NISTIR 7687

Test Suite for Building Energy Analysis of Conceptual Spatial Layout

Kenway K. Chen
Robert R. Lipman
Mark E. Palmer

National Institute of
Standards and Technology
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Robert R. Lipman
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Building and Fire Research Laboratory

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U.S. Department of Commerce
Gary Locke, Secretary

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Patrick D. Gallagher, Director

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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.

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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: **F**irst **L**evel **S**pace **B**oundaries, 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: **S**econd **L**evel **S**pace **B**oundaries, 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.

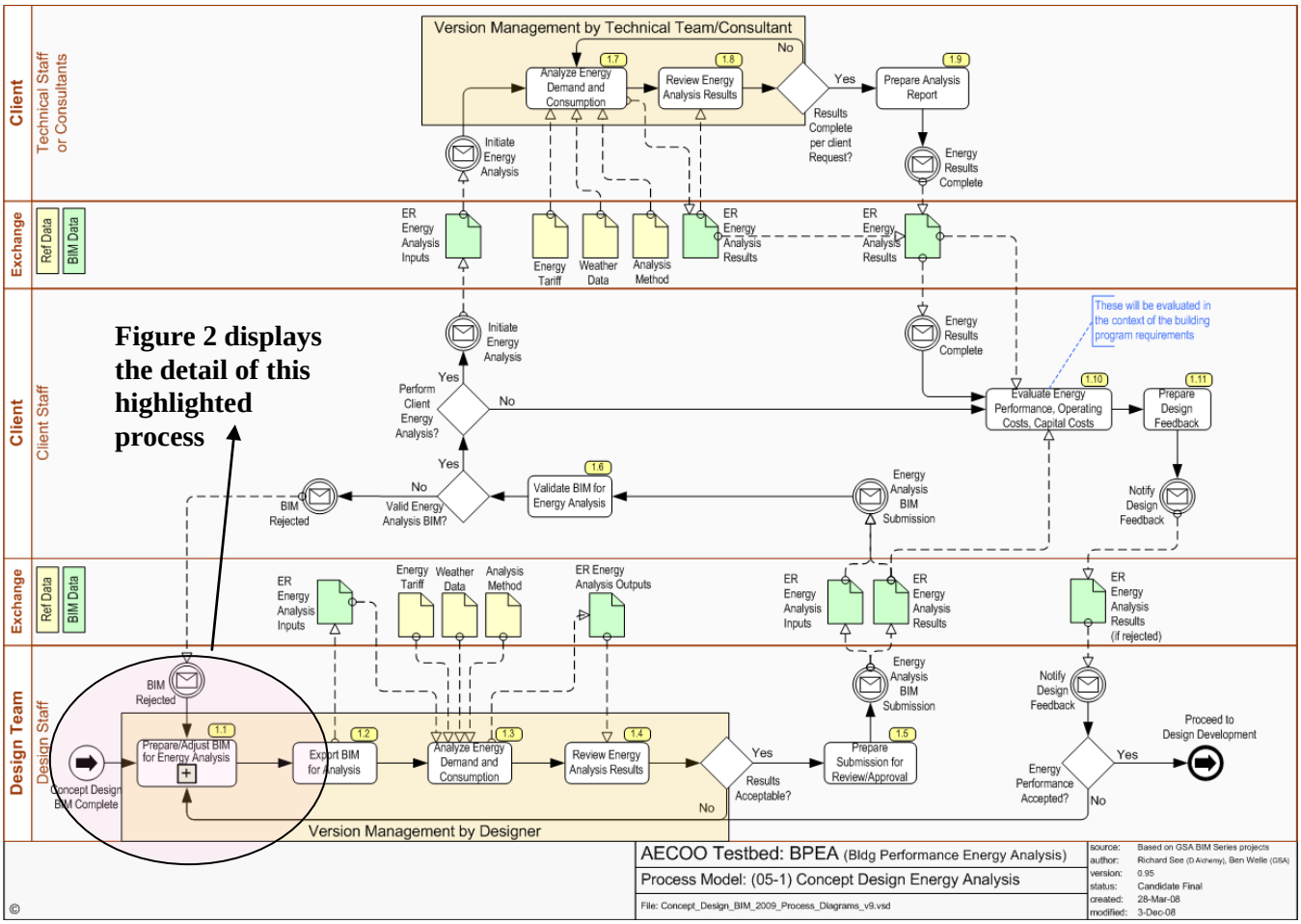


Figure 1. BPEA conceptual design process map
(Source: BPEA IDM [1])

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.

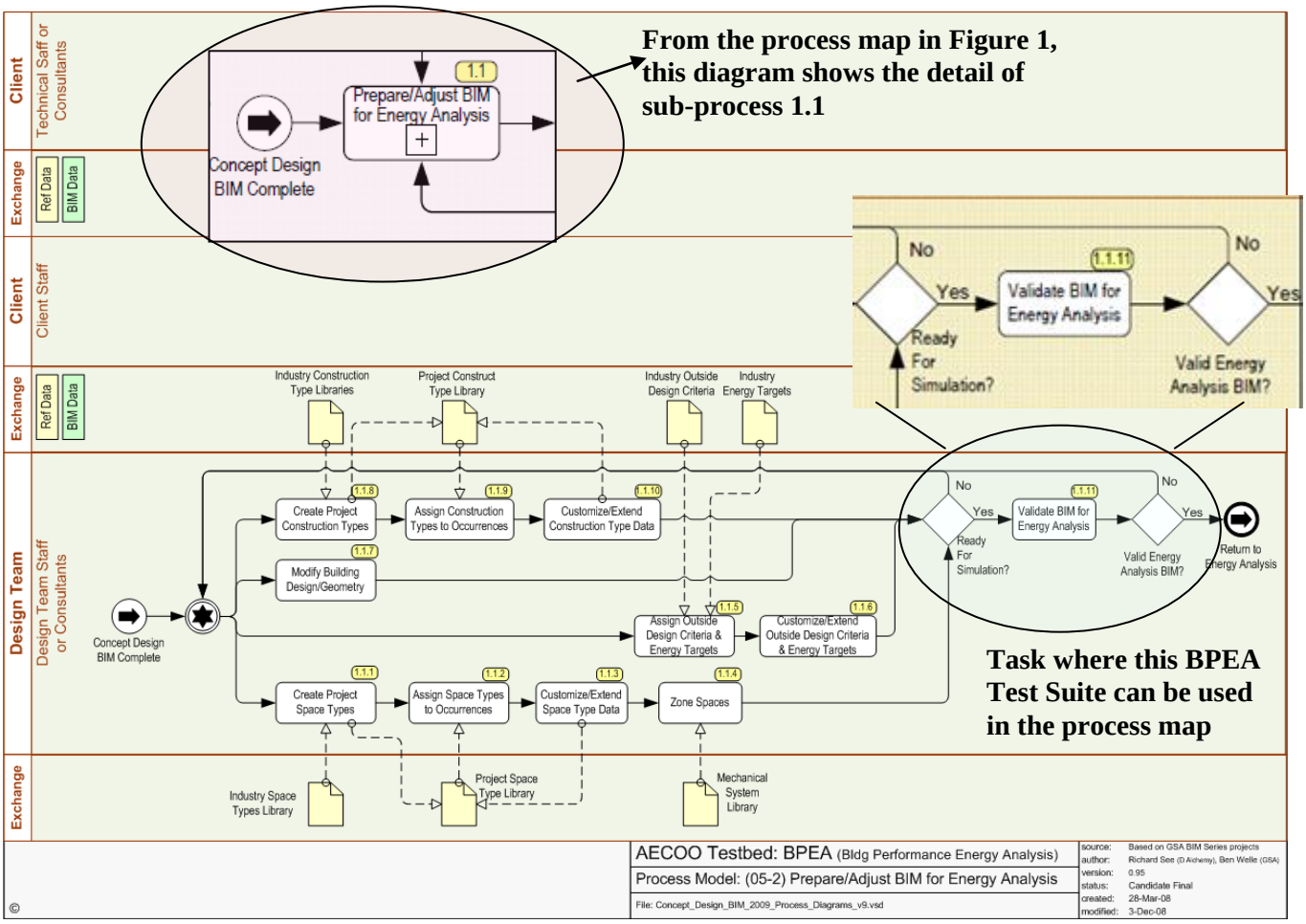


Figure 2. The details of sub-process 1.1: Preparing/Adjusting BIM for Energy Analysis (Source: BPEA IDM [1])

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.

Summary of Exchange Requirements in the BPEA IDM		
I. Conceptual Spatial Layout • Project information • Site information • Building information • Building stories • Spaces • Space boundaries • Building elements • Materials and material layers Focus of this BPEA Test Suite	II. Energy and Performance • Energy target • Space thermal comfort • Space ventilation • Building elements thermal information • Materials and material layers thermal information • Energy analysis zones	III. Analysis Inputs and Results • Site outside design criteria • Results for ventilation design • Results of peak load calculations • Rate of energy consumptions • Thermal comfort analysis • Energy tariff • Energy costs

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.

Type of Information	Information Needed	Required	Optional	Data Type	Units
Project	The following properties should be included:				
	o Identification	X		String	n/a
	o Owner/Client information		X	String	n/a
	o Model Author		X	String	n/a
Site	The following properties should be included:				
	o Address		X	String	n/a
	o Global Coordinates	X		(2) triples	deg/min/sec
	o Site Elevation (datum)(relative to sea level)	X		Real	m
	o 2D Geometry		X	IFC Geometry	varies
	o 3D Geometry		X	IFC Geometry	varies
Site Context	The following properties should be included for existing buildings adjacent to the subject building:				
	o Identification	X		String	n/a
	o 3D Geometry	X		IFC Geometry	m
Building	The following properties should be included (if not known then probable values should be used):				
	o Identification	X		String	n/a
	o Global Coordinates	X		(2) triples	deg/min/sec
	o Functional Classification (OmniClass)		X	String	n/a
	o Orientation (deviation of building grid from true north, clockwise)	X		Real	Angular Degrees
	o Elevation (relative to the site datum)	X		Real	m

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.

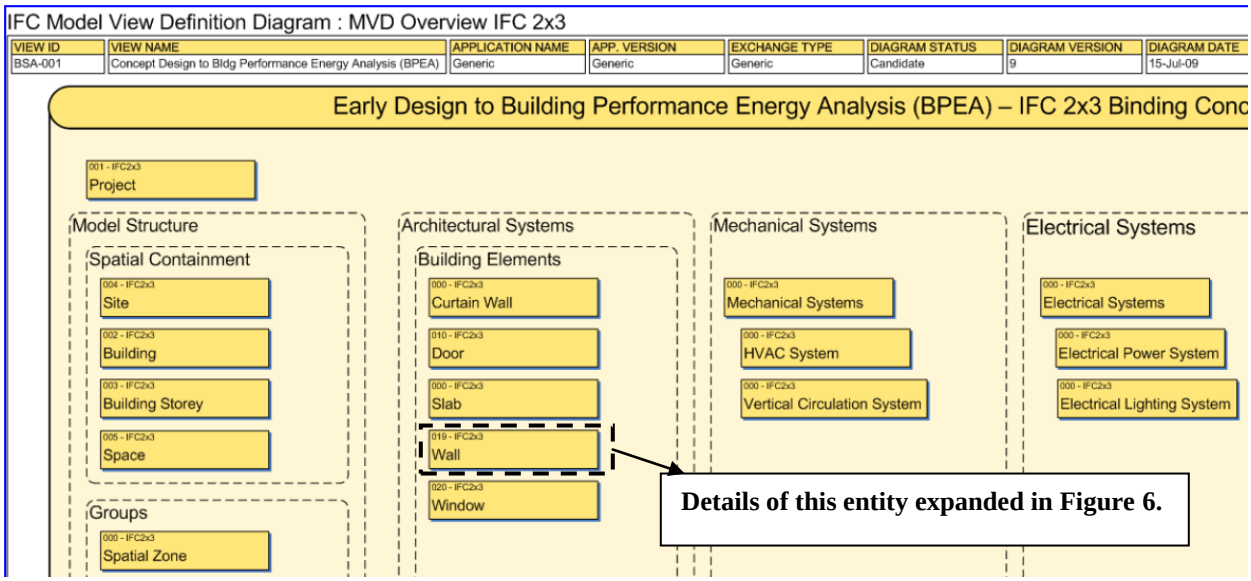


Figure 5. BPEA MVD: list of relevant entities (Source: BPEA MVD [3])

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

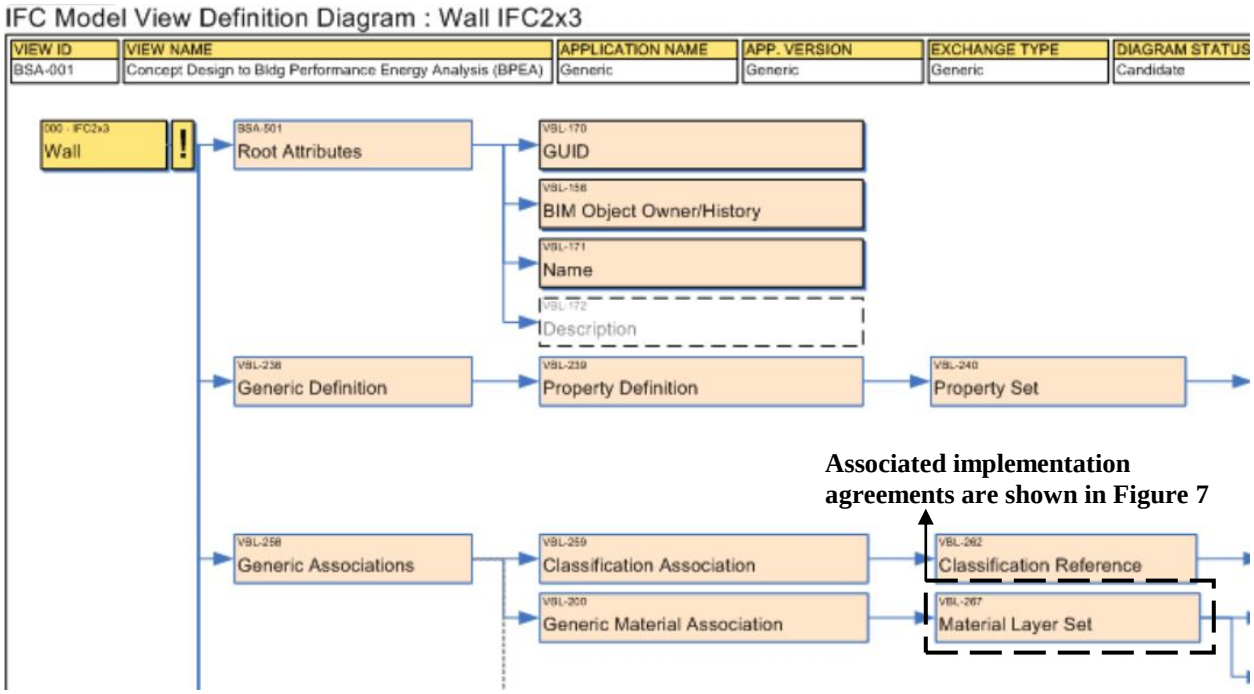


Figure 6. BPEA MVD: list of concepts associated with wall entity (Source: BPEA MVD [3])

IfcRelAssociatesMaterial

Attribute	Implementation agreements
GlobalId	Providing a GUID is mandatory, but the GUID is allowed to change.
OwnerHistory	Providing an OwnerHistory is mandatory, but it is allowed to use dummy data.
Name	Reserved.
Description	Reserved.
RelatedObjects	Must be IfcObjectDefinition or IfcPropertyDefinition.
RelatingMaterial	Must be IfcMaterialLayerSetUsage.

Figure 7. 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]:

Type of Information		Information Needed	Required	Optional	Data Type
Second Level Space Boundaries		The following properties should be included for 2nd level space boundaries:			
	(1)	o Space Boundary Type (1=internal, 2=external, 3=virtual)	X		Enum
	(2)	o Space Boundary Tag (2nd level, "face")	X		String
	(3)	o 3D planar geometry	X		IFC Geometry
	(4)	o Link to Space	X		Relationship
	(5)	o Link to Building Element	X		Relationship

2LSB MVD implementation agreements [3]:

Implementation agreements

IfcRelSpaceBoundary

Attribute		Implementation agreements
GlobalId		Must be given, but may change
OwnerHistory		Must be given, but may contain dummy data
Name	(2)	Must be '2nd Level' Not case sensitive
Description		Reserved
RelatingSpace	(4)	No agreements needed
RelatedBuildingElement	(5)	Must be subtype of IfcBuildingElement
ConnectionGeometry	(3)	Connection geometry must be provided NOTE: see concept VBL-457 Space Boundary Geometry
PhysicalOrVirtualBoundary	(1a)	Must be PHYSICAL
InternalOrExternalBoundary	(1b)	No agreements at this point

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]:

Type of Information	Information Needed	Required	Optional	Data Type
Building Elements *(General)*	The following properties should be included (if not known then probable values should be used):			
	o Building Element Type (wall (exterior/interior), curtain wall, roof, floor, ceiling, window, door, shading device)	X		Enum
(1)	o Construction type (e.g. wall type, door type, window type, shading device type, etc.) Window constructions from Window 6, opaque constructions from ASHRAE Fundamentals.	X		String
(2)	o Classification - UniFormat (reference to a classification -- see below)		X	String
(3)	o 3D Geometry	X		IFC Geometry
(4)	o Exterior or Interior Element (i.e. Is Exterior)	X		Boolean

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

IfcPropertySingleValue

Attribute	Implementation agreements
Name	Reference. ---This is used to exchange the wall construction type.
Description	Not used.
NominalValue (1)	This is a STRING that indicates IAI Standard 'construction type' property.
Unit	Not used for this property

IfcClassificationReference

Attribute	Implementation agreements
ItemReference	STRING = The Classification Assignment Number. Example: classification for "Exterior Walls" is: B2010 (2)
Name	STRING = The Classification Assignment Name. Example: the classification name for B2010 is: Exterior Walls.

IfcPropertySingleValue

Attribute	Implementation agreements
Name (4)	IsExternal. ---This is a Boolean flag which indicates whether the wall faces the outside air.
Description	Not used.
NominalValue	This is a BOOLEAN indicating if the building element is part of the building envelope or 'skin' That is: does this building element touch 'outside' space [TRUE] or not [FALSE]?
Unit	Not used for this property

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

```
#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.

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]:

