab
  - 3 IfcOpeningElement
  - 2 IfcWindow
  - 1 IfcDoor
  - 1 IfcSpace

Project
- Project identifier is required
  - IfcProject.LongName = "BPEA Test Case 5"

Sample IFC Code¹:
#54= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 5',$,'BPEA Test Case 5',$,#51,#110,#390),#26);

- Correct unit assignment
  - Length measurement is in "Meter"

Sample IFC Code:
#14= IFCSIUNIT(*,.LENGTHUNIT.,$,METRE.);

Site
- Site location is specified
  - IfcSite.LongName = "Washington D.C."
- Global coordinates (latitude and longitude) are required
  - IfcSite.RefLatitude = (38.55,0)
  - IfcSite.RefLongitude = (-77,0,0)
- Site elevation (relative to sea level) is required
  - IfcSite.RefElevation = 0 (m.)
- Coordinate of site origin is correctly specified
  - Coordinate of site origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code²:
#64= IFCSITE(GUID,#13,'Default Site','Washington D.C.',$,#61,$,'Washington D.C.',.ELEMENT.,(38,55,0),(-77,0,0),0.,$,,$);
#61= IFCLOCALPLACEMENT($,#44);
#44= IFCCARTESIANPOINT(0.,0.,0.);

¹ One of the attributes on many IFC entities is a globally unique identifier known as a GUID. The GUID is a 22 character string such as '0bY5Zt0r7xHf8OxWOsY$t'. In the examples, the GUID is shortened to the string 'GUID' to save space and improve readability.

² In some of the sample code the order of the entity instances has been changed from the original file and indentation added to show the hierarchy and relationship between the various entities.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

**Building**
- **Building identifier is required**
  - IfcBuilding.LongName = “TC5”
- **Elevation (base elevation of ground level floor above sea level) is required**
  - IfcBuilding.ElevationOfRefHeight = 0 (m.)
- **Coordinate of building origin is correctly specified**
  - Coordinate of building origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
```plaintext
#77= IFCBUILDING(GUID,#13,'Default Building', 'TC5', $, #74, $, 'TC5', .ELEMENT., 0., $, $);
#74= IFCLOCALPLACEMENT(#61, #44);
  #61= IFCLOCALPLACEMENT($, #44);
  #44= IFCAXIS2PLACEMENT3D(#40, #36, #28);
  #40= IFCCARTESIANPOINT((0.,0.,0.));
```

- **Number of stories is specified**
  - Pset_BuildingCommon.NumberOfStoreys = 1

Sample IFC Code:
```plaintext
#9970= IFCPROPERTYSINGLEVALUE('NumberOfStoreys', $, IFCINTEGER(1), $);
```

- **Building orientation (the degrees of clockwise from true north) is required**
  - IfcGeometricRepresentationContext.TrueNorth = (-0.5,0.866)

Sample IFC Code:
```plaintext
#51= IFCGEOMETRICREPRESENTATIONCONTEXT('Plan', 'Design', 3, 1.0000000E-5, #44, #47);
  #47= IFCDIRECTION((-0.5,0.866));
```

**Building Stories**
- **Identification is required**
  - IfcBuildingStorey.Name = “1st Floor”
- **Elevation (relative to building datum) is required**
  - IfcBuildingStorey.Elevation = 0
- **Coordinate of building story origin is correctly specified**
  - Coordinate of building story origin is the origin of world coordinate system, (0.,0.,0.)

Sample IFC Code:
```plaintext
#93= IFCBUILDINGSTOREY(GUID, #13, '1st Floor', $, $, #90, $, $, .ELEMENT., 0.);
#90= IFCLOCALPLACEMENT(#74, #87);
  #74= IFCLOCALPLACEMENT(#61, #44);
    #61= IFCLOCALPLACEMENT($, #44);
    #44= IFCAXIS2PLACEMENT3D(#40, #36, #28);
    #40= IFCCARTESIANPOINT((0.,0.,0.));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

Walls (South Wall)

- Check wall dimension and geometry\(^1\)
  - Origin = (0.,10.,0.)
  - XYZ directions: X = (0.,-1.,0.), Y = (1.,0.,0.), Z = (0.,0.,1.)
  - IfcShapeRepresentation.RepresentationIdentifier = “Body”
  - IfcShapeRepresentation.RepresentationType = “Clipping”
  - The Boolean operator for clipping is “Difference”
  - The first operand (initial solid model) of clipping operation is an IfcSweptAreaSolid
    - IfcExtrudedAreaSolid.Depth = 6 (m.)
    - IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
    - IfcExtrudedAreaSolid.Position = (0.,0.,0.)
    - IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
    - 4 Cartesian points for the swept area = (0.,0.), (10.,0.), (10.,0.48), (0.48,0.48)
  - The second operand of clipping operation is an IfcHalfSpaceSolid
    - Base surface: Origin = (-0.808,0.,2.487), X = (0.,1.,0.), Z = (-0.309,0.,0.951)
    - Normal of IfcPlane: AgreementFlag = FALSE
    - Position of Polygonal Boundary: Origin = (0.,0.,0.), X = (1.,0.,0.), Z = (0.,0.,1.)
    - Polygonal Boundary: (0.,-0.24), (0.,0.72), (10.,0.72), (10.,-0.24)

Sample IFC Code:

```plaintext
#355 = IFCWALLSTANDARDCASE(GUID,#13,'WA34', 'B2010 Exterior Wall Construction',
$,#352,#476,$);

#352= IFCLOCALPLACEMENT(#90,#349);
#349= IFCAXIS2PLACEMENT3D(#40,#36,#28);
  #40= IFCCARTESIANPOINT((0.,0.,0.));
  #36= IFCDIRECTION((0.,0.,1.));
  #28= IFCDIRECTION((1.,0.,0.));
#476= IFCPRODUCTDEFINITIONSHAPE($,$,#393,#470);
  #470= IFCSHAPEREPRESENTATION(#390,'Body','Clipping',(#467));
  #467= IFCBOOLEANCLIPPINGRESULT('DIFFERENCE',#464,#437);
  #464= IFCEXTRUDEDAREASOLID(#460,#461,#36,6);

#460= IFCBOOLEANCLIPPINGRESULT('DIFFERENCE',#464,#437);

#456= IFCPRODUCTDEFINITIONSHAPE($,$,#393,#470);

#461= IFCAXIS2PLACEMENT3D(#40,#36,28);
#437= IFCPOLYGONALBOUNDEDHALFSPACE(#410, #44, #44, #433);
#410= IFCPLANE(#407);
  #407= IFCAXIS2PLACEMENT3D(#403,#399,#32);
  #403= IFCCARTESIANPOINT((-0.808,0.,2.487));
  #399= IFCDIRECTION((-0.309,0.,0.951));
  #32= IFCDIRECTION((0.,1.,0.));
#44= IFCAXIS2PLACEMENT3D(#40,#36,28);
#433= IFCPOLYGONALBOUNDEDHALFSPACE(#410, #44, #44, #433);
#413= IFCCARTESIANPOINT((0.,-0.24));
#417= IFCCARTESIANPOINT((0.,0.72));
#421= IFCCARTESIANPOINT((10.,0.72));
#425= IFCCARTESIANPOINT((10.,-0.24));
#429= IFCCARTESIANPOINT((0.,-0.24));
```

\(^1\) Due to the slanted the roof, the wall is created using solid element operation, in this case, the subtraction of two solids.
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

Walls (The Curve Wall)
- Check wall dimension and geometry
  - Origin = (10., 0., 0.)
  - XYZ directions: X = (1., 0., 0.), Y = (0., 1., 0.), Z = (0., 0., 1.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcExtrudedAreaSolid.Depth = 6 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0., 0., 1.)
  - IfcExtrudedAreaSolid.Position = (0., 0., 0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"

4 edges of the curve wall (coordinates are relative to the origin (10, 0, 0)):
- Circle of radius 10 m with center (0., 10.) going from (0., 0.) to (0., 20.) (see #2593)
- Line segment from (0., 20.) to (0., 19.52) (see #2612 in sample IFC code)
- Circle of radius 9.52 m with center (0., 10.) going from (0., 19.52) to (0., 0.48) (#2635)
- Line segment from (0., 0.48) to (0., 0.) (#2654)

Sample IFC Code:
```
#2506= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Wall Construction');
#2503, #2675, $);
#2503= IFCLOCALPLACEMENT(#90,#2500);
#2500= IFCAXIS2PLACEMENT3D(#2496,#36,#28);
#2496= IFCCARTESIANPOINT((10.,0.,0.));
#36= IFCDIRECTION((0.,0.,1.));
#28= IFCDIRECTION((1.,0.,0.));
#2675= IFCPRODUCTDEFINITIONSHPA($,$,#2552,#2669));
#2669= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',#2666);
#2666= IFCEXTRUDEDAREASOLID(#2662,#2663,#36,#6.);
#2662= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2658),.F.);
#2593= IFCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2588);
#2588= IFCTRIMMEDCURVE(#2585,(#2558,IFCPARAMETERVALUE(0.)),(#2562,IFCPARAMETERVALUE(180.)),.T.,.CARTESIAN.);
#2585= IFCCIRCLE(#2582,10.);
#2582= IFCAXIS2PLACEMENT2D(#2578,#2574);
#2578= IFCCARTESIANPOINT((0.,10.));
#2574= IFCDIRECTION((0.,-1.));
#2612= IFCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2607);
#2607= IFCTRIMMEDCURVE(#2604,(IFCPARAMETERVALUE(0.),#2562),(IFCPARAMETERVALUE(0.48),#2566),.T.,.CARTESIAN.);
#2604= IFCLINE(#2562,#2601);
#2635= IFCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2630);
#2630= IFCTRIMMEDCURVE(#2627,#2566,IFCPARAMETERVALUE(180.)),(#2570,IFCPARAMETERVALUE(0.)),.F.,.CARTESIAN.);
#2627= IFCCIRCLE(#2624,9.52);
#2624= IFCAXIS2PLACEMENT2D(#2620,#2616);
#2620= IFCCARTESIANPOINT((0.,10.));
#2616= IFCDIRECTION((0.,-1.));
#2654= IFCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2649);
#2649= IFCTRIMMEDCURVE(#2646,(IFCPARAMETERVALUE(0.),#2570),(IFCPARAMETERVALUE(0.48),#2558),.T.,.CARTESIAN.);
#2646= IFCLINE(#2570,#2643);
#2558= IFCCARTESIANPOINT((0.,0.));
#2562= IFCCARTESIANPOINT((0.,20.));
#2666= IFCCARTESIANPOINT((0.,19.52));
#2670= IFCCARTESIANPOINT((0.,0.48));
#2663= IFCAXIS2PLACEMENT3D(#40,#36,#28);
```
### Verdict Criteria

All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

### Walls (All Walls)

- **Check material association (All Walls)**
  - IfcMaterialLayerSet.LayerSetName = "WA34"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Outside surface resistance"
  - IfcMaterialLayer.LayerThickness = 0.3048 (m.)
  - IfcMaterial.Name = "12 in. heavyweight concrete"
  - IfcMaterialLayer.LayerThickness = 0.15875 (m.)
  - IfcMaterial.Name = "R-19 batt insulation"
  - IfcMaterialLayer.LayerThickness = 0.015875 (m.)
  - IfcMaterial.Name = "Gyp board"
  - IfcMaterialLayer.LayerThickness = 0.0001 (m.)
  - IfcMaterial.Name = "Inside surface resistance"

- **Check wall properties (All Walls)**
  - Pset_WallCommon.Reference = "WA34" OR IfcWall.Name = "WA34"
  - IfcWall.Description = "B2010 Exterior Wall"
  - Pset_WallCommon.IsExternal = IfcBoolean(T)

### Sample IFC Code:

```lisp
#480= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#355),#348);
#348= IFCMATERIALLAYERSETUSAGE(#346,.AXIS2.,.POSITIVE.,0.);
  #346= IFCMATERIALLAYERSET(#116,#258,#304,#339,#344),' Wall Type 34 WA34 Precast and CIP Concrete Walls');
    #116= IFCMATERIALLAYER(#103,0.0001,.U.);
    #103= IFCMATERIAL('F01 Outside Surface Resistance');
    #258= IFCMATERIALLAYER(#118,0.3048,.U.);
    #118= IFCMATERIAL(' M16 12 in. Heavyweight Concrete');
    #304= IFCMATERIALLAYER (#260,0.15875,.U.);
    #260= IFCMATERIAL(' I05 R-19, 6-1/4 in. Batt Insulation');
    #339= IFCMATERIALLAYER (#306,0.015875,.U.);
    #306= IFCMATERIAL(' G01 5/8 in. Gyp Board');
    #344= IFCMATERIALLAYER (#341,0.0001,.U.);
    #341= IFCMATERIAL(' F02 Inside Vertical Surface Resistance');
```
<table>
<thead>
<tr>
<th>Verdict Criteria Summary for Non-Curve Exterior Walls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall dimension and geometry</strong></td>
</tr>
<tr>
<td>Origin of LCS</td>
</tr>
<tr>
<td>North Wall: (0.,20.,0.)</td>
</tr>
<tr>
<td>South Wall: (0.,0.,0.)</td>
</tr>
<tr>
<td>West Wall: (0.,0.,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS</td>
</tr>
<tr>
<td>North Wall: X: (1.,0.,0.)</td>
</tr>
<tr>
<td>South Wall: Y: (0.,1.,0.)</td>
</tr>
<tr>
<td>West Wall: Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Shape representation</td>
</tr>
<tr>
<td>North Wall: Body: Clipping, Difference</td>
</tr>
<tr>
<td>South Wall: Body: Clipping, Difference</td>
</tr>
<tr>
<td>West Wall: Body: Clipping, Difference</td>
</tr>
<tr>
<td><strong>First Operand:</strong></td>
</tr>
<tr>
<td>Extrusion type</td>
</tr>
<tr>
<td>North Wall: Swept Area Solid</td>
</tr>
<tr>
<td>South Wall: Swept Area Solid</td>
</tr>
<tr>
<td>West Wall: Swept Area Solid</td>
</tr>
<tr>
<td>Profile Type</td>
</tr>
<tr>
<td>North Wall: Area</td>
</tr>
<tr>
<td>South Wall: Area</td>
</tr>
<tr>
<td>West Wall: Area</td>
</tr>
<tr>
<td>Position</td>
</tr>
<tr>
<td>North Wall: (0.,0.,0.)</td>
</tr>
<tr>
<td>South Wall: (0.,0.,1.)</td>
</tr>
<tr>
<td>West Wall: (0.,0.,1.)</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>North Wall: 6 m.</td>
</tr>
<tr>
<td>South Wall: 6 m.</td>
</tr>
<tr>
<td>West Wall: 3 m.</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>North Wall: (0.,0.,1.)</td>
</tr>
<tr>
<td>South Wall: (0.,0.,1.)</td>
</tr>
<tr>
<td>West Wall: (0.,0.,1.)</td>
</tr>
<tr>
<td>Cartesian points for the swept area (from origin of LCS)</td>
</tr>
<tr>
<td>North Wall: (0.,0.), (10.,0.), (10.,0.48), (0.48,0.48)</td>
</tr>
<tr>
<td>South Wall: (0.,0.), (10.,0.), (10.,0.48), (0.48,0.48)</td>
</tr>
<tr>
<td>West Wall: (0.,0.), (20.,0.), (19.52,-0.48), (0.48,-0.48)</td>
</tr>
<tr>
<td><strong>Second Operand:</strong></td>
</tr>
<tr>
<td><strong>Half Space Solid</strong></td>
</tr>
<tr>
<td>Solid Type</td>
</tr>
<tr>
<td>North Wall: Polygonal Bounded Half Space Solid</td>
</tr>
<tr>
<td>South Wall: Polygonal Bounded Half Space Solid</td>
</tr>
<tr>
<td>West Wall: Half Space Solid</td>
</tr>
<tr>
<td>Base Surface</td>
</tr>
<tr>
<td>North Wall: X: (0.,1.,0.)</td>
</tr>
<tr>
<td>South Wall: Z: (-0.309, 0.,0.951)</td>
</tr>
<tr>
<td>West Wall: X: (0.,0.951,-0.309)</td>
</tr>
<tr>
<td>Origin</td>
</tr>
<tr>
<td>North Wall: (-0.808,0.,2.487)</td>
</tr>
<tr>
<td>South Wall: X: (0.,1.,0.)</td>
</tr>
<tr>
<td>West Wall: Z: (-0.309, 0.,0.951)</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>North Wall: X: (0.,1.,0.)</td>
</tr>
<tr>
<td>South Wall: Z: (-0.309, 0.,0.951)</td>
</tr>
<tr>
<td>West Wall: X: (0.,0.951,-0.309)</td>
</tr>
<tr>
<td>Normal of Plane</td>
</tr>
<tr>
<td>North Wall: Agreement Flag = F</td>
</tr>
<tr>
<td>South Wall: Agreement Flag = F</td>
</tr>
<tr>
<td>West Wall: Agreement Flag = F</td>
</tr>
<tr>
<td>Polygonal Boundary Origin (in LCS)</td>
</tr>
<tr>