```
#63= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 1',$,'BPEA Test
Case 1',$,(#60,#119,#407),#35);
```

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 geometry[1]**

___ Origin[2] = (0.,0.,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 = 120 (in.)
___ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
___ IfcExtrudedAreaSolid.SweptArea.ProfileType = "AREA"
___ 4 Cartesian points for the swept area[3] = (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)

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.

Numeric Values and Specifications Summary for 1st Floor Exterior Walls (Refer to West Wall Verdict Criteria Table for specific details)

	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,0.)	(15.,0.,0.)	(0.,0.,0.)	(0.,10.,0.)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid

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.

Building Plan				Roof			Floors					Interior Walls							Windows, Doors				Columns			Openings						Atria	Shading Devices	
Shape				Shape			Single	Two		Multiple		Single	Multiple	Shape		Floor-to-Floor		Other	Shape			Alignment	Free standing	Embedded		In Wall	In Slab	Shape						
Rectangular	Curved	Angular		Flat	Sloped	Curved		Same	Different	Same	Different			Straight	Curved	Same	Different		Rectangular	Curved	Angular			Interior wall	Exterior wall			Rectangle	Curved	Angular				

Figure 11. The columns of the BPEA Test Matrix identifying the characteristics of test scenarios

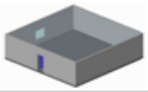
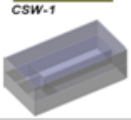
The matrix currently contains 28 test case scenarios that are created based on variations of building plan, roof and floor geometry, exterior and interior wall geometry, and inclusion of windows, doors, columns, curtain walls, and shading devices. Figure 12 provides a list of the 28 test case scenarios 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.

Test ID	LBNL ID	Description	Other
BPEA-1		Simple rectangular building with no windows, doors, floors, or interior walls	
BPEA-2		Same as [1], non-rectangular plan	
BPEA-3		Same as [1], sloped roof	
BPEA-4		Same as [1], curved roof	
BPEA-5	WW-1	Same as [1], one interior wall perpendicular to exterior	
BPEA-6		Same as [5], one interior wall at an angle to exterior	
BPEA-7	WW-2	Same as [5], wall with varying thickness	
BPEA-8		Same as [5], curved wall	
BPEA-9	Wi-1	Same as [1], typical window and door	
BPEA-10		Same as [9], non-rectangular window and door	
BPEA-11	Wi-2	Same as [9], glass curtain wall	
BPEA-12	CSW-1 - CSW-4	Same as [5], multiple walls	
BPEA-13		Same as [1], two floors	
BPEA-14		Same as [13], non-rectangular plan	
BPEA-15	CSW-1 - CSW-4	Same as [13], walls on first floor only	 
BPEA-16		Same as [13], same walls on both floors	
BPEA-17	SWW-1 - SWW-5	Same as [13], different walls on both floors	

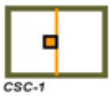
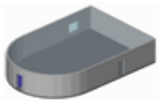
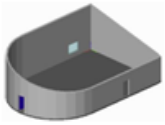
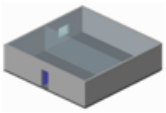
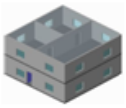
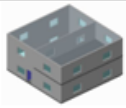
Test ID	LBNL ID	Description	Other
BPEA-18		Same as [17], with windows, doors	
BPEA-19	CSC-1 - CSC-3	Same as [18], with columns	
BPEA-20	CSO-1 - CSO-3	Same as [18], with openings	
BPEA-21		Room bounded by curve wall, with doors and windows	
BPEA-22		Room bounded by a curve wall and by clipped walls, with doors and windows	
BPEA-23		Room with a virtual element, with doors and windows	
BPEA-24		Two-story building, contains adjacent spaces separated by walls, slabs, and doors	
BPEA-25		Two-story building, contains an atrium and hence has space boundaries spanning over more than one storey	
BPEA-26		With a shading device that is detached from other building elements	
BPEA-27		With a shading device that is extruded from the interior slab	
BPEA-28		With a shading device that is free form	

Figure 12. The listing of the 28 test case scenarios in the BPEA Test Matrix

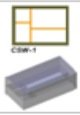
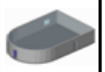
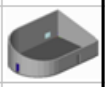
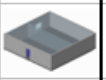
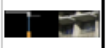
BPEA Test Matrix				Building Plan				Roof			Floors					Interior Walls							Windows, Doors				Columns			Openings						Atria	Shading Devices	
				Shape				Shape			Single	Two			Multiple	Single	Multiple	Shape			Floor-to-Floor	Other	Shape			Alignment	Freestanding		Embedded	In Wall	In Slab	Shape						
Test ID	LBNL ID	Description	Other	Rectangular	Curved	Angular		Flat	Sloped	Curved		Same	Different	Same	Different			Straight	Curved	Same	Different		Rectangular	Curved	Angular			Interior wall	Exterior wall			Rectangle	Curved	Angular				
BPEA-3		Same as [4], sloped roof		x					x		x																											
BPEA-4		Same as [4], curved roof		x						x	x																											
BPEA-5	WW-1	Same as [4], one interior wall perpendicular to exterior		x				x			x					x		x				Realtor virtual wall																
BPEA-6		Same as [5], one interior wall at an angle to exterior		x				x			x					x		x				Realtor virtual wall																
BPEA-7	WW-2	Same as [5], wall with varying thickness		x				x			x					x		x				Variable thickness																
BPEA-8		Same as [5], curved wall		x				x			x					x			x																				
BPEA-9	Wi-1	Same as [4], typical window and door		x				x			x												x			Typical												
BPEA-10		Same as [9], non-rectangular window and door		x				x			x													x	x														
BPEA-11	Wi-2	Same as [9], glass curtain wall		x				x			x												x			Glass curtain wall												
BPEA-12	CSW-1-CSW-4	Same as [5], multiple walls		x				x			x						x	x																				
BPEA-13		Same as [4], two floors		x				x				x																										
BPEA-14		Same as [13], non-rectangular plan			x	x		x				x																										
BPEA-15	CSW-1-CSW-4	Same as [13], walls on first floor only		x				x				x					x	x																				
BPEA-16		Same as [13], same walls on both floors		x				x				x					x	x		x																		
BPEA-17	SWW-1-SWW-5	Same as [13], different walls on both floors		x				x				x					x	x			x																	
BPEA-18		Same as [12], with windows, doors		x				x				x					x	x			x		x															
BPEA-19	CSC-1-CSC-3	Same as [18], with columns		x				x				x					x	x			x		x				x	x	x									
BPEA-20	CSO-1-CSO-3	Same as [18], with openings		x				x				x					x	x			x		x							x		x						
BPEA-21		Room bounded by curved wall, with doors and windows		x	x			x			x												x			Typical												
BPEA-22		Room bounded by a curved wall and by clipped walls, with doors and windows		x	x				x		x												x			Typical												
BPEA-23		Room with a virtual element, with doors and windows		x				x			x					x						Virtual Wall	x			Typical												
BPEA-24		Two-story building, contains adjacent spaces separated by walls, slabs, and doors		x				x				x					x				x		x			Typical												
BPEA-25		Two-story building, contains an atrium and lower has open boundaries spanning over more than one story		x				x				x					x				x		x			Typical											x		
BPEA-26		With a shading device that is detached from other building elements																																				Detached
BPEA-27		With a shading device that is extended from the interior slab																																				Extended from interior slab
BPEA-28		With a shading device that is free form																																				Free form

Figure 13. The BPEA Test Matrix
(Not meant to be legible, the purpose is to show a general overview of test case scenarios)

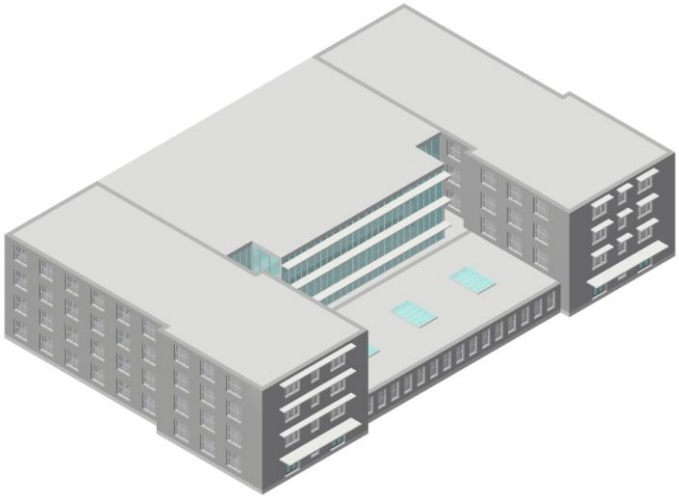


Figure 14. Simplified CAD model of the GSA Headquarters building

(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

	Test Case 1	Test Case 2	Test Case 3	Test Case 4	Test Case 5
Walls • Have openings, windows, doors	X		X	X	X
• Have interior walls		X	X		
• Have connection of two different types of walls		X	X	X	
• Non-orthogonal connection between walls				X	
• Have curvature					X
Slabs • Have only base-slab and roof (one-story)	X			X	X
• Have base-slab, floor(s), and roof (two or multi-stories)		X	X		
• Non-rectangular slabs					X
• Sloped slabs					X
• Shading device slabs				X	
Other Building Elements • Curtain walls				X	
• Columns			X		
• Virtual elements (i.e., air walls)		X			
• Have 2nd level space boundaries: Type 2a	X	X	X	X	X
• Have 2nd level space boundaries: Type 2b		X	X		

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 ruleId: 251667266
   ENTITY IFCAPPLICATION;
      UNIQUE
         UR1: 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):
            352323096    352323960    352324792    352325048
```

Express Engine

```
;;; ********** Run All Rules  ...

;;;;;;;; Checking Unique Constraints ;;;;;;;;

Instance #1032 fails uniqueness rule UR1 of entity type IFCAPPLICATION.
  It conflicts with Instance #5.
Instance #1032 fails uniqueness rule UR2 of entity type IFCAPPLICATION.
  It conflicts with Instance #5.
```

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.UR1' evaluates to FALSE
Instance with equal attribute value '['ArchiCAD']': #1032
Instance: OID: #5
Type: IfcApplication
References:
in file c:\progra~1\pdtec\ecco-v~1.1\util\check_lib.exp at line 2763
```

Figure 15. Error messages from IFC syntax checkers

```
=======================================================
Time to Run:                 2 seconds
=======================================================
Schema:                      IFC2X3
Schema File:                 C:\Documents and Settings\li
Entity Types in Schema:      653

Part 21 File:                BPEA Test Case 1 metric.ifc
Entities Read:               1,164
Instantiated Entity Types:   138  (21%)

Total Errors:                          15
    Errors at entity creation:          0
    EXPRESS program exceptions:         0
    Attribute value type errors:        9
    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

Reference IFC files testing results			
Error descriptions	EDM Supervisor	IfcObject Counter	Express Engine
IfcApplication Unique Rule 1 (UR1) - Application Identifier is unique Violation: identifier = “ArchiCAD” is duplicated (Cause: ArchiCAD creating multiple instances of same IfcApplication)	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes
IfcApplication UR2 - Application full name and version is unique Violation: “ArchiCAD 12.0” is duplicated (Cause: ArchiCAD creating multiple instances of same IfcApplication)	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes	Test Cases #1: No #2: No #3: No #4: No #5: No	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes
IfcNormalisedRatioMeasure WR1 - 0.0 <= value <= 1.0 Violation: none (Cause: the value are within range but are identified as out of range, appears to be a programming mistake in EDM supervisor)	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes	Test Cases #1: No #2: No #3: No #4: No #5: No	Test Cases #1: No #2: No #3: No #4: No #5: No
IfcBoolean (T) is not a valid type (Cause: data type is valid, appears to be a programming mistake in Express Engine)	Test Cases #1: No #2: No #3: No #4: No #5: No	Test Cases #1: No #2: No #3: No #4: No #5: No	Test Cases #1: Yes #2: Yes #3: Yes #4: Yes #5: Yes

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

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2. Bazjanac, V. "Definition of External Building Shading Elements", LBNL, 2008.

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

4. Gischner, B., "Ship Arrangements Test Plan and Test Cases", NSRP ASE ISE-4, 2005.

5. Hafele, K. H. and Liebich, T., "IFC Implementation Agreement: Space Boundary – Overview on the Common Agreements for Implementing Space Boundaries", buildingSMART alliance, 2009.

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

7. Kline, S. and Palmer, M., "Application Protocol 227 Validation Report", NIST, 1996.
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8. Liebich, T. and Weise, M., "Space Boundaries: Implementation Guide for Definition of Space Boundaries for Energy Analysis, *Draft 1.1*", AEC3 Ltd., 2007.

9. OGC GSA ASHRAE CEC Construction and Space Table

10. Weise, M., Liebich, T., et al. "Implementation Guide: Space Boundaries for Thermal Analysis", GSA, 2009.

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

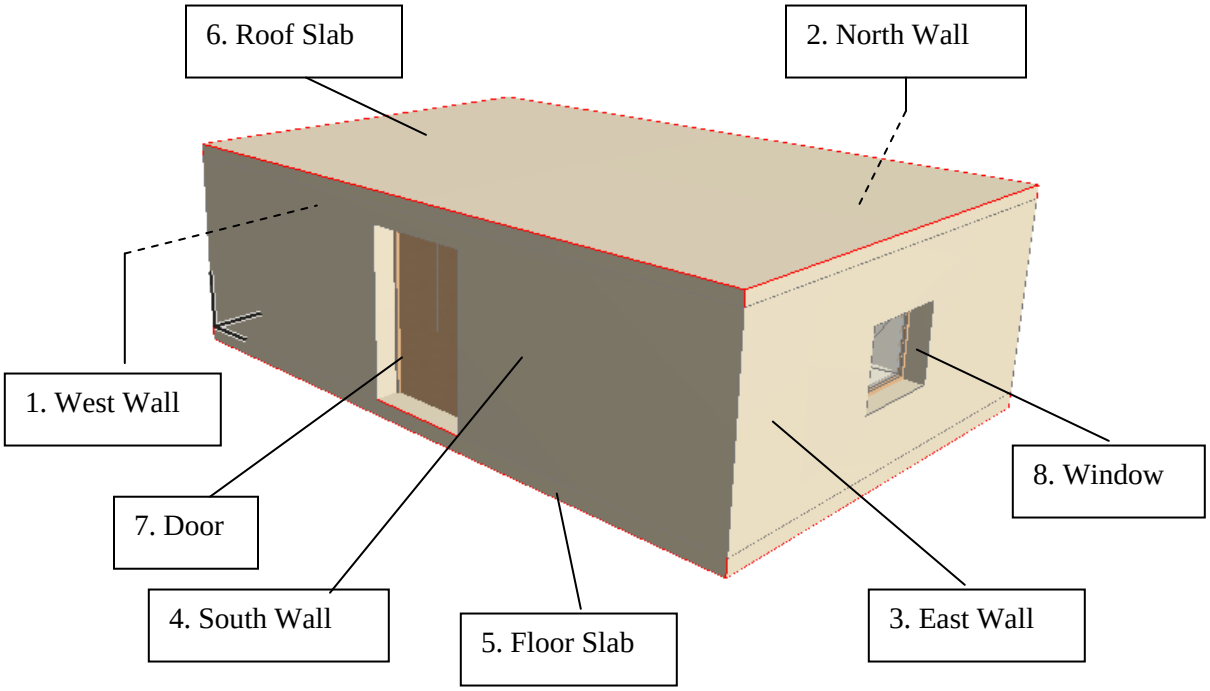


Figure A1: Simple one-story building

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)

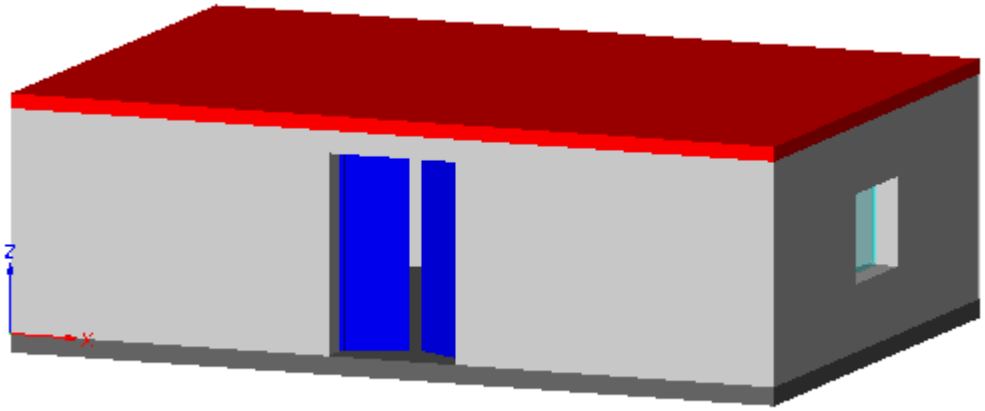
Total Number of Building Stories = 1
Name of 1st Building Story: "1st Floor"
Elevation (relative to building datum) = 0 m

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

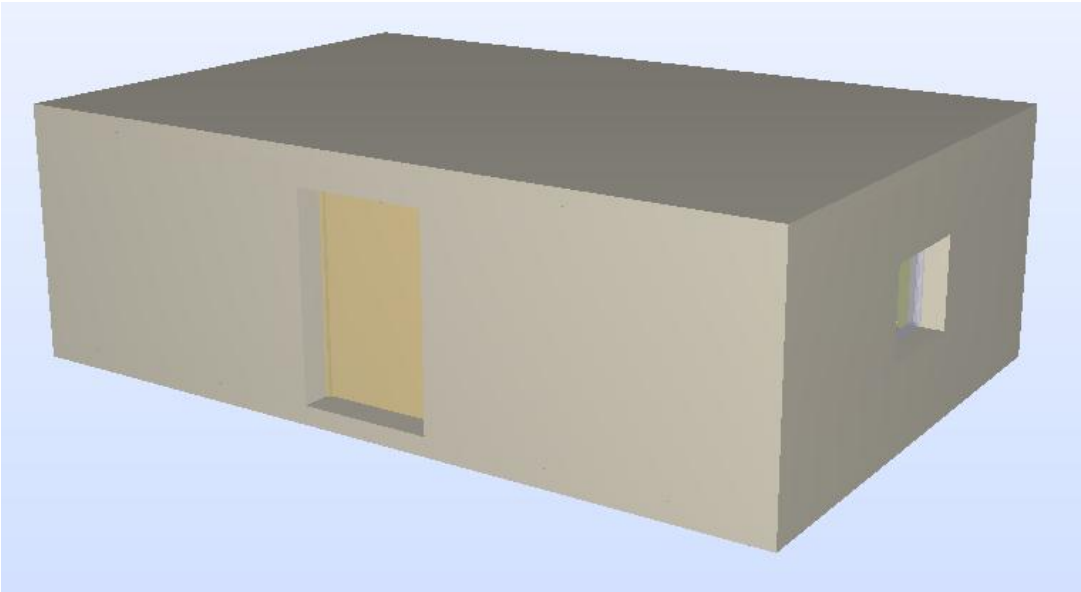
* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

Building Elements	Dimension	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
7. Door	W: 1.8288 m (6 ft) H: 2.7432 m (9 ft) Placement: center Sill to base: 0 m	D2	Steel slab (Foam insulated with metal edge in steel frame) Double door	D2030 External Doors
8. Window	W: 1.524 m (5 ft) H: 1.2192 m (4 ft) Placement: center Sill to base: 0.9144 m (3 ft)	WIA2	Double clear air window	B2020 Exterior Windows
9. Door Opening	W: 1.8288 m (6 ft) H: 2.7432 m (9 ft) Thickness: 0.4794 m (18 in)			
10. Window Opening	W: 1.524 m (5 ft) H: 1.2192 m (4 ft) Thickness: 0.4794 m (18 in)			
11. Space (Room)	Length: 10.014 m (32 ft and 10 in) Width: 6.3564 m (20 ft and 10 in) Height: 3.048 m(10 ft)			

Screenshots of the building model in different IFC Viewers



IfcStoreyView



Solibri Model Checker

DDS-CAD Viewer

Testing Details for BPEA Test Case 1

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 IfcOpeningElement
___ 1 IfcWindow
___ 2 IfcSlab
___ 1 IfcDoor
___ 1 IfcSpace

Project

- **Project identifier is required**

___ IfcProject.LongName = “BPEA Test Case 1”

Sample IFC Code[1]:

```
#63= IFCPROJECT(GUID,#13,'Default Project','BPEA Test Case 1',$,'BPEA Test
Case 1',$,(#60,#119,#407),#35);
```

- **Correct unit assignment**

___ Length measurement is in “Inch”

Sample IFC Code:

```
#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]:

```
#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 '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 0.0625 (1/16) inch [Pass / Fail]

Building[1]

- **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**[2]

___ 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);
      #96= 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[2] = (0.,0.,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 = 120 (in.)
___ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
___ IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
___ 4 Cartesian points for the swept area[3] = (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[4]:

```
#2228= 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($,$,(#2259,#2292));
      #2292= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2289));
         #2289= IFCEXTRUDEDAREASOLID(#2285,#2286,#45,120.);
            #2285= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2281);
               #2281= IFCPOLYLINE((#2265,#2269,#2273,#2277,#2265));
                  #2265= IFCCARTESIANPOINT((18.875,-18.875));
                  #2269= IFCCARTESIANPOINT((269.125,-18.875));
                  #2273= IFCCARTESIANPOINT((288.,0.));
                  #2277= IFCCARTESIANPOINT((0.,0.));
            #2286= IFCAXIS2PLACEMENT3D(#49,#45,#37);
               #49= IFCCARTESIANPOINT((0.,0.,0.));
               #45= IFCDIRECTION((0.,0.,1.));
               #37= IFCDIRECTION((1.,0.,0.));

#2394= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2228),#2368);
   #2368= IFCPROPERTYSET(GUID,#2372,'Pset_WallCommon',$,(#2374,#2378));
      #2374= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #2378= IFCPROPERTYSINGLEVALUE('IsExternal',$,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 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[1]
___ Pset_WallCommon.Reference = “WA34” OR IfcWall.Name[2] = “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= IFCPRODUCTDEFINITIONSHAPE($,$,(#2125,#2158));
      #2158= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2155));
         #2155= IFCEXTRUDEDAREASOLID(#2151,#2152,#45,120.);
            #2151= IFCARBITRARYCLOSEDPROFILEDEF(.AREA., $, #2147);
               #2147= IFCPOLYLINE((#2131,#2135,#2139,#2143,#2131));
                  #2131= IFCCARTESIANPOINT((18.875,-18.875));
                  #2135= IFCCARTESIANPOINT((413.125,-18.875));
                  #2139= IFCCARTESIANPOINT((432.,0.));
                  #2143= IFCCARTESIANPOINT((0.,0.));
            #2152= IFCAXIS2PLACEMENT3D(#49,#45,#37);
               #49= IFCCARTESIANPOINT((0.,0.,0.));
               #45= IFCDIRECTION((0.,0.,1.));
               #37= IFCDIRECTION((1.,0.,0.));

#2219= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2094),#2206);
   #2206= IFCPROPERTYSET(GUID,#13,'Pset_WallCommon',$,(#2211,#2215));
      #2211= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'), $);
      #2215= IFCPROPERTYSINGLEVALUE('IsExternal',$,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 0.0625 (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= IFCPRODUCTDEFINITIONSHAPE($,$,(#1107,#1140));
      #1140= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#1137));
         #1137= IFCEXTRUDEDAREASOLID(#1133,#1134,#45,120.);
            #1133= IFCARBITRARYCLOSEDPROFILEDEF(.AREA., $, #1129);
               #1129= IFCPOLYLINE((#1113,#1117,#1121,#1125,#1113));
                  #1113= IFCCARTESIANPOINT((18.875,-18.875));
                  #1117= IFCCARTESIANPOINT((269.125,-18.875));
                  #1121= IFCCARTESIANPOINT((288.,0.));
                  #1125= IFCCARTESIANPOINT((0.,0.));
            #1134= IFCAXIS2PLACEMENT3D(#49,#45,#37);
               #49= IFCCARTESIANPOINT((0.,0.,0.));
               #45= IFCDIRECTION((0.,0.,1.));
               #37= IFCDIRECTION((1.,0.,0.));

#2074= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#1076),#2048);
   #2048= IFCPROPERTYSET(GUID,#2052,'Pset_WallCommon',$,(#2054,#2058));
      #2054= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #2058= IFCPROPERTYSINGLEVALUE('IsExternal',$,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]

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.)
___ 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:

```
#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= IFCARBITRARYCLOSEDPROFILEDEF(.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',$,(#1032,#1036));
      #1032= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #1036= IFCPROPERTYSINGLEVALUE('IsExternal',$,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]

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,$,$,(#2094),#2083);
   #2083= IFCMATERIALLAYERSETUSAGE(#355,.AXIS2.,.POSITIVE.,-18.875);

#2302= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2228),#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');
         #313= IFCMATERIALLAYER(#269, 6.25, .U.);
            #269= IFCMATERIAL(' I05 | R-19, 6-1/4 in. Batt Insulation');
         #348= IFCMATERIALLAYER(#315, 0.625, .U.);
            #315= IFCMATERIAL(' G01 | 5/8 in. Gyp Board');
         #353= 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:

```
#2411= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,#2474,#2463,$,.BASESLAB.);
   #2474= IFCLOCALPLACEMENT(#99,#2471);
      #2471= IFCAXIS2PLACEMENT3D(#2467,#45,#41);
         #2467= IFCCARTESIANPOINT((0.,0.,-10.078));
         #45= IFCDIRECTION((0.,0.,1.));
         #41= IFCDIRECTION((0.,1.,0.));
   #2463= IFCPRODUCTDEFINITIONSHAPE($,$,(#2457));
      #2457= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#2454));
         #2454= IFCEXTRUDEDAREASOLID(#2450,#2451,#45,10.078);
            #2450= IFCARBITRARYCLOSEDPROFILEDEF(.AREA., $,#2446);
               #2446= IFCPOLYLINE((#2430,#2434,#2438,#2442,#2430));
                  #2430= IFCCARTESIANPOINT((0.,0.));
                  #2434= 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.));

#2733= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2411),#2720);
   #2720= IFCPROPERTYSET(GUID,#13,'Pset_SlabCommon',$,(#2725,#2729));
      #2725= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('FA5'), $);
      #2729= IFCPROPERTYSINGLEVALUE('IsExternal',$,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]

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:

```
#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= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2772);
               #2772= IFCPOLYLINE((#2756,#2760,#2764,#2768,#2756));
                  #2756= IFCCARTESIANPOINT((0.,0.));
                  #2760= IFCCARTESIANPOINT((288.,0.));
                  #2764= IFCCARTESIANPOINT((288.,-432.));
                  #2768= IFCCARTESIANPOINT((0.,-432.));
            #2777= IFCAXIS2PLACEMENT3D(#49,#45,#37);
               #49= IFCCARTESIANPOINT((0.,0.,0.));
               #45= IFCDIRECTION((0.,0.,1.));
               #37= IFCDIRECTION((1.,0.,0.));

#3183= IFCRELDEFINESBYPROPERTIES(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:

```
#2710= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2411),#2709);
   #2709= IFCMATERIALLAYERSETUSAGE(#2707,.AXIS3.,.NEGATIVE.,10.);
      #2707= IFCMATERIALLAYERSET((#2620,#2653,#2705),'Floor Type 05_FA5 Slab
      On Grade');
         #2620= IFCMATERIALLAYER(#2480,6.,.U.);
            #2480= IFCMATERIAL(' M14 | 6 in. Heavyweight Concrete');
         #2653= IFCMATERIALLAYER(#2622,0.078,.U.);
            #2622= IFCMATERIAL(' F20 | Vapor Barrier');
         #2705= IFCMATERIALLAYER(#2655,4.,.U.);
            #2655= IFCMATERIAL(' M18 | 4 in. Gravel');
```

___ 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”

Sample IFC Code:

```
#3160= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#2737),#3159);
   #3159= IFCMATERIALLAYERSETUSAGE(#3157,.AXIS3.,.NEGATIVE.,7.88);
      #3157= IFCMATERIALLAYERSET((#2806,#2852,#2962,#3008,#3150,#3155),'Roof
      Type 14_RA14 Concrete Roofs');
         #2806= IFCMATERIALLAYER(#112,0.004,.U.);
            #112= IFCMATERIAL('F01 Outside Surface Resistance');
         #2852= IFCMATERIALLAYER(#2808,0.375,.U.);
            #2808= IFCMATERIAL(' F13 | Built-Up Roofing');
         #2962= IFCMATERIALLAYER(#2854,0.5,.U.);
            #2854= IFCMATERIAL(' G03 | 1/2 in. Fiberboard Sheathing');
         #3008= IFCMATERIALLAYER(#2964,3.,.U.);
            #2964= IFCMATERIAL(' I03 | R15, 3 in. insulation board');
         #3150= IFCMATERIALLAYER(#3010,4.,.U.);
            #3010= IFCMATERIAL(' M11 | 4 in. Lightweight Concrete');
         #3155= IFCMATERIALLAYER(#3152,0.004,.U.);
            #3152= IFCMATERIAL('F03 Inside Horizontal 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[1]
___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
___ IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
___ 4 Cartesian points for the swept area[2] = (36.,0.), (36.,108.), (-36.,108.), (-36.,0.)
OR if Rectangle Profile is used to define the area[3]
Center point = (0.,54.), XDim = 72, YDim = 108

Sample IFC Code:

```
#497= IFCOPENINGELEMENT(GUID,#13,$,$,'Opening',#494,#483,'');
   #494= IFCLOCALPLACEMENT(#369,#491);
      #369= IFCLOCALPLACEMENT[4](#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= IFCRECTANGLEPROFILEDEF(.AREA.,'',#463,72.,108.);
               #463= IFCAXIS2PLACEMENT2D(#459,#455);
                  #459= IFCCARTESIANPOINT((0.,54.));
                  #455= IFCDIRECTION((-1.,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).

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 (Window)

- **Check opening dimension and geometry**

___ Origin = (413.,144.,36.)
___ 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 = 18.875 (in.)
___ IfcExtrudedAreaSolid.ExtrudedDirection = Y Direction[1]
___ IfcExtrudedAreaSolid.Position = (0.,0.,0.)
___ IfcExtrudedAreaSolid.SweptArea.ProfileType = “AREA”
___ 4 Cartesian points for the swept area[2] = (30.,0.), (30.,48.), (-30.,48.), (-30.,0.)
OR if Rectangle Profile is used to define the area
Center point = (0.,24.), XDim = 60, YDim = 48

Sample IFC Code:

```
#1194= IFCOPENINGELEMENT(GUID,#13,$,$,'Opening',#1191,#1180,'');
   #1191= IFCLOCALPLACEMENT(#1073,#1188);
      #1073= IFCLOCALPLACEMENT[3](#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:

```
#958= IFCDOOR(GUID,#13,'D2','D2030 Exterior Doors',$,#530,#954,$,108.,72.);
   #954= 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:

```
#1960= IFCWINDOW(GUID,#13,'W1A2','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.,$);
   #3231= IFCLOCALPLACEMENT(#99,#3228);
      #3228= IFCAXIS2PLACEMENT3D(#3224,#45,#41);
         #3224= IFCCARTESIANPOINT((18.875,18.875,0.));
         #45= IFCDIRECTION((0.,0.,1.));
         #41= IFCDIRECTION((0.,1.,0.));
   #3220= IFCPRODUCTDEFINITIONSHAPE($,$,(#3214));
      #3214= IFCSHAPEREPRESENTATION(#407,'Body','SweptSolid',(#3211));
         #3211= IFCEXTRUDEDAREASOLID(#3207,#3208,#45,120.);
            #3207= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#3203);
               #3203= IFCPOLYLINE((#3187,#3191,#3195,#3199,#3187));
                  #3187= IFCCARTESIANPOINT((0.,0.));
                  #3191= IFCCARTESIANPOINT((250.25,0.));
                  #3195= IFCCARTESIANPOINT((250.25,-394.25));
                  #3199= IFCCARTESIANPOINT((0.,-394.25));
            #3208= IFCAXIS2PLACEMENT3D(#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]

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)[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
___ 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
___ 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
___ 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
___ 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
___ P1: (0.,0.,0.) P2: (394.25,0.,0.) P3: (394.25,120.,0.) P4: (0.,120.,0.)

South Wall Space Boundary[2]
___ 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
___ P1: (0.,0.,0.) P2: (394.25,0.,0.) P3: (394.25,120.,0.) P4: (0.,120.,0.)

East Wall Space Boundary[2]
___ 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
___ 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',$,#3234,#958,#3561,
.PHYSICAL.,.EXTERNAL.);
   #3234= IFCSPACE(GUID,#13,'Room',$,$,...);
   #958= IFCDOOR(GUID,#13,'D2','D2030 Exterior Doors',$,...);
   #3561= IFCCONNECTIONSURFACEGEOMETRY(#3557,$);
      #3557= IFCCURVEBOUNDEDPLANE(#3522,#3553,());
         #3522= IFCPLANE(#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,#3533,#3537,#3541));
                  #3525= IFCCARTESIANPOINT((161.125,0.,0.));
                  #3529= IFCCARTESIANPOINT((233.125,0.,0.));
                  #3533= IFCCARTESIANPOINT((233.125,108.,0.));
                  #3537= IFCCARTESIANPOINT((161.125,108.,0.));
                  #3541= IFCCARTESIANPOINT((161.125,0.,0.));

#3338= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3234,#2411,#3337,
.PHYSICAL.,.EXTERNAL.);
   #3234= IFCSPACE(GUID,#13,'Room',$,$,...);
   #2411= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,...);
   #3337= IFCCONNECTIONSURFACEGEOMETRY(#3333,$);
      #3333= IFCCURVEBOUNDEDPLANE(#3306,#3329,());
         #3306= IFCPLANE(#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',$,#3234,#1960,#3613,
.PHYSICAL.,.EXTERNAL.);
   #3234= IFCSPACE(GUID,#13,'Room',$,$,...);
   #1960= IFCWINDOW(GUID,#13,'W1A2','B2020 Exterior Windows',$,...);
   #3613= IFCCONNECTIONSURFACEGEOMETRY(#3609,$);
      #3609= IFCCURVEBOUNDEDPLANE(#3574,#3605,());
         #3574= IFCPLANE(#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((-1.,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= IFCPLANE(#3263);
            #3263= IFCAXIS2PLACEMENT3D(#49,#3259,#3255);
               #49= IFCCARTESIANPOINT((0.,0.,0.));
               #3259= IFCDIRECTION((-1.,0.,0.));
               #3255= IFCDIRECTION((0.,-1.,0.));
         #3289= IFCCOMPOSITECURVE((#3285),.U.);
            #3285= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.F.,#3281);
               #3281= IFCPOLYLINE((#49,#3269,#3273,#3277,#49));
                  #49= IFCCARTESIANPOINT((0.,0.,0.));
                  #3269= IFCCARTESIANPOINT((394.25,0.,0.));
                  #3273= IFCCARTESIANPOINT((394.25,120.,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= IFCPLANE(#3347);
            #3347= IFCAXIS2PLACEMENT3D(#3343,#3339,#37);
               #3343= IFCCARTESIANPOINT((0.,-394.25,0.));
               #3339= IFCDIRECTION((0.,-1.,0.));
               #37= IFCDIRECTION((1.,0.,0.));
         #3373= IFCCOMPOSITECURVE((#3369),.U.);
            #3369= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.F.,#3365);
               #3365= IFCPOLYLINE((#49,#3353,#3357,#3361,#49));
                  #49= IFCCARTESIANPOINT((0.,0.,0.));
                  #3353= IFCCARTESIANPOINT((250.25,0.,0.));
                  #3357= IFCCARTESIANPOINT((250.25,120.,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

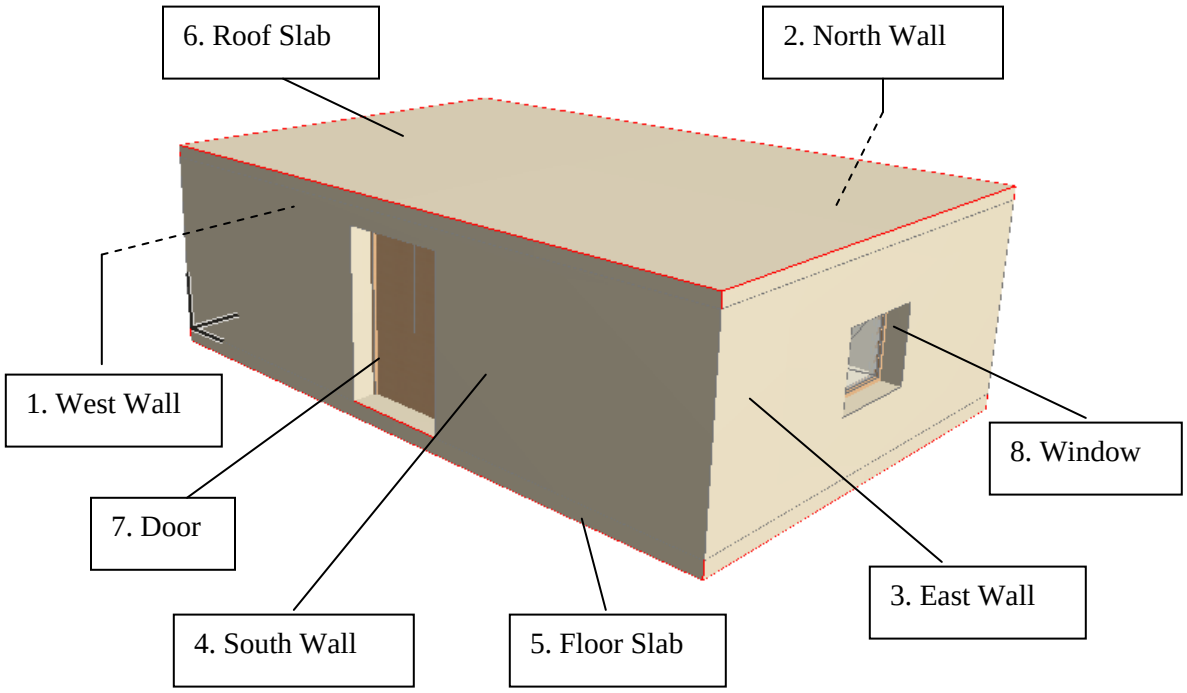


Figure A2: Simple one-story building

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

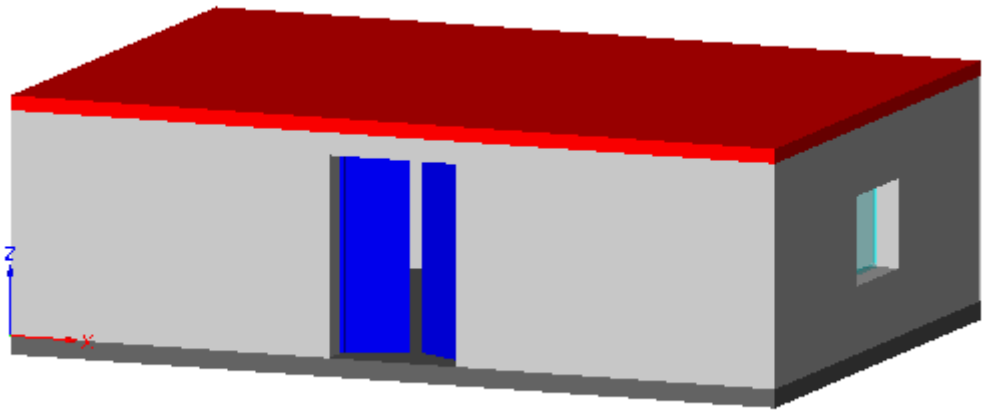
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)**	Description (ASHRAE)**	UniFormat Classification
1. Exterior Wall* (east)	Length: 7.3152 m Height: 3.048 m Thickness: 0.4794 m Origin: (10.9728, 7.3152, 0)	WA34	12-in HW concrete R-19 insulation Gypsum board	B2010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

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

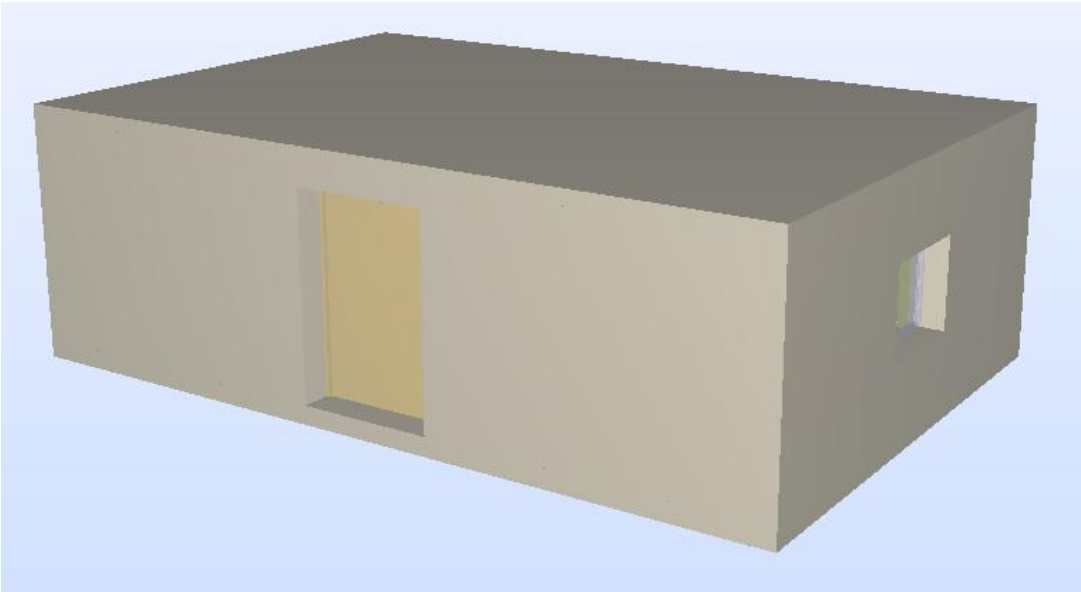
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type	Description (ASHRAE)	UniFormat Classification
7. Door	Width: 1.8288 m Height: 2.7432 m Placement: south wall, center Sill to base: 0 m	D2	Steel slab (Foam insulated with metal edge in steel frame) Double door	D2030 Exterior 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



Solibri Model Checker

DDS-CAD Viewer

Testing Details for BPEA Test Case 1 (metric)

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

- **Check that all building elements exist**

___ 4 IfcWallStandardCase
___ 2 IfcOpeningElement
___ 1 IfcWindow
___ 2 IfcSlab
___ 1 IfcDoor
___ 1 IfcSpace

Project

- **Project identifier is required**

___ IfcProject.LongName = “BPEA Test Case 1”

Sample IFC Code[1]:

```
#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[2]:

```
#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= 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 '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]

Building[1]

- **Building identifier is required**

___ IfcBuilding.LongName = "TC1"

- **Elevation (base elevation of ground level floor above sea level) is required**

___ IfcBuilding.ElevationOfRefHeight = 3 (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','TC1',$,#74,$,'TC1',.ELEMENT.,
3.,$,$);
   #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:

```
#3611= IFCPROPERTYSINGLEVALUE('NumberOfStoreys',$,IFCINTEGER(1),$);
```

- **Building orientation (the degrees of clockwise from true north) is required**[2]

___ IfcGeometricRepresentationContext.TrueNorth = (-0.5,0.866)

Sample IFC Code:

```
#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:

```
#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.));
```

[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.)
___ 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 = 3.048 (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.), (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[4]:

```
#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($,$,(#2250,#2283));
      #2283= IFCSHAPEREPRESENTATION(#398,'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.));
                  #2268= IFCCARTESIANPOINT((0.,0.));
            #2277= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #36= IFCDIRECTION((0.,0.,1.));
               #28= IFCDIRECTION((1.,0.,0.));

#2385= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2219),#2359);
   #2359= IFCPROPERTYSET(GUID,#2363,'Pset_WallCommon',$,(#2365,#2369));
      #2365= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #2369= IFCPROPERTYSINGLEVALUE('IsExternal',$,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 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[1]
___ Pset_WallCommon.Reference = “WA34” OR IfcWall.Name[2] = “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”
___ 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.), (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:

```
#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= IFCPRODUCTDEFINITIONSHAPE($,$,(#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,#1104));
                  #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:

```
#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.));
   #440= IFCPRODUCTDEFINITIONSHAPE($,$,(#401,#434));
      #434= 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,#36,3.048);
            #427= IFCARBITRARYCLOSEDPROFILEDEF(.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.));
            #428= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #36= IFCDIRECTION((0.,0.,1.));
               #28= IFCDIRECTION((1.,0.,0.));

#1043= IFCRELDEFINESBYPROPERTIES(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]

Walls (All Walls)

- **Check material association (for 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”

Sample IFC Code:

```
#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');
```

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:

```
#2402= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,#2465,#2454,$,.BASESLAB.);
   #2465= IFCLOCALPLACEMENT(#90,#2462);
      #2462= IFCAXIS2PLACEMENT3D(#2458,#36,#32);
         #2458= IFCCARTESIANPOINT((0.,0.,-0.256));
         #36= IFCDIRECTION((0.,0.,1.));
         #32= IFCDIRECTION((0.,1.,0.));
   #2454= IFCPRODUCTDEFINITIONSHAPE($,$,(#2448));
      #2448= IFCSHAPEREPRESENTATION(#398,'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((0.,1.,0.));
   #2780= IFCPRODUCTDEFINITIONSHAPE($,$,(#2774));
      #2774= IFCSHAPEREPRESENTATION(#398,'Body','SweptSolid',(#2771));
         #2771= IFCEXTRUDEDAREASOLID(#2767,#2768,#36,0.2);
            #2767= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2763);
               #2763= IFCPOLYLINE((#2747,#2751,#2755,#2759,#2747));
                  #2747= IFCCARTESIANPOINT((0.,0.));
                  #2751= IFCCARTESIANPOINT((7.3152,0.));
                  #2755= IFCCARTESIANPOINT((7.3152,-10.9728));
                  #2759= IFCCARTESIANPOINT((0.,-10.9728));
            #2768= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #36= IFCDIRECTION((0.,0.,1.));
               #28= IFCDIRECTION((1.,0.,0.));

#3174= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#2728),#3161);
   #3161= IFCPROPERTYSET(GUID,#13,'Pset_SlabCommon',$,(#3166,#3170));
      #3166= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('RA14'),$);
      #3170= IFCPROPERTYSINGLEVALUE('IsExternal',$,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]

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,#2644,#2696),' Floor Type 05_FA5 Slab
      On Grade');
         #2611= IFCMATERIALLAYER(#2471,0.1524,.U.);
            #2471= IFCMATERIAL(' M14 | 6 in. Heavyweight Concrete');
         #2644= 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');
```

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

Opening (Door)

- **Check opening dimension and geometry**

___ Origin = (5.4864,-0.4794,0.)
___ 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 = 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] =
(0.9144,0.), (0.9144,2.7432), (-0.9144,2.7432), (-0.9144,0.)
OR if Rectangle Profile is used to define the area[3]
Center point = (0.,1.3716), XDim = 1.8288, YDim = 2.7432

Sample IFC Code[4]:

```
#488= IFCOPENINGELEMENT(GUID,#13,$,$,'Opening',#485,#474,'');
   #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(#40,#32,#458);
               #40= 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).