<td>North Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>South Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>West Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>North Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>South Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>West Wall: (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)</td>
</tr>
<tr>
<td>Boundary coordinate points (in LCS)</td>
</tr>
<tr>
<td>North Wall: (0.,-0.72), (0.,-0.24), (10.,0.24), (10.,-0.72)</td>
</tr>
<tr>
<td>South Wall: (0.,-0.24), (0.,-0.72), (10.,0.72), (10.,-0.24)</td>
</tr>
<tr>
<td>West Wall: (0.,-0.24), (0.,-0.72), (10.,0.72), (10.,-0.24)</td>
</tr>
<tr>
<td>Corresponding code line number in reference IFC file</td>
</tr>
<tr>
<td>North Wall: #2153 (dimension and geometry)</td>
</tr>
<tr>
<td>South Wall: #2271 (materials)</td>
</tr>
<tr>
<td>West Wall: #1408 (dimension and geometry)</td>
</tr>
<tr>
<td>#2493 (properties)</td>
</tr>
<tr>
<td>North Wall: #355 (dimension and geometry)</td>
</tr>
<tr>
<td>South Wall: #480 (materials)</td>
</tr>
<tr>
<td>West Wall: #1506 (materials)</td>
</tr>
<tr>
<td>#1384 (properties)</td>
</tr>
<tr>
<td>#2125 (properties)</td>
</tr>
</tbody>
</table>
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

**Floor Slab**
- **Check slab dimension and geometry**
  - Origin = (0.0.,0.0.256)
  - X, Y, Z directions:
    - X = (1.0.,0.0.), Y = (0.1.,0.0.), Z = (0.0.,1.0.)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcExtrudedAreaSolid.Depth = 0.256 (m.)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.0.,0.1.)
  - IfcExtrudedAreaSolid.Position = (0.0.,0.0.)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  - 4 edges of the floor slab (coordinates are relative to the origin (0, 0, -0.256)):
    - Line segment from (0.,0.) to (10.,0.)
    - Circle of radius 10 m with center (10.,10.) going from (10.,0.) to (10.,20.)
    - Line segment from (10.,20.) to (0.,20.)
    - Line segment from (0.,20.) to (0.,0.)

Sample IFC Code:
```plaintext
#2820= IFCSLAB(GUID,#13,'FA5','A1030 Slabs-On-Grade',$,#2963,#2952,$,FLOOR.);
#2963= IFCLOCALPLACEMENT(#90,#2960);
#2960= IFCAXIS2PLACEMENT3D(#2956,#36,#28);
#2956= IFCCARTESIANPOINT((0.,0.,-0.256));
#36= IFCDIRECTION((0.,0.,1.));
#28= IFCDIRECTION((1.,0.,0.));
#2952= IFCPRODUCTDEFINITIONSHAPE($,$,($2946));
#2946= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',($2943));
#2943= IFCEXTRUDEDAREASOLID(#2939,#2940,0.256);
#2939= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2935);
#2935= IFCCOMPOSITECURVE((#2870,#2893,#2912,#2931),.F.);
#2870= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2865);
#2865= IFCTRIMMEDCURVE(#2862,(IFCPARAMETERVALUE(0.),#2839),
    (IFCPARAMETERVALUE(10.),#2843),.T.,.CARTESIAN.);
#2862= IFCLINE(#2839,#2859);
#2893= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2888);
#2888= IFCTRIMMEDCURVE(#2885,(#2843,IFCPARAMETERVALUE(0.)),
    (#2847,IFCPARAMETERVALUE(180.)),.T.,.CARTESIAN.);
#2885= IFCCIRCLE(#2882,10.);
#2882= IFCAXIS2PLACEMENT2D(#2878,#2874);
#2878= IFCCARTESIANPOINT((10.0.,10.0.));
#2874= IFCDIRECTION((0.,-1.));
#2912= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2907);
#2907= IFCTRIMMEDCURVE(#2904,(IFCPARAMETERVALUE(0.),#2847),
    (IFCPARAMETERVALUE(10.),#2851),.T.,.CARTESIAN.);
#2904= IFCLINE(#2847,#2901);
#2931= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2926);
#2926= IFCTRIMMEDCURVE(#2923,(IFCPARAMETERVALUE(0.),#2851),
    (IFCPARAMETERVALUE(20.),#2839),.T.,.CARTESIAN.);
#2923= IFCLINE(#2839,#2920);
#2839= IFCCARTESIANPOINT((0.,0.));
#2843= IFCCARTESIANPOINT((10.,0.));
#2847= IFCCARTESIANPOINT((10.,20.));
#2851= IFCCARTESIANPOINT((0.,20.));
#2940= IFCAXIS2PLACEMENT3D(#40,#36,28);
#40= IFCCARTESIANPOINT((0.,0.,0.));
#36= IFCDIRECTION((0.,0.,1.));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

**Roof Slab (the flat semi-circle portion)**
- **Check slab dimension and geometry**
  - Origin = (10.0, 0.0, 6.0)
  - XYZ directions: X = (0.0, 1.0, 0.0), Y = (-1.0, 0.0, 0.0), Z = (0.0, 0.1)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "SweptSolid"
  - IfcExtrudedAreaSolid.Depth = 0.2 (m)
  - IfcExtrudedAreaSolid.ExtrudedDirection = (0.0, 0.1, 0.0)
  - IfcExtrudedAreaSolid.Position = (0.0, 0.0, 0.0)
  - IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"

2 edges of the roof slab (coordinates are relative to the origin (10, 0, 6)):
- Circle of radius 10 m with center (10., 0.) going from (0., 0.) to (0., 20.) (see #3272)
- Line segment from (0., 20.) to (0., 0.) (see #3291 in sample IFC code)

Sample IFC Code:
```
#326= IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,#3323,#3312, $
$.ROOF.);
#3323= IFCCOMPOSITECURVE((#329,#327),.F.);
  #327= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#326);
    #326= IFCTRIMMEDCURVE(#325,#324,#323,#322,#321);
      #325= IFCCIRCLE(#320,10.);
      #320= IFCCARTESIANPOINT((10.,0.,0.));
```
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Roof Slab (the sloped portion)
- Check slab dimension and geometry
  ___ Origin = (0.,20.,2.75)
  ___ XYZ directions: X = (0.,-1.,0.), Z = (-0.309,0.,0.951)
  ___ IfcShapeRepresentation.RepresentationIdentifier = "Body"
  ___ IfcShapeRepresentation.RepresentationType = "SweptSolid"
  ___ IfcShapeRepresentation.Items must be one IfcExtrudedAreaSolid
  ___ IfcExtrudedAreaSolid.Depth = 0.2 (m.)
  ___ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.309,0.951)
  ___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
  ___ IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
  ___ 4 Cartesian points for the swept area =
          (20.,0.), (20.,10.515), (0.,10.515), (0.,0.)