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

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]:

```
#1185= IFCOPENINGELEMENT(GUID,#13,$,$,'Opening',#1182,#1171,'');
   #1182= IFCLOCALPLACEMENT(#1064,#1179);
      #1064= IFCLOCALPLACEMENT[3](#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);
                  #1147= IFCCARTESIANPOINT((0.,0.6096));
                  #1143= IFCDIRECTION((1.,0.));
            #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= IFCWINDOW(GUID,#13,'W1A2','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:

```
#3225= IFCSPACE(GUID,#13,'Room',$,$,#3222,#3211,'Room',.ELEMENT.,
.INTERNAL.,$);
   #3222= IFCLOCALPLACEMENT(#90,#3219);
      #3219= IFCAXIS2PLACEMENT3D(#3215,#36,#32);
         #3215= IFCCARTESIANPOINT((0.4794,0.4794,0.));
         #36= IFCDIRECTION((0.,0.,1.));
         #32= IFCDIRECTION((0.,1.,0.));
   #3211= IFCPRODUCTDEFINITIONSHAPE($,$,(#3205));
      #3205= IFCSHAPEREPRESENTATION(#398,'Body','SweptSolid',(#3202));
         #3202= IFCEXTRUDEDAREASOLID(#3198,#3199,#36,3.048);
            #3198= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#3194);
               #3194= IFCPOLYLINE((#3178,#3182,#3186,#3190,#3178));
                  #3178= IFCCARTESIANPOINT((0.,0.));
                  #3182= IFCCARTESIANPOINT((6.3564,0.));
                  #3186= IFCCARTESIANPOINT((6.3564,-10.014));
                  #3190= IFCCARTESIANPOINT((0.,-10.014));
            #3199= IFCAXIS2PLACEMENT3D(#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)[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: (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
___ 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
___ 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
___ 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
___ 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
___ P1: (0.,0.,0.) P2: (10.014,0.,0.) P3: (10.014,3.048,0.) P4: (0.,3.048,0.)

South Wall Space Boundary[2]
___ 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
___ P1: (0.,0.,0.) P2: (10.014,0.,0.) P3: (10.014,3.048,0.) P4: (0.,3.048,0.)

East Wall Space Boundary[2]
___ 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
___ 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:

```
#3553= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3225,#949,#3552,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #949= IFCDOOR(GUID,#13,'D2','D2030 Exterior Doors',$,...);
   #3552= IFCCONNECTIONSURFACEGEOMETRY(#3548,$);
      #3548= IFCCURVEBOUNDEDPLANE(#3513,#3544,());
         #3513= IFCPLANE(#3510);
            #3510= IFCAXIS2PLACEMENT3D(#40,#3506,#3502);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #3506= IFCDIRECTION((-1.,0.,0.));
               #3502= IFCDIRECTION((0.,-1.,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',$,#3225,#2402,#3328,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #2402= IFCSLAB(GUID,#13,'FA5','Slabs-On-Grade',$,...);
   #3328= IFCCONNECTIONSURFACEGEOMETRY(#3324,$);
      #3324= IFCCURVEBOUNDEDPLANE(#3297,#3320,());
         #3297= IFCPLANE(#3294);
            #3294= IFCAXIS2PLACEMENT3D(#40,#3290,#28);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #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',$,#3225,#1951,#3604,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #1951= IFCWINDOW(GUID,#13,'W1A2','B2020 Exterior Windows',$,...);
   #3604= IFCCONNECTIONSURFACEGEOMETRY(#3600,$);
      #3600= IFCCURVEBOUNDEDPLANE(#3565,#3596,());
         #3565= IFCPLANE(#3562);
            #3562= IFCAXIS2PLACEMENT3D(#3558,#3554,#28);
               #3558= IFCCARTESIANPOINT((0.,-10.014,0.));
               #3554= IFCDIRECTION((0.,-1.,0.));
               #28= IFCDIRECTION((1.,0.,0.));
         #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',$,#3225,#2728,#3416,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #2728= IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,...);
   #3416= IFCCONNECTIONSURFACEGEOMETRY(#3412,$);
      #3412= IFCCURVEBOUNDEDPLANE(#3385,#3408,());
         #3385= IFCPLANE(#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= IFCPOLYLINE((#40,#3388,#3392,#3396,#40));
                  #40= IFCCARTESIANPOINT((0.,0.,0.));
                  #3388= IFCCARTESIANPOINT((10.014,0.,0.));
                  #3392= IFCCARTESIANPOINT((10.014,6.3564,0.));
                  #3396= IFCCARTESIANPOINT((0.,6.3564,0.));

#3461= IFCRELSPACEBOUNDARY(GUID,#13,'2ndLevel',$,#3225,#2219,#3460,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #2219= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',...);
   #3460= IFCCONNECTIONSURFACEGEOMETRY(#3456,$);
      #3456= IFCCURVEBOUNDEDPLANE(#3429,#3452,());
         #3429= IFCPLANE(#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= IFCPOLYLINE((#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',$,#3225,#2085,#3500,
.PHYSICAL.,.EXTERNAL.);
   #3225= IFCSPACE(GUID,#13,'Room',$,$,...);
   #2085= IFCWALLSTANDARDCASE(GUID,#13,'WA34','B2010 Exterior Walls',...);
   #3500= IFCCONNECTIONSURFACEGEOMETRY(#3496,$);
      #3496= IFCCURVEBOUNDEDPLANE(#3469,#3492,());
         #3469= IFCPLANE(#3466);
            #3466= IFCAXIS2PLACEMENT3D(#3462,#28,#32);
               #3462= IFCCARTESIANPOINT((6.3564,-10.014,0.));
               #28= IFCDIRECTION((1.,0.,0.));
               #32= IFCDIRECTION((0.,1.,0.));
         #3492= IFCCOMPOSITECURVE((#3488),.U.);
            #3488= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.F.,#3484);
               #3484= IFCPOLYLINE((#40,#3472,#3476,#3480,#40));
                  #40= IFCCARTESIANPOINT((0.,0.,0.));
                  #3472= IFCCARTESIANPOINT((10.014,0.,0.));
                  #3476= IFCCARTESIANPOINT((10.014,3.048,0.));
                  #3480= 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= IFCAXIS2PLACEMENT3D(#40,#3250,#3246);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #3250= IFCDIRECTION((-1.,0.,0.));
               #3246= IFCDIRECTION((0.,-1.,0.));
         #3280= IFCCOMPOSITECURVE((#3276),.U.);
            #3276= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.F.,#3272);
               #3272= IFCPOLYLINE((#40,#3260,#3264,#3268,#40));
                  #40= IFCCARTESIANPOINT((0.,0.,0.));
                  #3260= IFCCARTESIANPOINT((10.014,0.,0.));
                  #3264= IFCCARTESIANPOINT((10.014,3.048,0.));
                  #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= IFCAXIS2PLACEMENT3D(#3334,#3330,#28);
               #3334= IFCCARTESIANPOINT((0.,-10.014,0.));
               #3330= IFCDIRECTION((0.,-1.,0.));
               #28= IFCDIRECTION((1.,0.,0.));
         #3364= IFCCOMPOSITECURVE((#3360),.U.);
            #3360= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.F.,#3356);
               #3356= IFCPOLYLINE((#40,#3344,#3348,#3352,#40));
                  #40= 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.

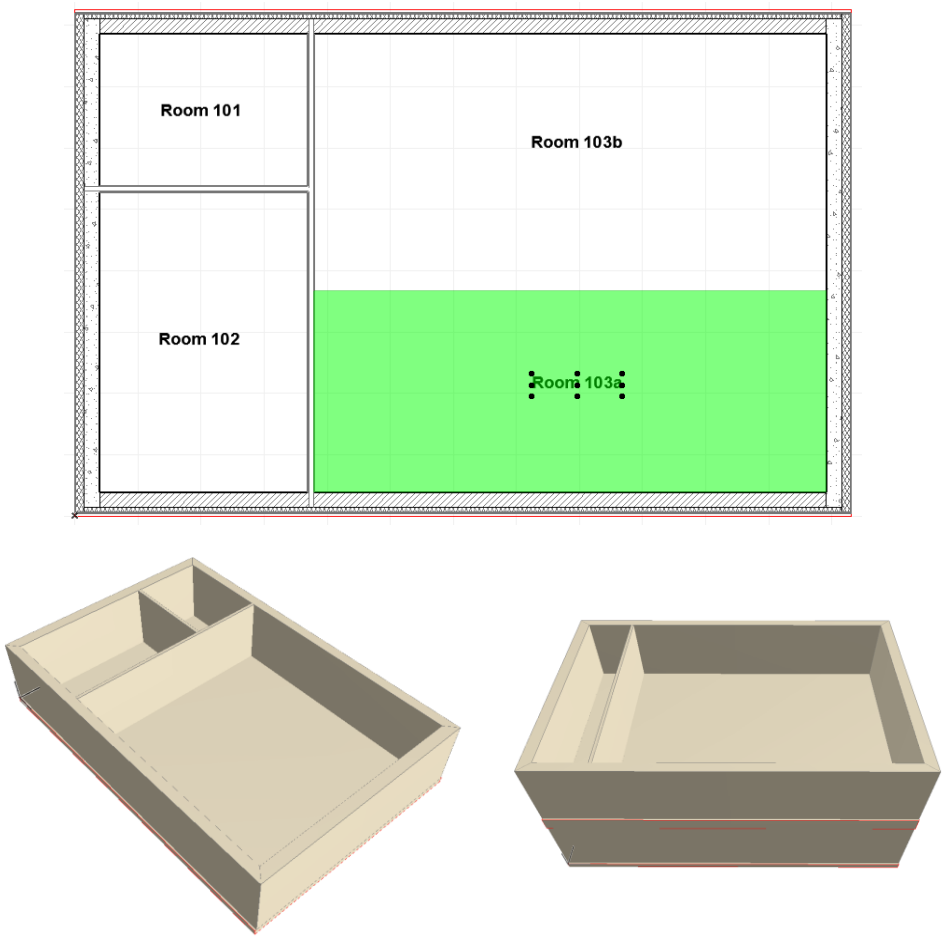


Figure A3: Two Stories Building with Different Floor Plan

Detailed Description:

Project Name: BPEA Test Case 2

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

Building Name: TC2
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

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

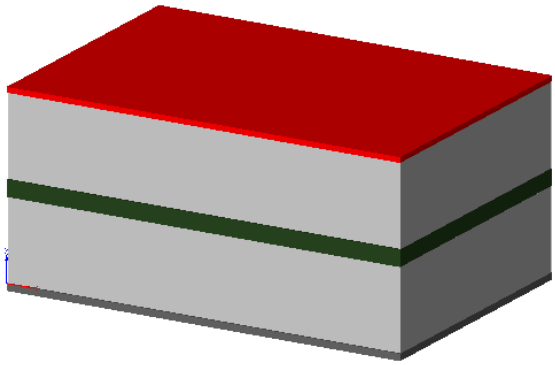
* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

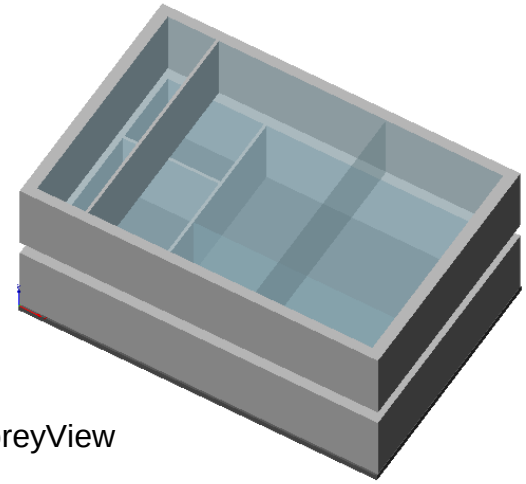
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
7. Exterior Wall (2nd floor south)	Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 3.61)	WA26	12-in LW CMU Fill insulation Gypsum board	B2010 Exterior Walls
8. Exterior Wall (2nd floor north)	Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 3.61)	WA26	12-in LW CMU Fill insulation Gypsum board	B2010 Exterior Walls
9. Interior Wall (1st floor hori.)	Length: 4 m Height: 3 m Thickness: 0.12 m Origin: (0, 6, 0)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
10. Interior Wall (1st floor vert.)	Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (5, 0, 0)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
11. Interior Wall (2nd floor)	Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (3, 0, 3.61)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
12. Base Slab	15 m by 10 m Thickness: 0.256 m Origin: (0, 0, -0.254) X-axis: (1, 0, 0)	FA5	6-in HW concrete 4-in Gravel	A1030 Slab-on-grade
13. Floor Slab (between 1st and 2nd)	15 m by 10 m Thickness: 0.61 m Origin: (0, 0, 3) X-axis: (1, 0, 0)	FA2	Acoustical tile Air wall resistance 6-in HW concrete	B1010 Floor Construction
14. Roof Slab	15 m by 10 m Thickness: 0.2 m Origin: (0, 0, 6.61) X-axis: (1, 0, 0)	RA14	R-15 insulation 4-in LW concrete	B1020 Roof Construction
15. Virtual Element (air wall in Room 103)	Length: 9.9 m Thickness: N/A			
16. Virtual Element (air wall in Room 202)	Length: 9.1 m Thickness: N/A			

Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
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)				

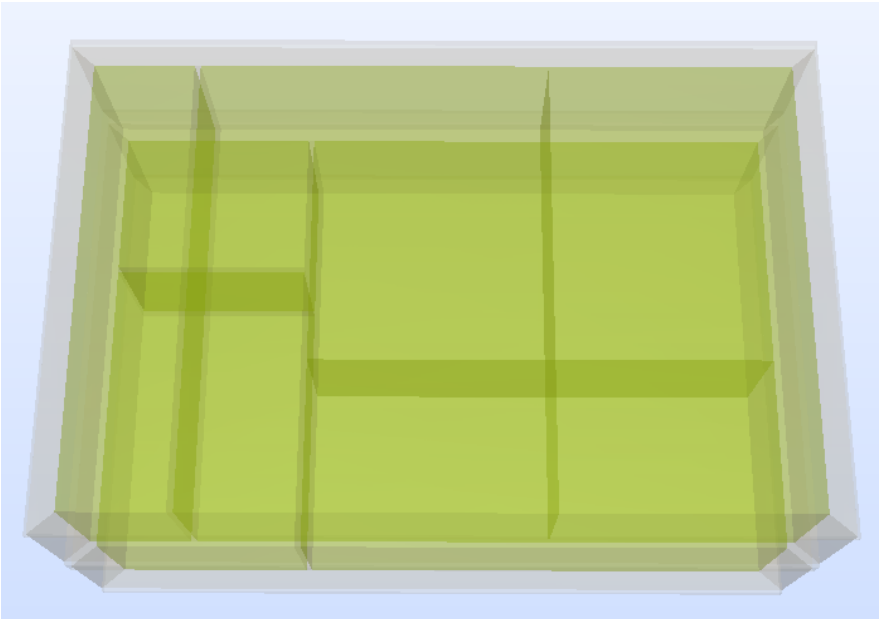
When creating slabs and spaces in CAD, the first edge is drawn along the X-axis from the origin.

Screenshots of the building model in different IFC Viewers

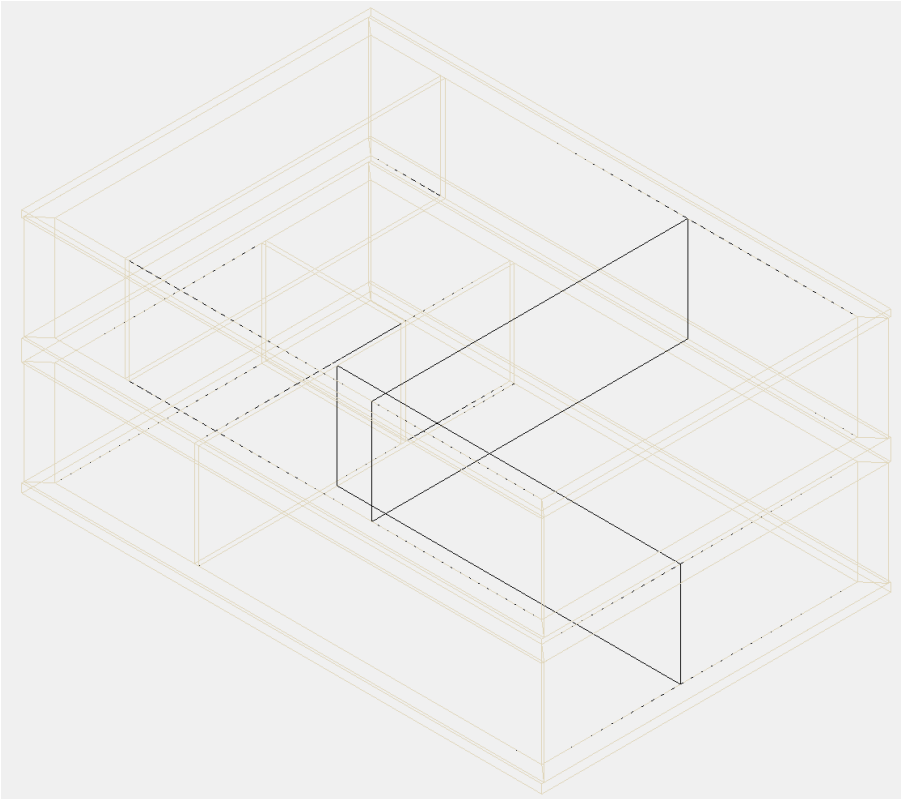




IfcStoreyView



Solibri Model Checker



DDS-CAD Viewer

Testing Details for BPEA Test Case 2

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**

___ 11 IfcWallStandardCase ___ 3 IfcSlab
___ 2 IfcVirtualElement ___ 7 IfcSpace

Project

- **Project identifier is required**

___ IfcProject.LongName = “BPEA Test Case 2”

Sample IFC Code[1]:

```
#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**

___ 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 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 '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 0.005 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:

```
#77= IFCBUILDING(GUID,#13,'Default Building','TC2',$,#74,$,'TC2',.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:

```
#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:

```
#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:

```
#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.));

#2129= IFCBUILDINGSTOREY(GUID,#13,'2nd Floor',$,$,#2126,$,$,.ELEMENT.,3.61);
   #2126= IFCLOCALPLACEMENT(#74,#2123);
      #74= IFCLOCALPLACEMENT(#61,#44);
      #2123= IFCAXIS2PLACEMENT3D(#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**[1]

___ 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]:

```
#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,#36,3.);
            #1017= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#1013);
               #1013= IFCPOLYLINE((#997,#1001,#1005,#1009,#997));
                  #997= IFCCARTESIANPOINT((0.07,0.));
                  #1001= IFCCARTESIANPOINT((9.93,0.));
                  #1005= 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.));

#1126= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#960),#1100);
   #1100= IFCPROPERTYSET(GUID,#1104,'Pset_WallCommon',$,(#1106,#1110));
      #1106= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #1110= IFCPROPERTYSINGLEVALUE('IsExternal',$,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 #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 = 0.3048 (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:

```
#694= IFCRELASSOCIATESMATERIAL(GUID,#13,$,$,(#620),#609);
   #609= IFCMATERIALLAYERSETUSAGE(#607,.AXIS2.,.NEGATIVE.,0.48);
      #607= IFCMATERIALLAYERSET((#377,#519,#565,#600,#605),' Wall Type 34_WA34
      Precast and CIP Concrete Walls');
         #377= IFCMATERIALLAYER(#374,0.0001,.U.);
            #374= IFCMATERIAL('F01 Outside Surface Resistance');
         #519= IFCMATERIALLAYER(#379,0.3048,.U.);
            #379= IFCMATERIAL(' M16 | 12 in. Heavyweight Concrete');
         #565= IFCMATERIALLAYER(#521,0.15875,.U.);
            #521= IFCMATERIAL(' I05 | R-19, 6-1/4 in. Batt Insulation');
         #600= IFCMATERIALLAYER(#567,0.015875,.U.);
            #567= IFCMATERIAL(' G01 | 5/8 in. Gyp Board');
         #605= IFCMATERIALLAYER(#602,0.0001,.U.);
            #602= 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');
```

Numeric Values and Specifications Summary for 1st Floor Exterior Walls (Refer to West Wall Verdict Criteria Table for specific details)				
	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,0.)	(15.,0.,0.)	(0.,0.,0.)	(0.,10.,0.)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.07),(15.,0.07) (14.52,0.48), (0.48,0.48)	(0.07,0.), (9.93,0.), (9.52,0.48), (0.48,0.48)	(0.,0.07),(15.,0.07) (14.52,0.48) (0.48,0.48)	(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)
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 - Insulation Batt Thickness: 0.092075 m - Gypsum Board Thickness: 0.015875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Block Masonry 0.3048 m - Insulation Batt 0.092075 m - Gypsum Board 0.015875 m	- Outside Surface Resistance 0.001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.001 m
Corresponding code line number in reference IFC file	#790 (dimension and geometry) #864 (materials) #928 (properties)	#620 (dimension and geometry) #694 (materials) #758 (properties)	#236 (dimension and geometry) #317 (materials) #355 (properties)	#960 (dimension and geometry) #1034 (materials) #1126 (properties)

Verdict Criteria Summary for 2nd Floor Exterior Walls				
	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,3.61)	(15.,0.,3.61)	(0.,0.,3.61)	(0.,10.,3.61)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.07),(15.,0.07) (14.52,0.48), (0.48,0.48)	(0.07,0.), (9.93,0.), (9.52,0.48), (0.48,0.48)	(0.,0.07),(15.,0.07) (14.52,0.48) (0.48,0.48)	(0.07,0.), (9.93,0.), (9.52,0.48), (0.48,0.48)
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 - Insulation Batt Thickness: 0.092075 m - Gypsum Board Thickness: 0.015875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Block Masonry 0.3048 m - Insulation Batt 0.092075 m - Gypsum Board 0.015875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m
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)

Verdict Criteria Summary for all Interior Walls				
	1st Floor Horizontal Wall	1st Floor Vertical Wall	2nd Floor Wall	
Wall dimension and geometry				
Origin of LCS	(0.,6.46,0.)	(4.54,0.,0.)	(2.54,0.,3.61)	
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	
Cartesian points for the swept area (from origin of LCS)	(0.48,-0.06), (4.48,-0.06), (4.48,0.06), (0.48,0.06)	(0.48,-0.06), (9.52,-0.06), (9.52,0.06), (0.48,0.06)	(0.48,-0.06), (9.52,-0.06), (9.52,0.06), (0.48,0.06)	
Wall properties				
Construction type	WA36	WA36	WA36	
UniFormat classification	C1010 Interior Fixed Partitions	C1010 Interior Fixed Partitions	C1010 Interior Fixed Partitions	
Exterior / Interior	Interior	Interior	Interior	
Wall material association				
Layer name	WA36	WA36	WA36	
Material layer and thickness	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	
Corresponding code line number in reference IFC file	#1365 (dimension and geometry) #1439 (materials) #1531 (properties)	#1169 (dimension and geometry) #1243 (materials) #1335 (properties)	#2818 (dimension and geometry) #2892 (materials) #2984 (properties)	

Verdict Criteria Summary for all Slabs				
	Base slab	Floor slab	Roof slab	
Slab dimension and geometry				
Origin of LCS	(0.,0.,-0.256)	(0.,0.,3.)	(0.,0.,6.61)	
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 0.256 m. (0.,0.,1.)	 Area (0.,0.,0.) 0.61 m. (0.,0.,1.)	 Area (0.,0.,0.) 0.2 m. (0.,0.,1.)	
Cartesian points for the swept area (from origin of LCS)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	
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	
Corresponding code line number in reference IFC file	#1548 (dimension and geometry) #1847 (materials) #1870 (properties)	#3001 (dimension and geometry) #3115 (materials) #3138 (properties)	#3142 (dimension and geometry) #3565 (materials) #3588 (properties)	

Verdict Criteria Summary for all Spaces						
	Origin of LCS	XYZ Direction of LCS	Shape Repr.	Extrusion: Profile type, Position, Depth, Direction	Cartesian points of swept area (from origin of LCS)	Space Properties: Longname, Ext. / Int.
Room 101 (#1921 in Reference IFC file)	(0.48,6.53,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (4.,0.), (4.,3.), (0.,3.)	“Room 101” Internal
Room 102 (#1985)	(0.48,0.48,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (4.,0.), (4.,5.92), (0.,5.92)	“Room 102” Internal
Room 103a (#2103)	(4.6,0.48,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (9.92,0.), (9.92,4.), (0.,4.)	“Room 103a” Internal
Room 103b (#2044)	(4.6,4.48,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (9.92,0.), (9.92,5.04), (0.,5.04)	“Room 103b” Internal
Room 201 (#3639)	(0.48,0.48,3.61)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (2.,0.), (2.,9.04), (0.,9.04)	“Room 201” Internal
Room 202a (#3698)	(2.6,0.48,3.61)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (7.,0.), (7.,9.04), (0.,9.04)	“Room 202a” Internal
Room 202b (#3757)	(9.6,0.48,3.61)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (4.92,0.), (4.92,9.04), (0.,9.04)	“Room 202b” Internal

Verdict Criteria Summary for all Space Boundaries relating to Room 101				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 101 Space Boundary 1 (#4254 in Reference IFC)	"2nd Level" Physical External	Room 101 (#1921)	1st Floor North Wall (#790)	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 (#4210)	"2nd Level" Physical External	Room 101 (#1921)	1st Floor West Wall (#960)	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 (#4122)	"2nd Level" Physical Internal Type[1] 2a	Room 101 (#1921)	1st Floor Vertical Interior Wall (#1169)	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 (#4042)	"2nd Level" Physical Internal Type 2a	Room 101 (#1921)	1st Floor Horizontal Interior Wall (#1365)	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 (#4082)	"2nd Level" Physical External	Room 101 (#1921)	Base Slab (#1548)	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 (#4162)	"2nd Level" Physical Internal Type 2a	Room 101 (#1921)	Floor Slab (#3001)	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.,3.,0.) P4: (0.,3.,0.)
Room 101 Space Boundary 7 (#4302)	"2nd Level" Physical Internal Type 2a	Room 101 (#1921)	Floor Slab (#3001)	Origin: (0.,0.,3.) 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.)
Room 101 Space Boundary 8 (#4350)	"2nd Level" Physical Internal Type 2b (due to 2nd floor interior wall)	Room 101 (#1921)	Floor Slab (#3001)	Origin: (0.,0.,3.) 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.)
Count of Space Boundaries relating to Room 101 = 8				

[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				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 102 Space Boundary 1 (#4390 in Reference IFC)	"2nd Level" Physical External	Room 102 (#1985)	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 (#4566)	"2nd Level" Physical External	Room 102 (#1985)	1st Floor West Wall (#960)	Origin: (0.,5.92,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (0.,0.,0.) P2: (5.92,0.,0.) P3: (5.92,3.,0.) P4: (0.,3.,0.)
Room 102 Space Boundary 3 (#4650)	"2nd Level" Physical Internal Type 2a	Room 102 (#1985)	1st Floor Vertical Interior Wall (#1169)	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 4 (#4478)	"2nd Level" Physical Internal Type 2a	Room 102 (#1985)	1st Floor Vertical Interior Wall (#1169)	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.,3.,0.)
Room 102 Space Boundary 5 (#4610)	"2nd Level" Physical Internal Type 2a	Room 102 (#1985)	1st Floor Horizontal Interior Wall (#1365)	Origin: (4.,5.92,0.) 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 6 (#4430)	"2nd Level" Physical External	Room 102 (#1985)	Base Slab (#1548)	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 7 (#4518)	"2nd Level" Physical Internal Type 2a	Room 102 (#1985)	Floor Slab (#3001)	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.,5.92,0.) P4: (0.,5.92,0.)
Room 102 Space Boundary 8 (#4746)	"2nd Level" Physical Internal Type 2b (due to 2nd floor interior wall)	Room 102 (#1985)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (2.,0.,0.) P2: (2.12,0.,0.) P3: (2.12,5.92,0.) P4: (2.,5.92,0.)
Room 102 Space Boundary 9 (#4698)	"2nd Level" Physical Internal Type 2a	Room 102 (#1985)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (2.12,0.,0.) P2: (4.,0.,0.) P3: (4.,5.92,0.) P4: (2.12,5.92,0.)
Count of Space Boundaries relating to Room 102 = 9				

Verdict Criteria Summary for all Space Boundaries relating to Room 103a				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 103a Space Boundary 1 (#5158 in Reference IFC)	"2nd Level" Physical External	Room 103a (#2103)	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 103a Space Boundary 2 (#5238)	"2nd Level" Physical External	Room 103a (#2103)	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: (4.,0.,0.) P3: (4.,3.,0.) P4: (0.,3.,0.)
Room 103a Space Boundary 3 (#5326)	"2nd Level" Physical Internal Type 2a	Room 103a (#2103)	1st Floor Vertical Interior Wall (#1169)	Origin: (0.,4.,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 103a Space Boundary 4 (#3885)	"2nd Level" Virtual Internal	Room 103a (#2103)	1st Floor Virtual Element (#3865)	Origin: (9.92,4.,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 103a Space Boundary 5 (#5198)	"2nd Level" Physical External	Room 103a (#2103)	Base Slab (#1548)	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.,9.92,0.) P4: (0.,9.92,0.)
Room 103a Space Boundary 6 (#5278)	"2nd Level" Physical Internal Type 2a	Room 103a (#2103)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (0.,0.,0.) P2: (5.,0.,0.) P3: (5.,4.,0.) P4: (0.,4.,0.)
Room 103a Space Boundary 7 (#5374)	"2nd Level" Physical Internal Type 2a	Room 103a (#2103)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (5.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,4.,0.) P4: (5.,4.,0.)
Count of Space Boundaries relating to Room 103a = 7				

Verdict Criteria Summary for all Space Boundaries relating to Room 103b				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 103b Space Boundary 1 (#4826 in Reference IFC)	"2nd Level" Physical External	Room 103b (#2044)	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 (#2044)	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 (#2044)	1st Floor Vertical Interior Wall (#1169)	Origin: (0.,5.04,0.) 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 103b Space Boundary 4 (#5070)	"2nd Level" Physical Internal Type 2b (due to 1st floor horizontal wall)	Room 103b (#2044)	1st Floor Vertical Interior Wall (#1169)	Origin: (0.,5.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (3.,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 (#2044)	1st Floor Vertical Interior Wall (#1169)	Origin: (0.,5.04,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,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 (#2044)	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 (#2044)	Base Slab (#1548)	Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) 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 (#2044)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) 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 (#2044)	Floor Slab (#3001)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (5.,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 103a = 9				

Verdict Criteria Summary for all Space Boundaries relating to Room 201				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 201 Space Boundary 1 (#5414 in Reference IFC)	"2nd Level" Physical External	Room 201 (#3639)	2nd Floor South Wall (#2146)	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.)
Room 201 Space Boundary 2 (#5634)	"2nd Level" Physical External	Room 201 (#3639)	2nd Floor North Wall (#2454)	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.)
Room 201 Space Boundary 3 (#5590)	"2nd Level" Physical External	Room 201 (#3639)	2nd Floor West Wall (#2624)	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.)
Room 201 Space Boundary 4 (#5502)	"2nd Level" Physical Internal Type 2a	Room 201 (#3639)	2nd Floor Interior Wall (#2818)	Origin: (2.,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 5 (#5674)	"2nd Level" Physical Internal Type 2a	Room 201 (#3639)	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: (5.92,2.,0.) P4: (0.,2.,0.)
Room 201 Space Boundary 6 (#5722)	"2nd Level" Physical Internal Type 2b (due to 1st floor interior wall)	Room 201 (#3639)	Floor Slab (#3001)	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.)
Room 201 Space Boundary 7 (#5462)	"2nd Level" Physical Internal Type 2a	Room 201 (#3639)	Floor Slab (#3001)	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.)
Room 201 Space Boundary 8 (#5542)	"2nd Level" Physical External	Room 201 (#3639)	Roof Slab (#3142)	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.)
Count of Space Boundaries relating to Room 201 = 8				

Verdict Criteria Summary for all Space Boundaries relating to Room 202a				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 202a Space Boundary 1 (#5762 in Reference IFC)	"2nd Level" Physical External	Room 202a (#3698)	2nd Floor South Wall (#2146)	Origin: (0.,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.)
Room 202a Space Boundary 2 (#5942)	"2nd Level" Physical External	Room 202a (#3698)	2nd Floor North Wall (#2454)	Origin: (7.,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.)
Room 202a Space Boundary 3 (#5898)	"2nd Level" Physical Internal Type 2a	Room 202a (#3698)	2nd Floor Interior Wall (#2818)	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.)
Room 202a Space Boundary 4 (#4001)	"2nd Level" Virtual Internal	Room 202a (#3698)	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.)
Room 202a Space Boundary 5 (#5810)	"2nd Level" Physical Internal Type 2a	Room 202a (#3698)	Floor Slab (#3001)	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: (9.04,1.88,0.) P4: (6.04,1.88,0.)
Room 202a Space Boundary 6 (#5982)	"2nd Level" Physical Internal Type 2a	Room 202a (#3698)	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.)
Room 202a Space Boundary 7 (#6030)	"2nd Level" Physical Internal Type 2a	Room 202a (#3698)	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.)
Room 202a Space Boundary 8 (#6078)	"2nd Level" Physical Internal Type 2a	Room 202a (#3698)	Floor Slab (#3001)	Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,2.,0.) P2: (4.,2.,0.) P3: (4.,7.,0.) P4: (0.,7.,0.)
Room 202a Space Boundary 9 (#6142)	"2nd Level" Physical Internal Type 2b (due to 1st floor interior walls)	Room 202a (#3698)	Floor Slab (#3001)	Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,2.,0.) P2: (0.,1.88,0.) P3: (5.92,1.88,0.) P4: (5.92,0.,0.) P5: (6.04,0.,0.) P6: (6.04,1.88,0.) P7: (9.04,1.88,0.) P8: (9.04,2.,0.)
Room 202a Space Boundary 10 (#5850)	"2nd Level" Physical External	Room 202a (#3698)	Roof Slab (#3142)	Origin: (0.,0.,3.) 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.)
Count of Space Boundaries relating to Room 201 = 10				

Verdict Criteria Summary for all Space Boundaries relating to Room 202b				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 202b Space Boundary 1 (#6182 in Reference IFC)	"2nd Level" Physical External	Room 202b (#3757)	2nd Floor South Wall (#2146)	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.)
Room 202b Space Boundary 2 (#6270)	"2nd Level" Physical External	Room 202b (#3757)	2nd Floor East Wall (#2284)	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.)
Room 202b Space Boundary 3 (#6354)	"2nd Level" Physical External	Room 202b (#3757)	2nd Floor North Wall (#2454)	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.)
Room 202b Space Boundary 4 (#4002)	"2nd Level" Virtual Internal	Room 202b (#3757)	2nd Floor Virtual Element (#3982)	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.)
Room 202b Space Boundary 5 (#6394)	"2nd Level" Physical Internal Type 2a	Room 202b (#3757)	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.,0.,0.) P3: (4.,4.92,0.) P4: (0.,4.92,0.)
Room 202b Space Boundary 6 (#6230)	"2nd Level" Physical Internal Type 2a	Room 202b (#3757)	Floor Slab (#3001)	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.)
Room 202b Space Boundary 7 (#6310)	"2nd Level" Physical External	Room 202b (#3757)	Roof Slab (#3142)	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.)
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.

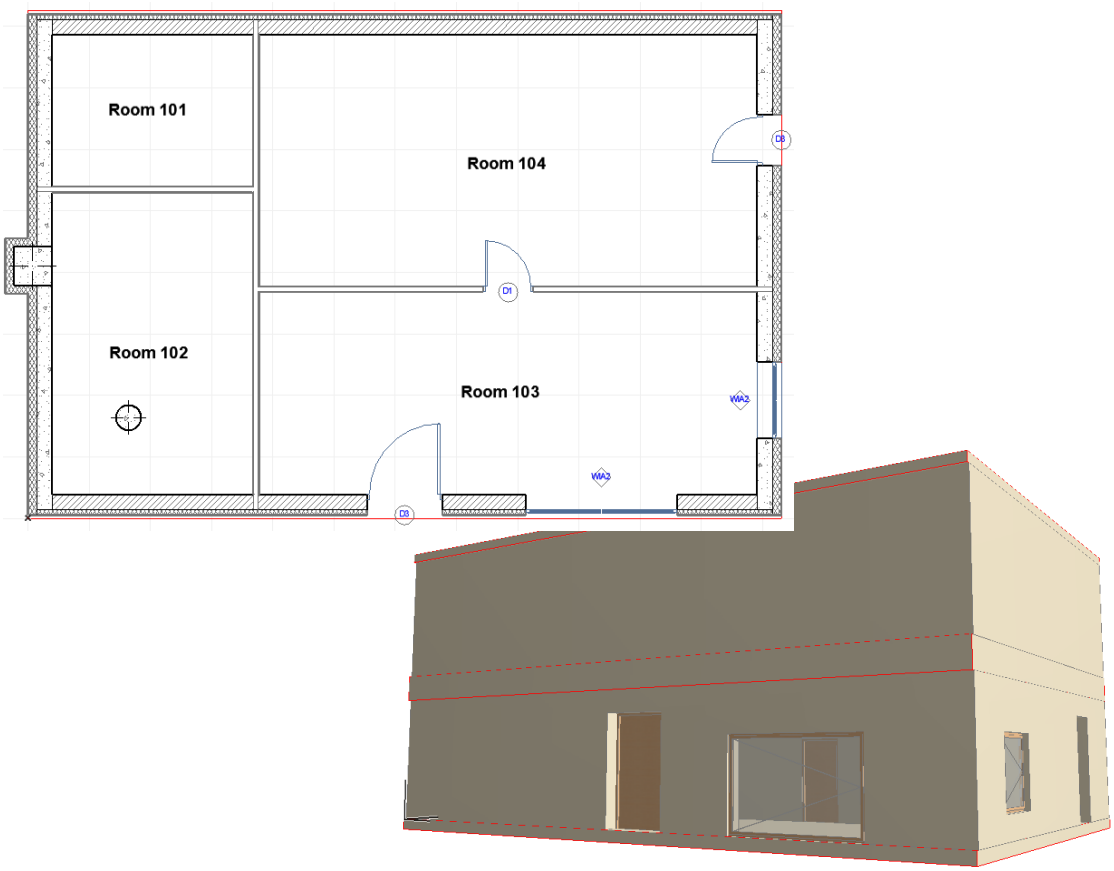


Figure A4: Two Stories Building with Doors, Windows, and Columns

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

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

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

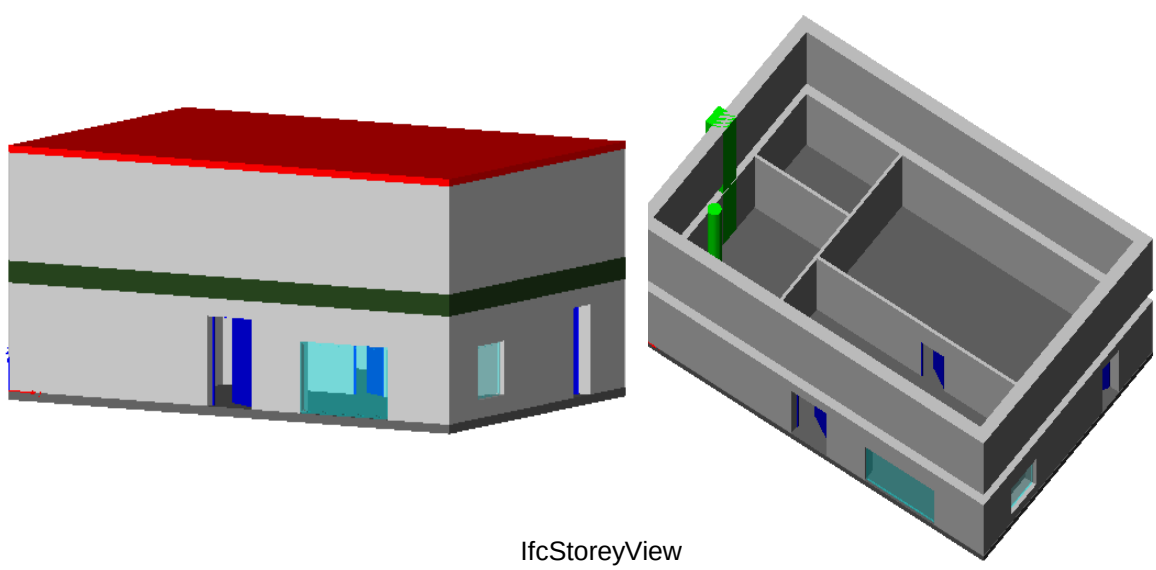
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
7. Exterior Wall (2nd floor south)	Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (0, 0, 3.61)	WA26	12-in LW CMU Fill insulation Gypsum board	B2010 Exterior Walls
8. Exterior Wall (2nd floor north)	Length: 15 m Height: 3 m Thickness: 0.41 m Origin: (15, 10, 3.61)	WA26	12-in LW CMU Fill insulation Gypsum board	B2010 Exterior Walls
9. Interior Wall (1st floor hori.)	Length: 4 m Height: 3 m Thickness: 0.12 m Origin: (0, 6, 0)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
10. Interior Wall (1st floor vert.)	Length: 9.1 m Height: 3 m Thickness: 0.12 m Origin: (5, 0, 0)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
11. Interior Wall (1st floor hori.)	Length: 9.9 m Height: 3 m Thickness: 0.12 m Origin: (4.6, 4.6, 0)	WA36	2 Gypsum boards Wall air space	C1010 Interior Fixed Partitions
12. Base Slab	15 m by 10 m Thickness: 0.256 m Origin: (0, 0, -0.256) X-axis: (1, 0, 0)	FA5	6-in HW concrete 4-in Gravel	A1030 Slab-on-grade
13. Floor Slab (between 1st and 2nd)	15 m by 10 m Thickness: 0.61 m Origin: (0, 0, 3) X-axis: (1, 0, 0)	FA2	Acoustical tile Air wall resistance 6-in HW concrete	B1010 Floor Construction
14. Roof Slab	15 m by 10 m Thickness: 0.2 m Origin: (0, 0, 6.61) X-axis: (1, 0, 0)	RA14	R-15 insulation 4-in LW concrete	B1020 Roof Construction
15. Exterior Door (south wall)	Width: 1.5 m Height: 2.5 m Sill to base: 0 m Origin: (6.75, 0, 0)	D3	Single door	D2030 Exterior Doors
16. Exterior Door (east wall)	Width: 1 m Height: 2.5 m Sill to base: 0 m Origin: (15, 7, 0)	D3	Single door	D2030 Exterior Doors

Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
17. Interior Door (1st floor hori. wall)	Width: 1 m Height: 2.5 m Sill to base: 0 m Origin: (9, 4.48, 0)	D1	Single door	C1010 Interior Doors
18. Exterior Window (south wall)	Width: 3 m Height: 2 m Sill to base: 0 m Origin: (9.9, 0, 0)	WIA2	Double clear air window	B2020 Exterior Windows
19. Exterior Window (east wall)	Width: 1.5 m Height: 1.5 m Sill to base: 0.5 m Origin: (15, 1.6, 0)	WIA2	Double clear air window	B2020 Exterior Windows
20. Door Opening (south wall door)	Width: 1.5 m Height: 2.5 m Thickness: 0.41 m Origin: (7.5, 0, 0)			
21. Door Opening (east wall door)	Width: 1 m Height: 2.5 m Thickness: 0.48 m Origin: (15, 7.5, 0)			
22. Door Opening (interior door)	Width: 1 m Height: 2.5 m Thickness: 0.12 m Origin: (9.56, 4.48, 0)			
23. Window Opening (south wall window)	Width: 3 m Height: 2 m Thickness: 0.41 m Origin: (11.4, 0, 0)			
24. Window Opening (east wall window)	Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (15, 2.35, 0.5)			
25. Embedded Rectangular Column	0.76 m by 0.76 m Height: 6.61 m Origin: (0.1, 5.41, 0)	C3	30-in. by 30-in. rectangular concrete column	B1020 Roof Construction
26. Freestanding Circular Column	0.5 m diameter Height: 6.61 m Origin: (2, 2, 0)	C4	20-in diameter concrete round column	B1020 Roof Construction

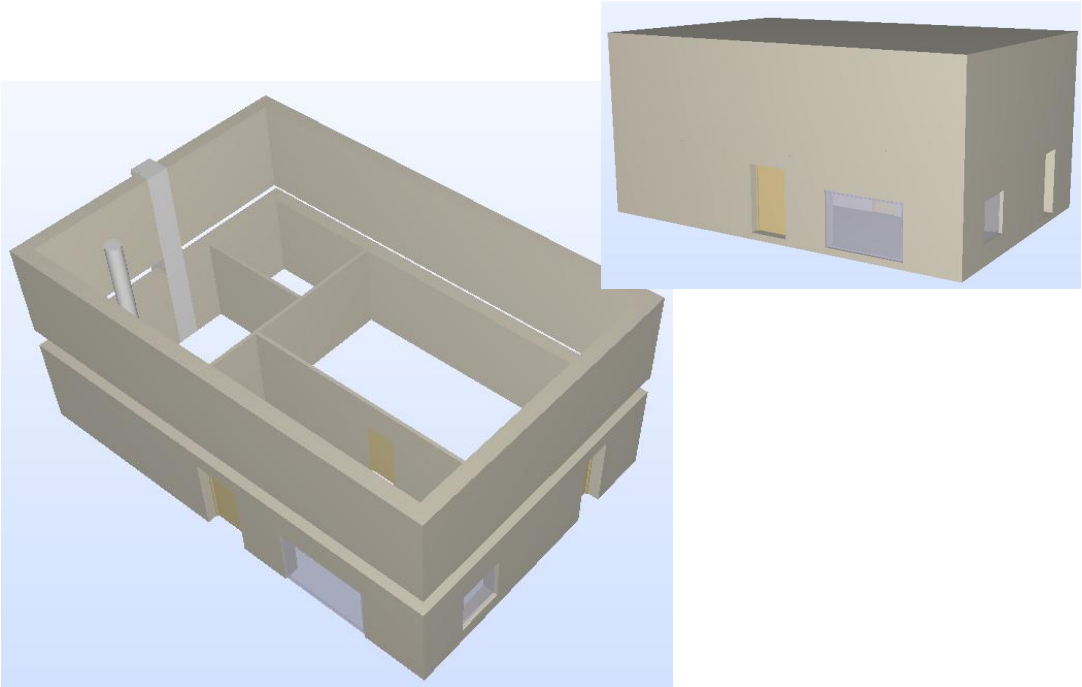
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
27. Space (Room 101)	Length: 4 m Width: 3 m Height: 3 m Origin: (0.48, 6.6, 0)			
28. Space (Room 102)	Length: 4 m Width: 6 m Height: 3 m Origin: (0.48, 0.48, 0)			
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 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.

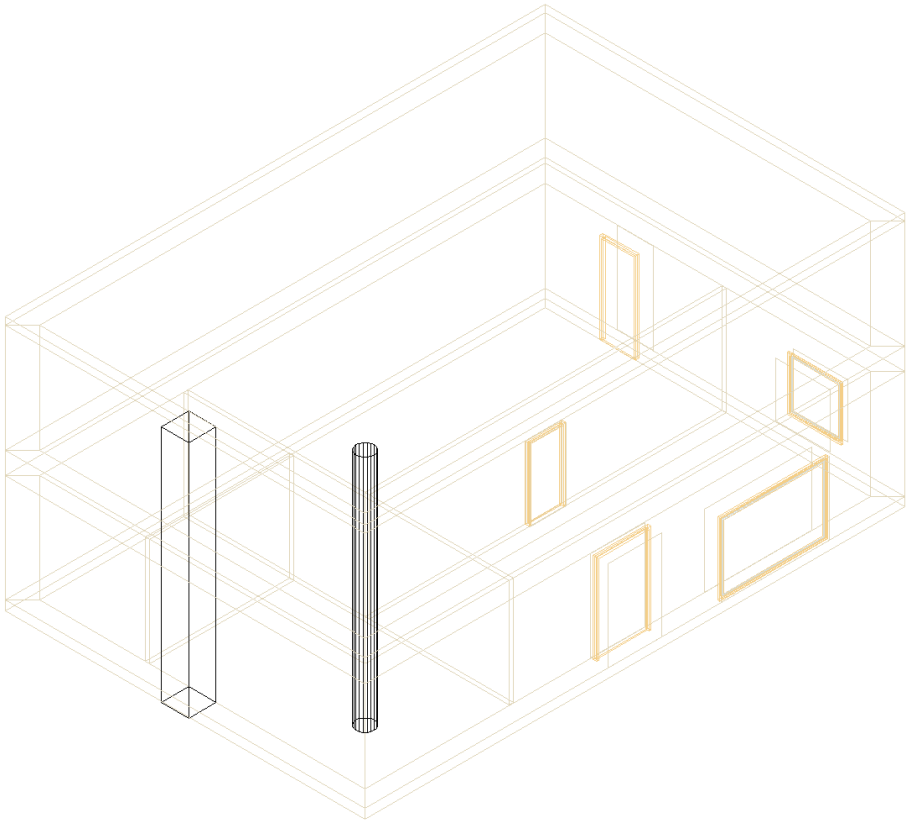
Screenshots of the building model in different IFC Viewers



IfcStoreyView



Solibri Model Checker



DDS-CAD Viewer

Testing Details for BPEA Test Case 3

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**

___ 11 IfcWallStandardCase
___ 5 IfcOpeningElement
___ 2 IfcWindow
___ 2 IfcColumn
___ 3 IfcSlab
___ 3 IfcDoor
___ 5 IfcSpace

Project

- **Project identifier is required**

___ IfcProject.LongName = “BPEA Test Case 3”

Sample IFC Code[1]:

```
#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 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 '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 0.005 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= IFCPROPERTYSINGLEVALUE('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= 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:

```
#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.));

#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**[1]

___ 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= IFCAXIS2PLACEMENT3D(#3566,#36,#3562);
         #3566= IFCCARTESIANPOINT((0.,10.,0.));
         #36= IFCDIRECTION((0.,0.,1.));
         #3562= IFCDIRECTION((0.,-1.,0.));
   #3646= IFCPRODUCTDEFINITIONSHAPE($,$,(#3607,#3640));
      #3640= IFCSHAPEREPRESENTATION(#271,'Body','SweptSolid',(#3637));
         #3637= IFCEXTRUDEDAREASOLID(#3633,#3634,#36,3.);
            #3633= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#3629);
               #3629= IFCPOLYLINE((#3613,#3617,#3621,#3625,#3613));
                  #3613= IFCCARTESIANPOINT((0.07,0.));
                  #3617= IFCCARTESIANPOINT((9.93,0.));
                  #3621= IFCCARTESIANPOINT((9.52,0.48));
                  #3625= IFCCARTESIANPOINT((0.48,0.48));
            #3634= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #40= IFCCARTESIANPOINT((0.,0.,0.));
               #36= IFCDIRECTION((0.,0.,1.));
               #28= IFCDIRECTION((1.,0.,0.));

#3742= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#3576),#3716);
   #3716= IFCPROPERTYSET(GUID,#3720,'Pset_WallCommon',$,(#3722,#3726));
      #3722= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #3726= IFCPROPERTYSINGLEVALUE('IsExternal',$,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 #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 = 0.0001 (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:

```
#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');
```

Verdict Criteria Summary for 1st Floor Exterior Walls				
	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,0.)	(15.,0.,0.)	(0.,0.,0.)	(0.,10.,0.)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.07),(15.,0.07) (14.52,0.48), (0.48,0.48)	(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)	(0.,0.07),(15.,0.07) (14.52,0.48) (0.48,0.48)	(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)
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 - Insulation Batt Thickness: 0.092075 m - Gypsum Board Thickness: 0.015875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Block Masonry 0.3048 m - Insulation Batt 0.092075 m - Gypsum Board 0.015875 m	- Outside Surface Resistance 0.001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.001 m
Corresponding code line number in reference IFC file	#3406 (dimension and geometry) #3480 (materials) #3544 (properties)	#1961 (dimension and geometry) #2035 (materials) #3374 (properties)	#236 (dimension and geometry) #317 (materials) #1655 (properties)	#3576 (dimension and geometry) #3650 (materials) #3742 (properties)

Verdict Criteria Summary for 2nd Floor Exterior Walls				
	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,3.61)	(15.,0.,3.61)	(0.,0.,3.61)	(0.,10.,3.61)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.07),(15.,0.07) (14.52,0.48), (0.48,0.48)	(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)	(0.,0.07),(15.,0.07) (14.52,0.48) (0.48,0.48)	(0.,0.07), (9.93,0.), (9.52,0.48), (0.48,0.48)
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 - Insulation Batt Thickness: 0.092075 m - Gypsum Board Thickness: 0.015875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Block Masonry 0.3048 m - Insulation Batt 0.092075 m - Gypsum Board 0.015875 m	- Outside Surface Resistance 0.001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.001 m
Corresponding code line number in reference IFC file	#5991 (dimension and geometry) #6065 (materials) #6129 (properties)	#5821 (dimension and geometry) #5895 (materials) #5959 (properties)	#5683 (dimension and geometry) #5757 (materials) #5793 (properties)	#6161 (dimension and geometry) #6235 (materials) #6327 (properties)

Verdict Criteria Summary for all Interior Walls				
	1st Floor Left Horizontal Wall	1st Floor Right Horizontal Wall	1st Floor Vertical Wall	
Wall dimension and geometry				
Origin of LCS	(0.,6.46,0.)	(4.54,4.54,0.)	(4.54,0.,0.)	
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	 Area (0.,0.,0.) 3 m. (0.,0.,1.)	
Cartesian points for the swept area (from origin of LCS)	(0.48,-0.06), (4.48,-0.06), (4.48,0.06), (0.48,0.06)	(0.06,-0.06), (9.98,-0.06), (9.98,0.06), (0.06,0.06)	(0.48,-0.06), (9.52,-0.06), (9.52,0.06), (0.48,0.06)	
Wall properties				
Construction type	WA36	WA36	WA36	
UniFormat classification	C1010 Interior Fixed Partitions	C1010 Interior Fixed Partitions	C1010 Interior Fixed Partitions	
Exterior / Interior	Interior	Interior	Interior	
Wall material association				
Layer name	WA36	WA36	WA36	
Material layer and thickness	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Inside Surface Resistance 0.0001 m - Gypsum Board 0.015875 m - Wall Air Space Resistance 0.092075 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	
Corresponding code line number in reference IFC file	#3981 (dimension and geometry) #4055 (materials) #4147 (properties)	#4175 (dimension and geometry) #4249 (materials) #4765 (properties)	#3785 (dimension and geometry) #3859 (materials) #3951 (properties)	

Verdict Criteria Summary for all Slabs				
	Base slab	Floor slab	Roof slab	
Slab dimension and geometry				
Origin of LCS	(0.,0.,-0.256)	(0.,0.,3.)	(0.,0.,6.61)	
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 0.256 m. (0.,0.,1.)	 Area (0.,0.,0.) 0.61 m. (0.,0.,1.)	 Area (0.,0.,0.) 0.2 m. (0.,0.,1.)	
Cartesian points for the swept area (from origin of LCS)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	(0.,0.), (15.,0), (15.,10.), (0.,10.)	
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	
Corresponding code line number in reference IFC file	#5085 (dimension and geometry) #5384 (materials) #5407 (properties)	#6344 (dimension and geometry) #6458 (materials) #6481 (properties)	#6483 (dimension and geometry) #6906 (materials) #6929 (properties)	

Verdict Criteria Summary for all Openings, Doors, and Windows					
	South wall door opening	East wall door opening	Interior wall door opening	South wall window opening	East wall window opening
Opening dimen. and geometry					
Origin of LCS from the LCS of the wall	(7.5,0.07,0.)	(7.5,0.,0.)	(5.,-0.07,0.)	(11.5,0.07,0.)	(2.5,0.,0.5)
XYZ directions of LCS relative to XYZ of LCS of the wall	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position from LCS Depth Direction in LCS	 Area (0.,0.,0.) 0.41 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.12 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.41 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)
Rectangle Profile Center from LCS XDim, YDim	 (0.,1.25) 1.5, 2.5	 (0.,1.25) 1, 2.5	 (0.,1.) 1, 2	 (0.,1.) 3, 2	 (0.,0.75) 1.5, 1.5
Code line number in reference IFC file	#361	#2079	#4293	#801	#2513
	South wall door	East wall door	Interior wall door	South wall window	East wall window
Door / Window dimension and geometry					
Shape representation	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box
Overall Height Overall Width	2.5 m 1.5 m	2.5 m 1 m	2 m 1 m	2 m 3 m	1.5 m 1.5 m
Door / Window properties					
Construction type	D3	D3	D1	WIA2	WIA2
UniFormat classification	D2030 Exterior Doors	D2030 Ext. Doors	C1010 Interior Doors	B2020 Exterior Windows	B2020 Ext. Windows
Exterior / Interior	Exterior	Exterior	Interior	Exterior	Exterior
Code line number in reference IFC file	#705 #746	#2419 #2452	#4633 #4666	#1567 #1608	#3277 #3310

Verdict Criteria Summary for all Columns				
	Rectangular column	Round column		
Column dimension and geometry Origin of LCS XYZ directions of LCS Shape representation Extrusion: Profile type Position Depth Direction Profile Center from LCS XDim, YDim OR Radius	 (0.1,5.,0.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) Body: Swept Solid Area (0.,0.,0.) 6.61 m. (0.,0.,1.) Rectangle (0.,0.) 0.76, 0.76	 (2.,2.,0.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) Body: Swept Solid Area (0.,0.,0.) 6.61 m. (0.,0.,1.) Circular (0.,0.) 0.25		
Column properties Construction type UniFormat classification Exterior / Interior **Column material association** Material	 C3 B1020 Roof Construction Exterior Concrete Structural	 C4 B1020 Roof Construction Interior Concrete Structural		
Corresponding code line number in reference IFC file	#4775 (dimension and geometry) #4972 (materials) #4997 (properties)	#5001 (dimension and geometry) #5058 (materials) #5081 (properties)		

Verdict Criteria Summary for all Spaces						
	Origin of LCS	XYZ Direction of LCS	Shape Repr.	Extrusion: Profile type, Position, Depth, Direction	Cartesian points of swept area (from origin of LCS)	Space Properties: Longname, Ext. / Int.
Room 101 (#5522 in Reference IFC file)	(0.48,6.53,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (4.,0.), (4.,3.), (0.,3.)	“Room 101” Internal
Room 102 (#5458)	(0.48,0.48,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (4.,0.), (4.,5.92), (0.,5.92)	“Room 102” Internal
Room 103 (#5640)	(4.6,0.48,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (9.92,0.), (9.92,4.), (0.,4.)	“Room 103a” Internal
Room 104 (#5581)	(4.6,4.6,0.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (9.92,0.), (9.92,4.92), (0.,4.92)	“Room 104” Internal
Room 201 (#6978)	(0.48,0.48,3.61)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (14.04,0.), (14.04,9.04), (0.,9.04)	“Room 201” Internal
Total number of spaces: 5						

Verdict Criteria Summary for all Space Boundaries relating to Room 101				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
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				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
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: (-1.,0.,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: (-1.,0.,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: (4.12,0.,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: (0.,0.,0.) P2: (4.,0.,0.) P3: (4.,3.,0.) P4: (0.,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: (-1.,0.,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.,1.,0.) 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				

Verdict Criteria Summary for all Space Boundaries relating to Room 103				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 103 Space Boundary 1 (#8205 in Reference IFC)	"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 (#8285)	"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 (#8373)	"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: (4.,0.,0.) P3: (4.,3.,0.) P4: (0.,3.,0.)
Room 103 Space Boundary 4 (#8417)	"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.) P6: (9.92,0.,0.) P7: (9.92,3.,0.) P8: (0.,3.,0.)
Room 103 Space Boundary 5 (#8513)	"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 (#8465)	"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 (#8561)	"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 (#8613)	"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 (#8245)	"2nd Level" Physical External	Room 103 (#5640)	Base Slab (#5085)	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.,9.92,0.) P4: (0.,9.92,0.)
Room 103 Space Boundary 10 (#8325)	"2nd Level" Physical Internal Type 2a	Room 103 (#5640)	Floor Slab (#6344)	Origin: (0.,0.,3.) 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				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 104 Space Boundary 1 (#7825 in Reference IFC)	"2nd Level" Physical External	Room 104 (#5581)	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: (4.92,0.,0.) P3: (4.92,3.,0.) P4: (0.,3.,0.)
Room 104 Space Boundary 2 (#7965)	"2nd Level" Physical External	Room 104 (#5581)	1st Floor North Wall (#3406)	Origin: (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.)
Room 104 Space Boundary 3 (#8109)	"2nd Level" Physical Internal Type 2a	Room 104 (#5581)	1st Floor Vertical Interior Wall (#3785)	Origin: (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: (0.,3.,0.)
Room 104 Space Boundary 4 (#7921)	"2nd Level" Physical Internal Type 2a	Room 104 (#5581)	1st Floor Vertical Interior Wall (#3785)	Origin: (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: (3.12,3.,0.)
Room 104 Space Boundary 5 (#8165)	"2nd Level" Physical Internal Type 2b (due to 1st floor hori. left wall)	Room 104 (#5581)	1st Floor Vertical Interior Wall (#3785)	Origin: (0.,4.92,0.) X: (0.,-1.,0.) Y: (0.,0.,1.) Z: (-1.,0.,0.) P1: (3.,0.,0.) P2: (3.12,0.,0.) P3: (3.12,3.,0.) P4: (3.,3.,0.)
Room 104 Space Boundary 6 (#7745)	"2nd Level" Physical Internal Type 2a	Room 104 (#5581)	1st Floor Horizontal Interior Wall (#4175)	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 104 Space Boundary 7 (#8013)	"2nd Level" Physical External	Room 104 (#5581)	1st Floor East Wall Ext. Door (#2419)	Origin: (9.92,0.,0.) X: (0.,1.,0.) Y: (0.,0.,1.) Z: (1.,0.,0.) P1: (2.4,0.,0.) P2: (3.4,0.,0.) P3: (3.4,2.5,0.) P4: (2.4,2.5,0.)
Room 104 Space Boundary 8 (#8061)	"2nd Level" Physical Internal Type 2a	Room 104 (#5581)	1st Floor Interior Door (#4633)	Origin: (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.)
Room 104 Space Boundary 9 (#7785)	"2nd Level" Physical External	Room 104 (#5581)	Base Slab (#5085)	Origin: (0.,0.,0.) X: (0.,1.,0.) Y: (1.,0.,0.) Z: (0.,0.,-1.) P1: (0.,0.,0.) P2: (4.92,0.,0.) P3: (4.92,9.92,0.) P4: (0.,9.92,0.)
Room 104 Space Boundary 10 (#7865)	"2nd Level" Physical Internal Type 2a	Room 104 (#5581)	Floor Slab (#6344)	Origin: (0.,0.,3.) X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.) P1: (0.,0.,0.) P2: (9.92,0.,0.) P3: (9.92,4.92,0.) P4: (0.,4.92,0.)
Count of Space Boundaries relating to Room 104 = 10				

Verdict Criteria Summary for all Space Boundaries relating to Room 201				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
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.)

Verdict Criteria Summary for all Space Boundaries relating to Room 201 (Continued)				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room 201 Space Boundary 10 (#9073)	"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: (4.12,4.12,0.) P2: (9.04,4.12,0.) P3: (9.04,14.04,0.) P4: (4.12,14.04,0.)
Room 201 Space Boundary 11 (#9201)	"3rd Level" Physical Internal Type 2b (due to 1st Floor Interior Walls)	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.,0.) P2: (5.92,4.,0.) P3: (5.92,0.,0.) P4: (6.04,0.,0.) P5: (6.04,4.,0.) P6: (9.04,4.,0.) P7: (9.04,4.12,0.) P8: (4.12,4.12,0.) P9: (4.12,14.04,0.) P10: (4.,14.04,0.) P11: (4.,4.12,0.) P12: (0.,4.12,0.)
Room 201 Space Boundary 12 (#8773)	"2nd Level" Physical External	Room 201 (#6978)	Roof Slab (#6483)	Origin: (0.,0.,3.) X: (1.,0.,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.

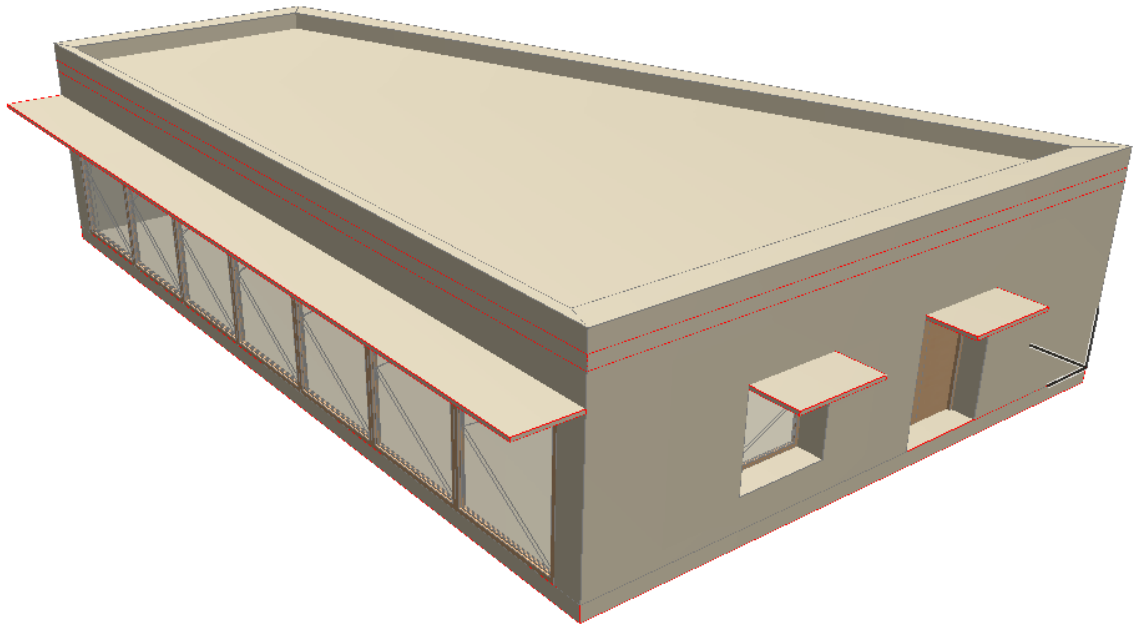


Figure A5: One Story Non-rectangular Building with Curtain Wall and Shading Devices

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

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

* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

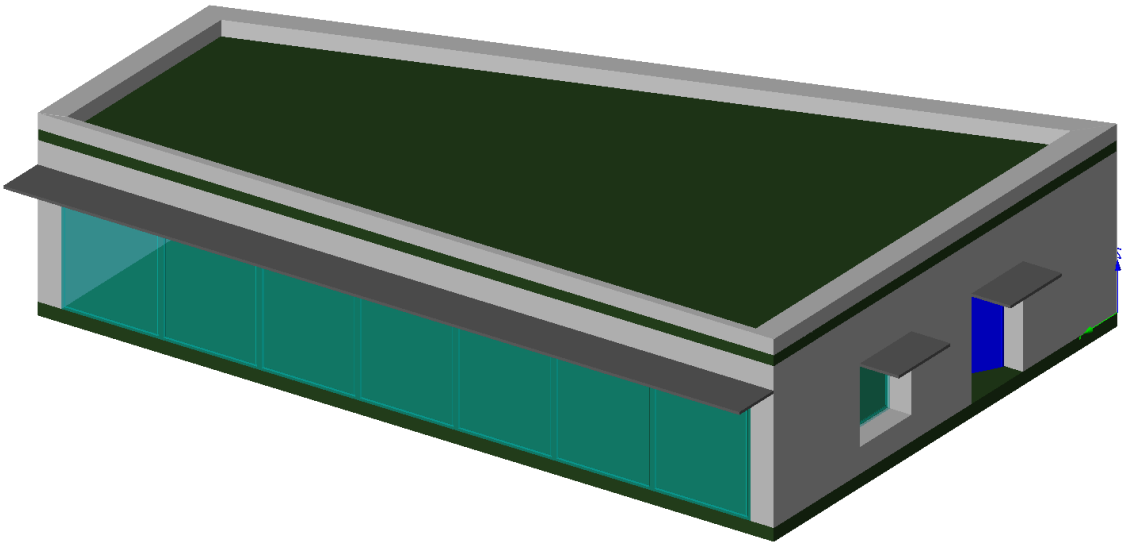
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
7. Exterior Door (west wall)	Width: 1.5 m Height: 2 m Sill to base: 0 m Origin: (4.25, 0, 0)	D3	Double door	D2030 Exterior Doors
8. Exterior Window (west wall)	Width: 1.5 m Height: 1.5 m Sill to base: 0.5 m Origin: (7.5, 0, 0)	WIA2	Double clear air window	B2020 Exterior Windows
9. Curtain Wall Window 1 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (2.48, 10, 0)	WIA2	Double clear air window	B2020 Exterior Windows
10. Curtain Wall Window 2 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (4.48, 10, 0)	WIA2	Double clear air window	B2020 Exterior Windows
11. Curtain Wall Window 3 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (6.48, 10, 0)	WIA2	Double clear air window	B2020 Exterior Windows
12. Curtain Wall Window 4 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (8.48, 10, 0)	WIA2	Double clear air window	B2020 Exterior Windows
13. Curtain Wall Window 5 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (10.48,10,0)	WIA2	Double clear air window	B2020 Exterior Windows
14. Curtain Wall Window 6 (north wall)	Width: 2 m Height: 2.5 m Sill to base: 0 m Origin: (12.48,10,0)	WIA2	Double clear air window	B2020 Exterior Windows
15. Curtain Wall Window 7 (north wall)	Width: 2.04 m Height: 2.5 m Sill to base: 0 m Origin: (14.52,10,0)	WIA2	Double clear air window	B2020 Exterior Windows
16. Door Opening (west wall door)	Width: 1.5 m Height: 2 m Thickness: 0.48 m Origin: (0, 3.5, 0)			

Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
23. Window Opening (west wall window)	Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (0, 6.75, 0.5)			
24. Window Opening (curtain wall window 1)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (1.48, 10, 0)			
25. Window Opening (curtain wall window 2)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (3.48, 10, 0)			
26. Window Opening (curtain wall window 3)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (5.48, 10, 0)			
27. Window Opening (curtain wall window 4)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (7.48, 10, 0)			
28. Window Opening (curtain wall window 5)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (9.48, 10, 0)			
29. Window Opening (curtain wall window 6)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (11.48, 10, 0)			
30. Window Opening (curtain wall window 7)	Width: 2 m Height: 2.5 m Thickness: 0.165 m Origin: (13.5, 10, 0)			
31. Shading Device Slab (west wall door)	0.8 m by 1.5 m Thickness: 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 Thickness: 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

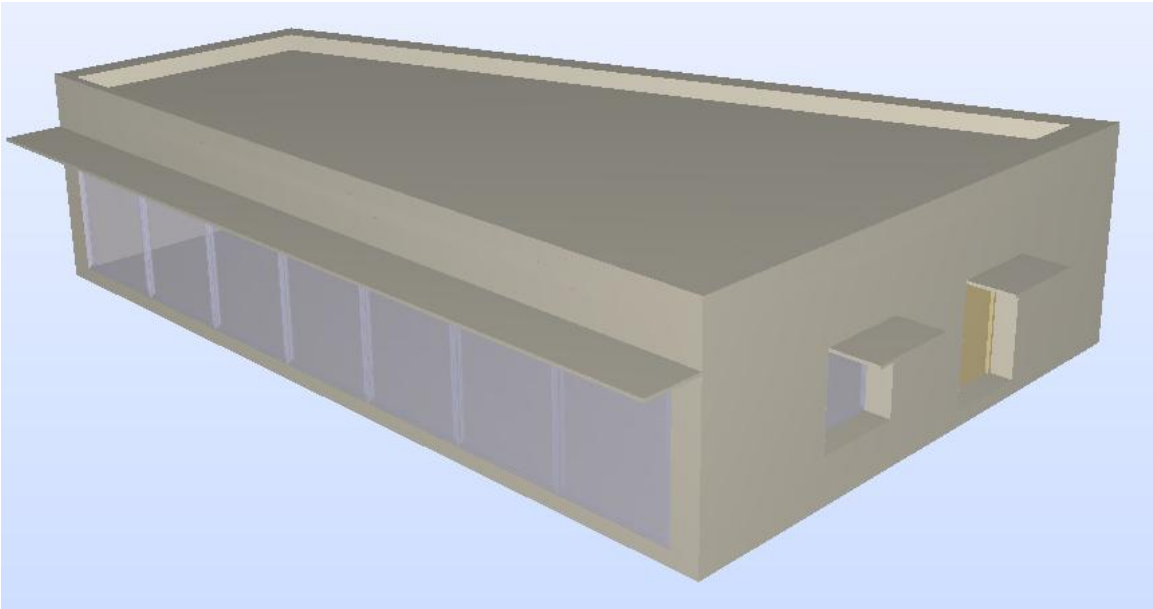
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
33. Shading Device Slab (entire curtain wall windows)	15 m by 1 m Thickness: 0.054 m Origin: (0, 10, 2.5) X-axis (1, 0, 0)	FA4	Metal surface 2-in lightweight concrete	B2010 Exterior Protection Devices for Openings
34. Space (Room)	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.)			

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 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.”

- **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 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 '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 0.005 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:

```
#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:

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

- **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= 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:

```
#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**[1]

___ 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]:

```
#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= IFCSHAPEREPRESENTATION(#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',$,(#5575,#5579));
      #5575= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #5579= IFCPROPERTYSINGLEVALUE('IsExternal',$,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				
	North Wall	East Wall	South Wall	West Wall
Wall dimension and geometry				
Origin of LCS	(15.,10.,0.)	(15.,5.,0.)	(0.,0.,0.)	(0.,10.,0.)
XYZ directions of LCS	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	X: (0.95,0.32,0.) Z: (0.,0.,1.)	X: (0.,-1.,0.) Y: (1.,0.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position Depth Direction	 Area (0.,0.,0.) 3.5 m. (0.,0.,1.)	 Area (0.,0.,0.) 3.5 m. (0.,0.,1.)	 Area (0.,0.,0.) 3.5 m. (0.,0.,1.)	 Area (0.,0.,0.) 3.5 m. (0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.), (15.,0.) (14.52,0.165), (0.48,0.165)	(0.,0.), (5.,0.), (4.83,0.48), (0.35,0.48)	(0.,0.), (15.81,0.), (15.47,0.48), (0.67,0.48)	(0.,0.), (10.,0.), (9.33,0.48), (0.165,0.48)
Wall properties				
Construction type	WA41	WA34	WA34	WA34
UniFormat classification	B2020 Glazed Curtain Walls	B2010 Exterior Wall Construction	B2010 Exterior Wall Construction	B2010 Exterior Wall Construction
Exterior / Interior	Exterior	Exterior	Exterior	Exterior
Wall material association				
Layer name	WA41	WA34	WA34	WA34
Material layer and thickness	- Opaque Spandrel Glass Thickness: 0.0064 m - R-19 Batt Insulation Thickness: 0.15875 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Outside Surface Resistance 0.0001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.0001 m	- Outside Surface Resistance 0.001 m - 12-in HW Concrete 0.3048 m - R-19 Batt Insulation 0.15875 m - Gypsum Board 0.015875 m - Inside Surface Resistance 0.001 m
Corresponding code line number in reference IFC file	#732 (dimension and geometry) #806 (materials) #4005 (properties)	#508 (dimension and geometry) #582 (materials) #646 (properties)	#359 (dimension and geometry) #440 (materials) #478 (properties)	#4037 (dimension and geometry) #4111 (materials) #5595 (properties)

Verdict Criteria Summary for all Slabs			
	Base Slab	Roof Slab	
Slab dimension and geometry Origin of LCS XYZ directions of LCS Shape representation Extrusion: Profile type Position Depth Direction Cartesian points for the swept area (from origin of LCS)	 (0.,0.,-0.256) X: (0.95,0.32,0.) Z: (0.,0.,1.) Body: Swept Solid Area (0.,0.,0.) 0.256 m. (0.,0.,1.) (0.,0.), (15.81,0.), (17.39,4.74), (3.16,9.49)	 (0.,0.,3.) X: (0.95,0.32,0.) Z: (0.,0.,1.) Body: Swept Solid Area (0.,0.,0.) 0.2 m. (0.,0.,1.) (0.,0.), (15.81,0.), (17.39,4.74), (3.16,9.49)	
Slab properties Construction type UniFormat classification Exterior / Interior **Slab material association** Layer name Material layer and thickness	 FA5 A1030 Slabs-On- Grade Exterior FA5 - 6-in Heavyweight Concrete 0.1524 m - Vapor Barrier 0.002 m - 4-in Gravel 0.1016 m	 RA14 B1020 Roof Construction Exterior RA14 - Outside Surface Resistance Thickness: 0.0001 m - Built-up Roofing Thickness: 0.0095 m - Fiberboard Sheathing Thickness: 0.0127 m - R-15 Insulation Board Thickness: 0.0762 m - 4-in LW Concrete Thickness: 0.1016 m - Inside Surface Resistance Thickness: 0.0001 m	
Corresponding code line number in reference IFC file	#5612 (dimension and geometry) #5915 (materials) #6938 (properties)	#5942 (dimension and geometry) #6369 (materials) #6392 (properties)	

Verdict Criteria Summary for all Shading Device Slabs			
	Curtain Wall Shading	Door Shading	Window Shading
Slab dimension and geometry			
Origin of LCS	(0.,10.,2.5)	(0.,2.75,2.)	(0.,6.,2.)
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)	X: (-1.,0.,0.) Y: (0.,-1.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion:			
Profile type	Area	Area	Area
Position	(0.,0.,0.)	(0.,0.,0.)	(0.,0.,0.)
Depth	0.054 m.	0.054 m.	0.054 m.
Direction	(0.,0.,1.)	(0.,0.,1.)	(0.,0.,1.)
Cartesian points for the swept area (from origin of LCS)	(0.,0.), (15.,0.), (15.,1.), (0.,1.)	(0.,0.), (0.8,0), (0.8,-1.5), (0.,-1.5)	(0.,0.), (0.8,0), (0.8,-1.5), (0.,-1.5)
Slab properties			
Construction type	FA4	FA4	FA4
UniFormat classification	B2010 Exterior Protection Devices for Openings	B2010 Exterior Protection Devices for Openings	B2010 Exterior Protection Devices for Openings
Exterior / Interior	Exterior	Exterior	Exterior
Slab material association			
Layer name	FA4	FA4	FA4
Material layer and thickness	- Outside Surface Resistance Thickness: 0.0001 m - Metal Surface Thickness: 0.003175 m - 2-in LW Concrete Roof Ballast Thickness: 0.0508 m - Outside Surface Resistance Thickness: 0.0001 m	- Outside Surface Resistance Thickness: 0.0001 m - Metal Surface Thickness: 0.003175 m - 2-in LW Concrete Roof Ballast Thickness: 0.0508 m - Outside Surface Resistance Thickness: 0.0001 m	- Outside Surface Resistance Thickness: 0.0001 m - Metal Surface Thickness: 0.003175 m - 2-in LW Concrete Roof Ballast Thickness: 0.0508 m - Outside Surface Resistance Thickness: 0.0001 m
Corresponding code line number in reference IFC file	#6396 (dimension and geometry) #6673 (materials) #6696 (properties)	#6700 (dimension and geometry) #6774 (materials) #6797 (properties)	#6799 (dimension and geometry) #6873 (materials) #6896 (properties)

Verdict Criteria Summary for all Openings					
	West wall door opening	West wall window opening	Curtain wall window opening 1	Curtain wall window opening 2	Curtain wall window opening 3
Opening dimen. and geometry					
Origin of LCS from the LCS of the wall	(6.5,0.,0.)	(3.25,0.,0.5)	(13.52,0.,0.)	(11.52,0.,0.)	(9.52,0.,0.)
XYZ directions of LCS relative to XYZ of LCS of the wall	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid
Extrusion: Profile type Position from LCS Depth Direction in LCS	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)
Area Cartesian points / rectangle center & X,Y Dim	Rect. profile (0.,1.) 1.5, 2	Rect. profile (0.,0.75) 1.5, 1.5	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)
Code line number in reference IFC file	#4155	#4706	#859	#1730	#2576
	Curtain wall window opening 4	Curtain wall window opening 5	Curtain wall window opening 6	Curtain wall window opening 7	
Opening dimen. and geometry					
Origin of LCS from the LCS of the wall	(7.52,0.,0.)	(5.52,0.,0.)	(3.52,0.,0.)	(1.5,0.,0.)	
XYZ directions of LCS relative to XYZ of LCS of the wall	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) 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 (0.,0.,0.) 0.165 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.165 m. (0.,1.,0.)	
Cartesian points for the swept area (from origin of LCS)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	(-1.,0.), (1.,0.) (1.,2.5), (-1.,2.5)	
Code line number in reference IFC file	#2728	#2880	#3014	#3148	

Verdict Criteria Summary for all Doors and Windows					
	West wall door	West wall window	Curtain wall window 1	Curtain wall window 2	Curtain wall window 3
Door / Window dimension and geometry					
Shape representation	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box
Overall Height Overall Width	2 m 1.5 m	1.5 m 1.5 m	2.5 m 2 m	2.5 m 2 m	2.5 m 2 m
Door / Window properties					
Construction type	D3	WIA2	WIA2	WIA2	WIA2
UniFormat classification	D2030 Exterior Doors	B2020 Exterior Windows	B2020 Exterior Windows	B2020 Exterior Windows	B2020 Exterior Windows
Exterior / Interior	Exterior	Exterior	Exterior	Exterior	Exterior
Code line number in reference IFC file	#4608 #4649	#5470 #5503	#1625 #1666	#2490 #2523	#2642 #2675
	Curtain wall window 4	Curtain wall window 5	Curtain wall window 6	Curtain wall window 7	
Door / Window dimension and geometry					
Shape representation	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	
Overall Height Overall Width	2.5 m 2 m	2.5 m 2 m	2.5 m 2 m	2.5 m 2.04 m	
Door / Window properties					
Construction type	WIA2	WIA2	WIA2	WIA2	
UniFormat classification	B2020 Exterior Windows	B2020 Exterior Windows	B2020 Exterior Windows	B2020 Exterior Windows	
Exterior / Interior	Exterior	Exterior	Exterior	Exterior	
Code line number in reference IFC file	#2794 #2827	#2928 #2961	#3062 #3095	#3908 #3941	

Verdict Criteria Summary for all Spaces						
	Origin of LCS	XYZ Direction of LCS	Shape Repr.	Extrusion: Profile type, Position, Depth, Direction	Cartesian points of swept area (from origin of LCS)	Space Properties: Longname, Ext. / Int.
Room (#6949 in Reference IFC file)	(0.48,0.67,0.)	X: (0.95,0.32,0.) Z: (0.,0.,1.)	Body: Swept Solid	Area (0.,0.,0.) 3 m. (0.,0.,1.)	(0.,0.), (14.8,0.), (16.2,4.26), (2.9,8.7)	"Room" Internal
Total Number of Spaces: 1						

Verdict Criteria Summary for all Space Boundaries relating to "Room"				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room Space Boundary 1 (#7009 in Reference IFC)	"2nd Level" Physical External	Room (#6949)	South Wall (#359)	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.)
Room Space Boundary 2 (#7053)	"2nd Level" Physical External	Room (#6949)	Base Slab (#5612)	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.)
Room Space Boundary 3 (#7101)	"2nd Level" Physical External	Room (#6949)	East Wall (#508)	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.)
Room Space Boundary 4 (#7141)	"2nd Level" Physical External	Room (#6949)	Roof Slab (#5942)	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.)
Room Space Boundary 5 (#7189)	"2nd Level" Physical External	Room (#6949)	West Wall (#4037)	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.)
Continue to the next page				

Verdict Criteria Summary for all Space Boundaries relating to "Room" (Continued)				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
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)				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room Space Boundary 15 (#7733)	"2nd Level" Physical External	Room (#6949)	West Wall Door (#4608)	Origin: (2.9,8.7,0.) X: (-0.32,-0.95,0.) Z: (-0.95,0.32,0.) P1: (5.58,0.,0.) P2: (7.08,0.,0.) P3: (7.08,2.,0.) P4: (5.58,2.,0.)
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.

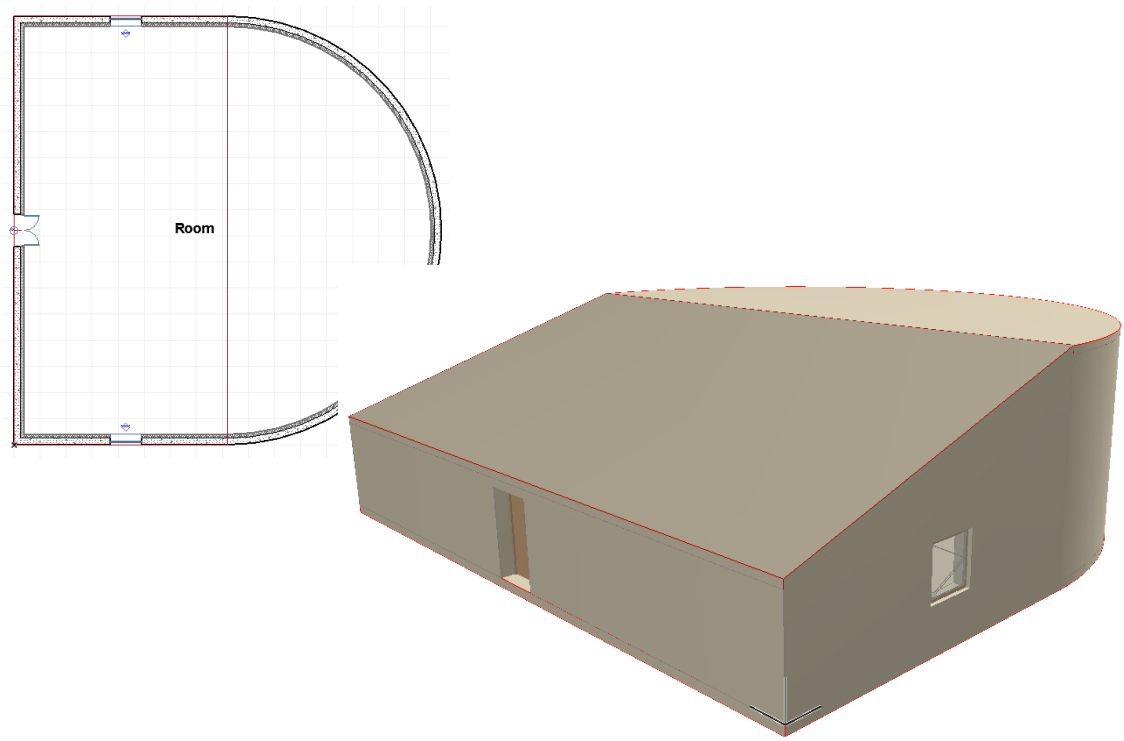


Figure A6: One Story Non-rectangular Building with Curve Wall and Sloped Roof

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

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

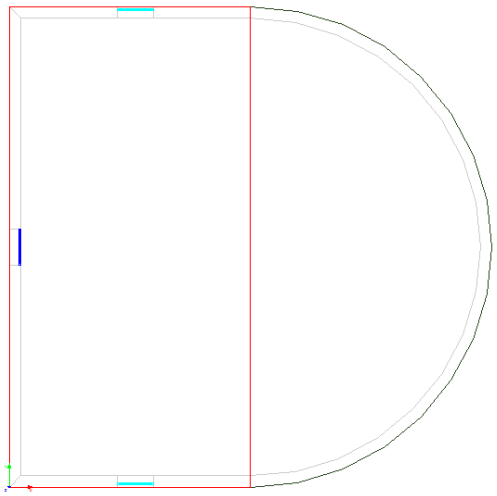
* The length of exterior walls refers to the length of the exterior side of the walls
** ASHRAE Fundamentals Chapter 30 Tables 17, 18, 19

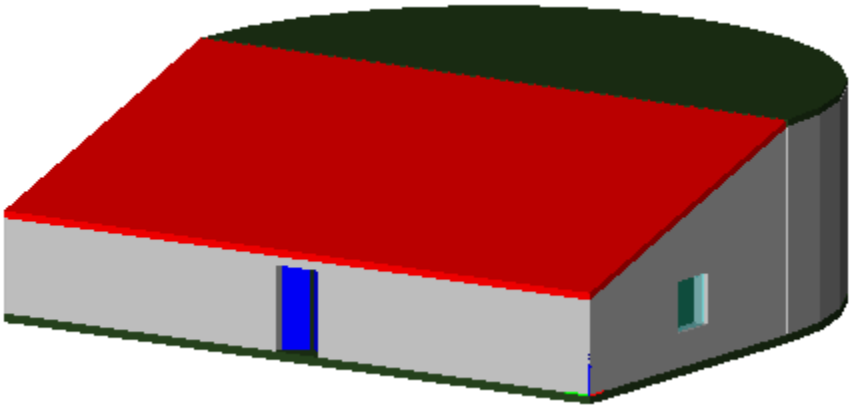
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
5. Base Slab	Thickness: 0.256 m Origin: (0, 0, -0.256) X-axis (1, 0, 0) 4 edges of the slab on the XY plane: 1. line segment from (0,0) to (10,0) 2. semicircle from (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 (the semi-circular portion)	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 (the sloped portion)	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 (west wall)	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 (south wall)	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