Sample IFC Code:
#3710= IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,#3785,#3766, $,.ROOF.);
  #3785= IFCLLOCALPLACEMENT(#90,#3782);
    #3782= IFCAxis2Placement3D(#3778,#3774,#3770);
    #3778= IFCCartesianPoint((0.,20.,2.75));
    #3774= IFCDirection((-0.309,0.,0.951));
    #3770= IFCDirection((0.,-1.,0.));
#3766= IFCPolyline((#3729,#3733,#3737,#3741,#3729));
    #3729= IFCCartesianPoint((20.,0.));
    #3733= IFCCartesianPoint((20.,10.515));
    #3737= IFCCartesianPoint((0.,10.515));
    #3741= IFCCartesianPoint((0.,0.));
#3745= IFCPolyline((#3729,#3733,#3737,#3741,#3729));
#3750= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',(#3757));
    #3757= IFCEXTRUDEDAREASOLID(#3749,#3750,#3753,0.2);
    #3749= IFCArbitraryClosedProfileDef('AREA.',$,#3745);
    #3745= IFCPolyline((#3729,#3733,#3737,#3741,#3729));
    #3729= IFCCartesianPoint((20.,0.));
    #3733= IFCCartesianPoint((20.,10.515));
    #3737= IFCCartesianPoint((0.,10.515));
    #3741= IFCCartesianPoint((0.,0.));
#40= IFCCartesianPoint((0.,0.,0.));
#36= IFCDirection((0.,0.,1.));
#28= IFCDirection((1.,0.,0.));
#3753= IFCDirection((0.,0.309,0.951));
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

<table>
<thead>
<tr>
<th>Slabs (Floor and Root Slabs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Check material association</td>
</tr>
<tr>
<td>- IfcMaterialLayerSet.LayerSetName = “FA5”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.1524 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “6in. heavyweight concrete”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.002 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “Vapor barrier”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.1016 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “4in. gravel”</td>
</tr>
</tbody>
</table>

Sample IFC Code:
```
#3199= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2820),#3198);
#3198= IFCMATERIALLAYERSETUSAGE(#3196,.AXIS3.,.NEGATIVE.,0.256);
   #3196= IFCMATERIALLAYERSET({#3109,#3142,#3194},' Floor Type 05_FA5 Slab On Grade');
      #3109= IFCMATERIALLAYER(#2969,0.1524,.U.);
         #2969= IFCMATERIAL(' M14 | 6 in. Heavyweight Concrete');
      #3142= IFCMATERIALLAYER(#3111,0.002,.U.);
         #3111= IFCMATERIAL(' F20 | Vapor Barrier');
      #3194= IFCMATERIALLAYER(#3144,0.1016,.U.);
         #3144= IFCMATERIAL(' M18 | 4 in. Gravel');
```

<table>
<thead>
<tr>
<th>IfcMaterialLayerSet.LayerSetName = “RA14”</th>
</tr>
</thead>
<tbody>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.0001 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “Outside surface resistance”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.0095 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “Build-up roofing”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.0127 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “1/2 in. fiberboard sheathing”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.0762 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “R-15 insulation board”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.1016 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “4 in. lightweight concrete”</td>
</tr>
<tr>
<td>- IfcMaterialLayer.LayerThickness = 0.0001 (m.)</td>
</tr>
<tr>
<td>- IfcMaterial.Name = “Inside surface resistance”</td>
</tr>
</tbody>
</table>

Sample IFC Code:
```
#3683= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#3226),#3682);
#3682= IFCMATERIALLAYERSETUSAGE(#3680,.AXIS3.,.NEGATIVE.,0.2);
   #3680= IFCMATERIALLAYERSET({#3329,#3375,#3485,#3531,#3673,#3678},' Roof Type 14 RA14 Concrete Roofs');
      #3329= IFCMATERIALLAYER(#103,0.0001,.U.);
         #103= IFCMATERIAL('F01 Outside Surface Resistance');
      #3375= IFCMATERIALLAYER(#3331,0.0095,.U.);
         #3331= IFCMATERIAL(' F13 | Built-Up Roofing');
      #3485= IFCMATERIALLAYER(#3377,0.0127,.U.);
         #3377= IFCMATERIAL(' G03 | 1/2 in. Fiberboard Sheathing');
      #3531= IFCMATERIALLAYER(#3487,0.0762,.U.);
         #3487= IFCMATERIAL(' I03 | R15. 3 in. insulation board');
      #3673= IFCMATERIALLAYER(#3533,0.1016,.U.);
         #3533= IFCMATERIAL(' M11 | 4 in. Lightweight Concrete');
      #3678= IFCMATERIALLAYER(#3675,0.0001,.U.);
         #3675= IFCMATERIAL('F03 Inside Horizontal Surface Resistance');
```
## Verdict Criteria Summary for all Openings, Doors, and Windows

<table>
<thead>
<tr>
<th>South wall window opening</th>
<th>West wall door opening</th>
<th>North wall window opening</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opening dimen. and geometry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of LCS from the LCS of the wall</td>
<td>(5.24,0.,1.)</td>
<td>(10.,-0.48,0.)</td>
</tr>
<tr>
<td>XYZ directions of LCS relative to XYZ of LCS of the wall</td>
<td>X: (1.,0.,0.)</td>
<td>X: (1.,0.,0.)</td>
</tr>
<tr>
<td>Y: (0.,1.,0.)</td>
<td>Y: (0.,1.,0.)</td>
<td>Y: (0.,1.,0.)</td>
</tr>
<tr>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
<td>Z: (0.,0.,1.)</td>
</tr>
<tr>
<td><strong>Shape representation</strong></td>
<td>Body: Swept Solid</td>
<td>Body: Swept Solid</td>
</tr>
<tr>
<td><strong>Extrusion:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profile type</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
</tr>
<tr>
<td>Position from LCS</td>
<td>0.48 m.</td>
<td>0.48 m.</td>
</tr>
<tr>
<td>Depth</td>
<td>(0.,1.,0.)</td>
<td>(0.,1.,0.)</td>
</tr>
<tr>
<td>Direction in LCS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectangle Profile</td>
<td>Area (0.,0.,0.)</td>
<td>Area (0.,0.,0.)</td>
</tr>
<tr>
<td>Center from LCS</td>
<td>(0.,0.75)</td>
<td>(0.,1.25)</td>
</tr>
<tr>
<td>XDim, YDim</td>
<td>1.5, 1.5</td>
<td>1.5, 2.5</td>
</tr>
<tr>
<td><strong>Code line number in reference IFC file</strong></td>
<td>#524</td>
<td>#1550</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South wall window</th>
<th>West wall door</th>
<th>North wall window</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Door / Window dimension and geometry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape representation</td>
<td>Body: Brep/Swept Solid/Bounding Box</td>
<td>Body: Brep/Swept Solid/Bounding Box</td>
</tr>
<tr>
<td>Overall Height</td>
<td>1.5 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Overall Width</td>
<td>1.5 m</td>
<td>1.5 m</td>
</tr>
<tr>
<td><strong>Door / Window properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction type</td>
<td>WIA2</td>
<td>D3</td>
</tr>
<tr>
<td>Exterior / Interior</td>
<td>Exterior</td>
<td>Exterior</td>
</tr>
<tr>
<td>Code line number in reference IFC file</td>
<td>#1294 #1335</td>
<td>#2007 #2048</td>
</tr>
</tbody>
</table>
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [Pass / Fail]

**Space**
- **Check space dimension and geometry**
  - Origin = (0.48,0.48,0.0)
  - XYZ directions: X = (1.0,0.0), Y = (0.0,1.0), Z = (0.0,0.0)
  - IfcShapeRepresentation.RepresentationIdentifier = "Body"
  - IfcShapeRepresentation.RepresentationType = "Clipping"
  - The Boolean operator for clipping is "Difference"
  - The first operand (initial solid model) of clipping operation is an IfcSweptAreaSolid
    - IfcSweptAreaSolid.Depth = 6 (m.)
    - IfcSweptAreaSolid.ExtrudedDirection = (0.0,0.0,1.0)
    - IfcSweptAreaSolid.Position = (0.0,0.0)
    - IfcSweptAreaSolid.SweptArea.ProfileType = "AREA"
    - 4 edges of the space (coordinates are relative to the origin (0.48, 0.48, 0.0)):
      - Line segment from (0.0,0.0) to (9.52,0.0) (see #3924 in sample IFC code)
      - Circle of radius 9.52 m with center (9.52,9.52) going from (9.52,0.0) to (9.52,19.04) (see #3947 in sample IFC code)
      - Line segment from (9.52,19.04) to (0.0,19.04) (see #3966)
      - Line segment from (0.0,19.04) to (0.0,0.0) (see #3985)
  - The second operand of clipping operation is an IfcHalfSpaceSolid
    - Base surface: Origin = (-0.854,0.0,2.628), X = (0.0,1.0), Z = (-0.309,0.0,0.951)
    - Normal of IfcPlane: AgreementFlag = FALSE
    - Position of Polygonal Boundary: Origin = (0.0,0.0), X = (1.0,0.0), Z = (0.0,1.0)
    - Polygonal Boundary: (-0.48,-0.48), (9.52,-0.48), (9.52,19.52), (-0.48,19.52)
- **Check space properties**
  - IfcSpace.Name OR IfcSpace.LongName = “Room”
  - IfcSpace.InteriorOrExteriorSpace = “INTERNAL”
Verdict Criteria: All the requirements below are fulfilled and all the specified numeric values are within a tolerance of 0.005 meter [ Pass / Fail ]

Space

Sample IFC Code:
```
#3988= IFCSPACE(GUID,#13,'\',S,S,#3985,#3974,'Room','ELEMENT',.INTERNAL.,$);
#4985= IFCLOCALPLACEMENT(#90,#3982);
#3982= IFCAXIS2PLACEMENT3D(#3978,#36,#28);
#3978= IFCAXIS2PLACEMENT3D((0.48,0.48,0.));
#36= IFCAXIS2PLACEMENT3D((0.,0.,1.));
#28= IFCAXIS2PLACEMENT3D((1.,0.,0.));
#3974= IFCPRODUCTDEFINITIONSHAPE(S,S,(#3968));
#3968= IFCBOOLEANCLIPPINGRESULT(.DIFFERENCE.,#3962,#3855);
#3962= IFCAXIS2PLACEMENT3D(#3958,#3959,#36,#6);(#3958= IFCCARTESIANPOINT((0.,0.));
#3959= IFCCARTESIANPOINT((9.52,0.));
#3966= IFCCARTESIANPOINT((9.52,19.04));
#3970= IFCCARTESIANPOINT((0.,19.04));
#3959= IFCAXIS2PLACEMENT3D(#40,#36,#28);
#40= IFCAXIS2PLACEMENT3D((0.,0.,0.));
```

- 150 -
| Room Space Boundary 1 (ID: 9804 in Reference IFC) | “2nd Level” Physical External | Room (#3988) | South Wall (#355) | Origin: (9.52,0.6) X: (-0.951,0.0,-0.309) Z: (0.0,-1.0) P1: (0.0,0.0) P2: (10.0,0.0) P3: (10.91,2.76,0.0) P4: (1.85,5.71,0.0) |
| Room Space Boundary 2 (ID: 9860) | “2nd Level” Physical External | Room (#3988) | South Wall Window (#1294) | Origin: (9.52,0.6) X: (-0.951,0.0,-0.309) Z: (0.0,-1.0) P1: (5.36,3.52,0.0) P2: (6.79,3.05,0.0) P3: (6.32,1.63,0.0) P4: (4.92,1.0) |
| Room Space Boundary 3 (ID: 9756) | “2nd Level” Physical External | Room (#3988) | West Wall (#1408) | Origin: (0.0,0.2,0.91) X: (0.1,0.0) Z: (-1.0,0.0) P1: (0.0,0.0) P2: (19.04,0.0) P3: (19.04,2.91,0.0) P4: (0.2,2.91,0.0) |
| Room Space Boundary 4 (ID: 9912) | “2nd Level” Physical External | Room (#3988) | West Wall Door (#2007) | Origin: (0.0,0.2,0.91) X: (0.1,0.0) Z: (-1.0,0.0) P1: (10.27,2.91,0.0) P2: (8.77,2.91,0.0) P3: (8.77,0.41,0.0) P4: (10.27,0.41,0.0) |
| Room Space Boundary 5 (ID: 5048) | “2nd Level” Physical External | Room (#3988) | North Wall (#2153) | Origin: (0.19.04,2.91) X: (0.951,0.309,0.0) Z: (0.1,0.0) P1: (0.0,0.0) P2: (8.15,5.71,0.0) P3: (8.15,5.71,0.0) P4: (-0.9,2.76,0.0) |
| Room Space Boundary 6 (ID: 9964) | “2nd Level” Physical External | Room (#3988) | North Wall Window (#2381) | Origin: (0.19.04,2.91) X: (0.951,0.309,0.0) Z: (0.1,0.0) P1: (4.65,3.51,0.0) P2: (5.12,2.09,0.0) P3: (3.69,1.63,0.0) P4: (3.22,2.09,0.0) |

Continue to the next page
| Room Space Boundary 7  
(#5004 in Reference IFC) | "2nd Level"  
Physical External | Room  
(#3988) | Floor Slab  
(#2820) | Origin: (0.,0.,0.)  
X: (-1.,0.,0.)  
Z: (0.,0.,-1.)  
(0.,0.,0.)  
(0.,19.04,0.)  
(-9.52,19.04,0.)  
(-9.52,0.,0.)  
+ points on the curvature |
| --- | --- | --- | --- | --- |
| Room Space Boundary 8  
(#4520) | "2nd Level"  
Physical External | Room  
(#3988) | Roof Slab, semicircle  
portion  
(#3226) | Origin: (9.52,19.04,6.)  
X: (0.,-1.,0.)  
Z: (0.,0.,1.)  
(0.,0.,0.)  
(19.04,0.,0.)  
+ points on the curvature |
| Room Space Boundary 9  
(#5100) | "2nd Level"  
Physical External | Room  
(#3988) | Roof Slab, Sloped  
portion  
(#3710) | Origin: (9.52,19.04,6.)  
X: (-0.951,0.,-0.309)  
Z: (-0.309,0.,0.951)  
P1: (0.,0.,.0)  
P2: (10.,0.,0.)  
P3: (10.,0.15,0.)  
P4: (0.,0.15,0.) |
| Room Space Boundary 10  
(#4056) | "2nd Level"  
Physical External | Room  
(#3988) | Curve Wall  
(#2506) | Origin: (9.52,19.04,6.)  
X: (0.,0.,1)  
Z: (0.,0.,1)  
P1: (0.,0.,0.)  
P2: (-6.,0.,0.)  
P3: (-6.,0.31,0.)  
P4: (0.,0.31,0.)  
TO  
Origin: (9.52,0.,6.)  
X: (0.,0.,-1)  
Z: (0.,0.,-1)  
P1: (0.,0.,0.)  
P2: (6.,0.,0.)  
P3: (6.,0.15,0.)  
P4: (0.,0.15,0.) |

Each space boundary has a dimension of 0.31 m by 6 m to cover the semicircular curve wall of radius 9.52 m (the inner edge of the wall), which leads to a total of 97 space boundaries for the curve wall. (There are 96 0.31 m by 6 m space boundaries and one 0.15 m by 6 m boundary)

Count of Space Boundaries relating to Room = 106

Total Space Boundary Count = 106