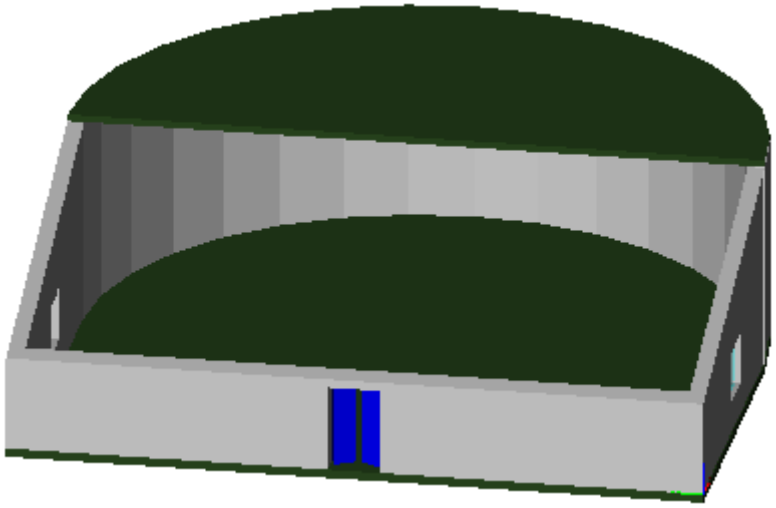
Building Elements	Dimension and Origin in World Coordinate Sys.	Construction Type (ASHRAE)	Description (ASHRAE)	UniFormat Classification
10. Exterior Window (north wall)	Width: 1.5 m Height: 1.5 m Sill to base: 1 m Origin: (4.49, 20, 0)	WIA2	Double clear air window	B2020 Exterior Windows
11. Door Opening (west wall door)	Width: 1.5 m Height: 2.5 m Thickness: 0.48 m Origin: (0, 10, 0)			
12. Window Opening (south wall window)	Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (5.24, 0, 0)			
13. Window Opening (north wall window)	Width: 1.5 m Height: 1.5 m Thickness: 0.48 m Origin: (5.24, 20, 0)			
14. Space (Room)	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) Trimmed to Roof			

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

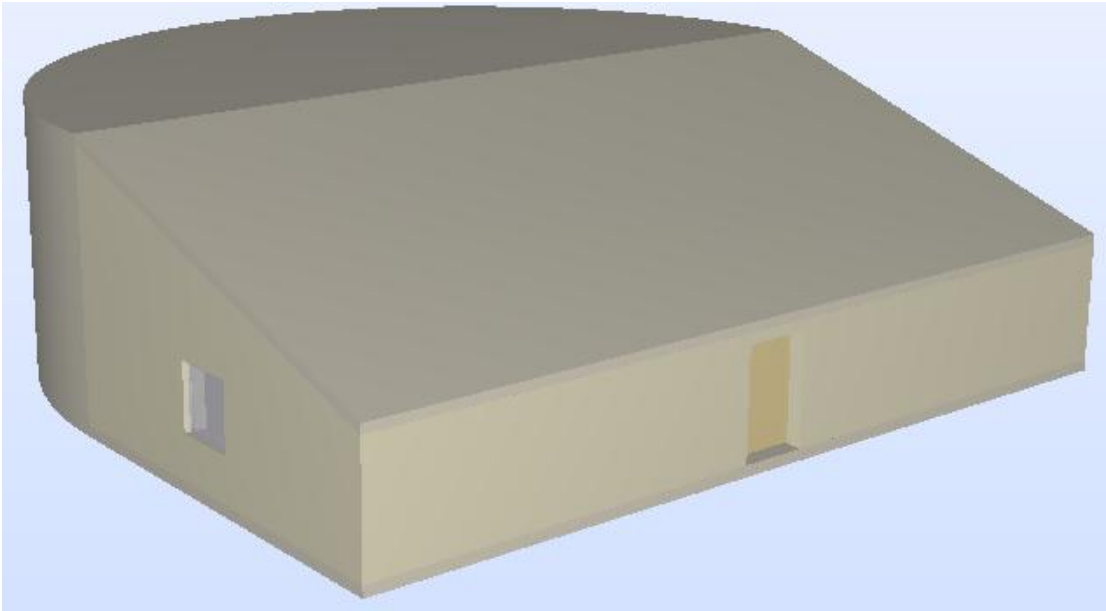
Screenshots of the building model in different IFC Viewers







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 IfcOpeningElement
___ 2 IfcWindow
___ 3 IfcSlab
___ 1 IfcDoor
___ 1 IfcSpace

Project

- **Project identifier is required**

___ IfcProject.LongName = “BPEA Test Case 5”

Sample IFC Code[1]:

```
#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 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 '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 0.005 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:

```
#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:

```
#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:

```
#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:

```
#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 (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:

```
#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= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#456);
                  #456= IFCPOLYLINE((#440,#444,#448,#452,#440));
                     #440= IFCCARTESIANPOINT((0.,0.));
                     #444= IFCCARTESIANPOINT((10.,0.));
                     #448= IFCCARTESIANPOINT((10.,0.48));
                     #452= IFCCARTESIANPOINT((0.48,0.48));
               #461= IFCAXIS2PLACEMENT3D(#40,#36,#28);
            #437= IFCPOLYGONALBOUNDEDHALFSPACE(#410,.F.,#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= IFCPOLYLINE((#413,#417,#421,#425,#429));
                  #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[1]**

___ 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= IFCPRODUCTDEFINITIONSHAPE($,$,(#2552,#2669));
      #2669= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',(#2666));
         #2666= IFCEXTRUDEDAREASOLID(#2662,#2663,#36,6.);
            #2662= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#2658);
               #2658= IFCCOMPOSITECURVE((#2593,#2612,#2635,#2654),.F.);
                  #2593= IFCCOMPOSITECURVESEGMENT(.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= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#2607);
                     #2607= IFCTRIMMEDCURVE(#2604,(IFCPARAMETERVALUE(0.),#2562),
                     (IFCPARAMETERVALUE(0.48),#2566),.T.,.CARTESIAN.);
                        #2604= IFCLINE(#2562,#2601);
                  #2635= IFCCOMPOSITECURVESEGMENT(.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= IFCCOMPOSITECURVESEGMENT(.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”

Sample IFC Code:

```
#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');
```

- **Check wall properties (All Walls)**

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)

```
#1384= IFCRELDEFINESBYPROPERTIES(GUID,#13,$,$,(#355),#1358);
   #1358= IFCPROPERTYSET(GUID,#1362,'Pset_WallCommon',$,(#1364,#1368));
      #1364= IFCPROPERTYSINGLEVALUE('Reference',$,IFCIDENTIFIER('WA34'),$);
      #1368= IFCPROPERTYSINGLEVALUE('IsExternal',$,IFCBOOLEAN(.T.),$);
```

Verdict Criteria Summary for Non-Curve Exterior Walls				
	North Wall	South Wall	West Wall	
Wall dimension and geometry				
Origin of LCS	(0.,20.,0.)	(0.,0.,0.)	(0.,0.,0.)	
XYZ directions of LCS	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (0.,1.,0.) Y: (-1.,0.,0.) Z: (0.,0.,1.)	
Shape representation	Body: Clipping, Difference	Body: Clipping, Difference	Body: Clipping, Difference	
<u>First Operand:</u> Extrusion type Profile Type Position Depth Direction	 Swept Area Solid Area (0.,0.,0.) 6 m. (0.,0.,1.)	 Swept Area Solid Area (0.,0.,0.) 6 m. (0.,0.,1.)	 Swept Area Solid Area (0.,0.,0.) 3 m. (0.,0.,1.)	
Cartesian points for the swept area (from origin of LCS)	(0.,0.), (10.,0.), (10.,0.48), (0.48,0.48)	(0.,0.), (10.,0.), (10.,0.48), (0.48,0.48)	(0.,0.), (20.,0.), (19.52,-0.48), (0.48,-0.48)	
<u>Second Operand:</u> <u>Half Space Solid</u>				
Solid Type	Polygonal Bounded Half Space Solid	Polygonal Bounded Half Space Solid	Half Space Solid	
Base Surface Origin Direction	 (-0.808,0.,2.487) X: (0.,1.,0.) Z: (-0.309, 0.,0.951)	 (-0.808,0.,2.487) X: (0.,1.,0.) Z: (-0.309, 0.,0.951)	 (-0.808,0.,2.487) X: (0.,0.951,-0.309) Z: (0.,0.309,0.951)	
Normal of Plane	Agreement Flag = F	Agreement Flag = F	Agreement Flag = F	
Polygonal Boundary Origin (in LCS) Direction	 (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)	 (0.,0.,0.), X: (1.,0.,0.), Z: (0.,0.,1.)		
Boundary coordinate points (in LCS)	(0.,-0.72) (0.,0.24) (10.,0.24) (10.,-0.72)	(0.,-0.24), (0.,0.72), (10.,0.72), (10., -0.24)		
Corresponding code line number in reference IFC file	#2153 (dimension and geometry) #2271 (materials) #2493 (properties)	#355 (dimension and geometry) #480 (materials) #1384 (properties)	#1408 (dimension and geometry) #1506 (materials) #2125 (properties)	

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.,-0.256)
___ XYZ directions: X = (1.,0.,0.), Y = (0.,1.,0.), Z = (0.,0.,1.)
___ IfcShapeRepresentation.RepresentationIdentifier = “Body”
___ IfcShapeRepresentation.RepresentationType = “SweptSolid”
___ IfcExtrudedAreaSolid.Depth = 0.256 (m.)
___ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
___ IfcExtrudedAreaSolid.Position = (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.) *(see #2870 in sample IFC code)*
___ Circle of radius 10 m with center (10.,10.) going from (10.,0.) to (10.,20.) *(#2893)*
___ Line segment from (10.,20.) to (0.,20.) *(#2912)*
___ Line segment from (0.,20.) to (0.,0.) *(#2931)*

Sample IFC Code:

```
#2820= IFCSLAB(GUID,#13,'FA5','A1030 Slabs-On-Grade',$,#2963,#2952,
$,.FLOOR.);
   #2963= IFCLOCALPLACEMENT(#90,#2960);
      #2960= IFCAXIS2PLACEMENT3D(#2956,#36,#28);
         #2956= IFCCARTESIANPOINT((0.,0.,-0.256));
         #36= IFCDIRECTION((0.,0.,1.));
         #28= IFCDIRECTION((1.,0.,0.));
   #2952= IFCPRODUCTDEFINITIONSHAPE($,$,(#2946));
      #2946= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',(#2943));
         #2943= IFCEXTRUDEDAREASOLID(#2939,#2940,#36,0.256);
            #2939= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#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.,10.));
                              #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(#2851,#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.,6.)
___ XYZ directions: X = (0.,1.,0.), Y = (-1.,0.,0.), Z = (0.,0.,1.)
___ IfcShapeRepresentation.RepresentationIdentifier = “Body”
___ IfcShapeRepresentation.RepresentationType = “SweptSolid”
___ IfcExtrudedAreaSolid.Depth = 0.2 (m.)
___ IfcExtrudedAreaSolid.ExtrudedDirection = (0.,0.,1.)
___ IfcExtrudedAreaSolid.Position = (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:

```
#3226= IFCSLAB(GUID,#13,'RA14','B1020 Roof Construction',$,#3323,#3312,
$,.ROOF.);
   #3323= IFCLOCALPLACEMENT(#90,#3320);
      #3320= IFCAXIS2PLACEMENT3D(#3316,#36,#32);
         #3316= IFCCARTESIANPOINT((10.,0.,6.));
         #36= IFCDIRECTION((0.,0.,1.));
         #32= IFCDIRECTION((0.,1.,0.));
   #3312= IFCPRODUCTDEFINITIONSHAPE($,$,(#3306));
      #3306= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',(#3303));
         #3303= IFCEXTRUDEDAREASOLID(#3299,#3300,#36,0.2);
            #3299= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#3295);
               #3295= IFCCOMPOSITECURVE((#3272,#3291),.F.);
                  #3272= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3267);
                     #3267= IFCTRIMMEDCURVE(#3264,(#3245,IFCPARAMETERVALUE(0.)),
                     (#3249,IFCPARAMETERVALUE(180.)),.T.,.CARTESIAN.);
                        #3264= IFCCIRCLE(#3261,10.);
                           #3261= IFCAXIS2PLACEMENT2D(#3257,#3253);
                              #3257= IFCCARTESIANPOINT((10.,0.));
                              #3253= IFCDIRECTION((-1.,0.));
                  #3291= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3286);
                     #3286= IFCTRIMMEDCURVE(#3283,(IFCPARAMETERVALUE(0.),#3249),
                     (IFCPARAMETERVALUE(20.),#3245),.T.,.CARTESIAN.);
                        #3283= IFCLINE(#3249,#3280);
                           #3280= IFCVECTOR(#3276,1.);
                              #3276= IFCDIRECTION((-1.,0.));
                        #3245= IFCCARTESIANPOINT((0.,0.));
                        #3249= IFCCARTESIANPOINT((20.,0.));
            #3300= 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 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,
$,.ROOF.);
   #3785= IFCLOCALPLACEMENT(#90,#3782);
      #3782= IFCAXIS2PLACEMENT3D(#3778,#3774,#3770);
         #3778= IFCCARTESIANPOINT((0.,20.,2.75));
         #3774= IFCDIRECTION((-0.309,0.,0.951));
         #3770= IFCDIRECTION((0.,-1.,0.));
   #3766= IFCPRODUCTDEFINITIONSHAPE($,$,(#3760));
      #3760= IFCSHAPEREPRESENTATION(#390,'Body','SweptSolid',(#3757));
         #3757= IFCEXTRUDEDAREASOLID(#3749,#3750,#3753,0.2);
            #3749= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#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.));
            #3750= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #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]

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:

```
#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');
```

___ 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:

```
#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					
	South wall window opening	West wall door opening	North wall window opening		
Opening dimen. and geometry					
Origin of LCS from the LCS of the wall	(5.24,0.,1.)	(10.,-0.48,0.)	(5.24,-0.48,1.)		
XYZ directions of LCS relative to XYZ of LCS of the wall	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)	X: (1.,0.,0.) Y: (0.,1.,0.) Z: (0.,0.,1.)		
Shape representation	Body: Swept Solid	Body: Swept Solid	Body: Swept Solid		
Extrusion: Profile type Position from LCS Depth Direction in LCS	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)	 Area (0.,0.,0.) 0.48 m. (0.,1.,0.)		
Rectangle Profile Center from LCS XDim, YDim	 (0.,0.75) 1.5, 1.5	 (0.,1.25) 1.5, 2.5	 (0.,0.75) 1.5, 1.5		
Code line number in reference IFC file	#524	#1550	#2315		
	South wall window	West wall door	North wall window		
Door / Window dimension and geometry					
Shape representation	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box	Body: Brep/ Swept Solid/ Bounding Box		
Overall Height Overall Width	1.5 m 1.5 m	2.5 m 1.5 m	1.5 m 1.5 m		
Door / Window properties					
Construction type	WIA2	D3	WIA2		
UniFormat classification	B2020 Exterior Windows	D2030 Ext. Doors	B2020 Exterior Windows		
Exterior / Interior	Exterior	Exterior	Exterior		
Code line number in reference IFC file	#1294 #1335	#2007 #2048	#2381 #2414		

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.)
___ XYZ directions: X = (1.,0.,0.), Y = (0.,1.,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 edges of the space (coordinates are relative to the origin (0.48, 0.48, 0.)):
  ___ Line segment from (0.,0.) to (9.52,0.) *(see #3924 in sample IFC code)*
  ___ Circle of radius 9.52 m with center (9.52,9.52) going from (9.52.,0.) to (9.52,19.04) *(see #3947 in sample IFC code)*
  ___ Line segment from (9.52,19.04) to (0.,19.04) *(see #3966)*
  ___ Line segment from (0.,19.04) to (0.,0.) *(see #3985)*

___ The second operand of clipping operation is an IfcHalfSpaceSolid
  ___ Base surface: Origin = (-0.854,0.,2.628), 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: (-0.48,-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,'',$,$,#3985,#3974,'Room',.ELEMENT.,.INTERNAL.,$);
   #4985= IFCLOCALPLACEMENT(#90,#3982);
      #3982= IFCAXIS2PLACEMENT3D(#3978,#36,#28);
         #3978= IFCCARTESIANPOINT((0.48,0.48,0.));
         #36= IFCDIRECTION((0.,0.,1.));
         #28= IFCDIRECTION((1.,0.,0.));
   #3974= IFCPRODUCTDEFINITIONSHAPE($,$,(#3968));
      #3968= IFCSHAPEREPRESENTATION(#390,'Body','Clipping',(#3965));
         #3965= IFCBOOLEANCLIPPINGRESULT(.DIFFERENCE.,#3962,#3855);
            #3962= IFCEXTRUDEDAREASOLID(#3958,#3959,#36,6.);
               #3958= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,$,#3954);
                  #3954= IFCCOMPOSITECURVE((#3889,#3912,#3931,#3950),.F.);
                     #3889= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3884);
                        #3884=IFCTRIMMEDCURVE(#3881,(IFCPARAMETERVALUE(0.),#3858),
                        (IFCPARAMETERVALUE(9.52),#3862),.T.,.CARTESIAN.);
                           #3881= IFCLINE(#3858,#3878);
                              #3878= IFCVECTOR(#3874,1.);
                                 #3874= IFCDIRECTION((1.,0.));
                     #3912= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3907);
                        #3907=IFCTRIMMEDCURVE(#3904,(#3862,IFCPARAMETERVALUE(0.)),
                        (#3866,IFCPARAMETERVALUE(180.)),.T.,.CARTESIAN.);
                           #3904= IFCCIRCLE(#3901,9.52);
                              #3901= IFCAXIS2PLACEMENT2D(#3897,#3893);
                                 #3897= IFCCARTESIANPOINT((9.52,9.52));
                                 #3893= IFCDIRECTION((0.,-1.));
                     #3931= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3926);
                        #3926=IFCTRIMMEDCURVE(#3923,(IFCPARAMETERVALUE(0.),#3866),
                        (IFCPARAMETERVALUE(9.52),#3870),.T.,.CARTESIAN.);
                           #3923= IFCLINE(#3866,#3920);
                              #3920= IFCVECTOR(#3916,1.);
                                 #3916= IFCDIRECTION((-1.,0.));
                     #3950= IFCCOMPOSITECURVESEGMENT(.CONTINUOUS.,.T.,#3945);
                        #3945=IFCTRIMMEDCURVE(#3942,(IFCPARAMETERVALUE(0.),#3870),
                        (IFCPARAMETERVALUE(19.04),#3858),.T.,.CARTESIAN.);
                           #3942= IFCLINE(#3870,#3939);
                              #3939= IFCVECTOR(#3935,1.);
                                 #3935= IFCDIRECTION((0.,-1.));
                           #3858= IFCCARTESIANPOINT((0.,0.));
                           #3862= IFCCARTESIANPOINT((9.52,0.));
                           #3966= IFCCARTESIANPOINT((9.52,19.04));
                           #3970= IFCCARTESIANPOINT((0.,19.04));
               #3959= IFCAXIS2PLACEMENT3D(#40,#36,#28);
                  #40= IFCCARTESIANPOINT((0.,0.,0.));
            #3855= IFCPOLYGONALBOUNDEDHALFSPACE(#3828,.F.,#44,#3851);
               #3828= IFCPLANE(#3825);
                  #3825= IFCAXIS2PLACEMENT3D(#3821,#3817,#32);
                     #3821= IFCCARTESIANPOINT((-0.854,0.,2.628));
                     #3817= IFCDIRECTION((-0.309,0.,0.951));
                     #32= IFCDIRECTION((0.,1.,0.));
               #44= IFCAXIS2PLACEMENT3D(#40,#36,#28);
               #3851= IFCPOLYLINE((#3831,#3835,#3839,#3843,#3847));
                  #3831= IFCCARTESIANPOINT((-0.48,-0.48));
                  #3835= IFCCARTESIANPOINT((9.52,-0.48));
                  #3839= IFCCARTESIANPOINT((9.52,19.52));
                  #3843= IFCCARTESIANPOINT((-0.48,19.52));
                  #3847= IFCCARTESIANPOINT((-0.48,-0.48));
```

Verdict Criteria Summary for all Space Boundaries relating to "Room"				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
Room Space Boundary 1 (#9804 in Reference IFC)	"2nd Level" Physical External	Room (#3988)	South Wall (#355)	Origin: (9.52,0.,6.) X: (-0.951,0.,-0.309) Z: (0.,-1.,0.) P1: (0.,0.,0.) P2: (10.,0.,0.) P3: (10.91,2.76,0.) P4: (1.85,5.71,0.)
Room Space Boundary 2 (#9860)	"2nd Level" Physical External	Room (#3988)	South Wall Window (#1294)	Origin: (9.52,0.,6.) X: (-0.951,0.,-0.309) Z: (0.,-1.,0.) P1: (5.36,3.52,0.) P2: (6.79,3.05,0.) P3: (6.32,1.63,0.) P4: (4.9,2.1,0.)
Room Space Boundary 3 (#9756)	"2nd Level" Physical External	Room (#3988)	West Wall (#1408)	Origin: (0.,0.,2.91) X: (0.,1.,0.) Z: (-1.,0.,0.) P1: (0.,0.,0.) P2: (19.04,0.,0.) P3: (19.04,2.91,0.) P8: (0,2.91,0.)
Room Space Boundary 4 (#9912)	"2nd Level" Physical External	Room (#3988)	West Wall Door (#2007)	Origin: (0.,0.,2.91) X: (0.,1.,0.) Z: (-1.,0.,0.) P1: (10.27,2.91,0.) P2: (8.77,2.91,0.) P3: (8.77,0.41,0.) P4: (10.27,0.41,0.)
Room Space Boundary 5 (#5048)	"2nd Level" Physical External	Room (#3988)	North Wall (#2153)	Origin: (0.,19.04,2.91) X: (0.951,0.309,0.) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (10.,0.,0.) P3: (8.15,5.71,0.) P4: (-0.9,2.76,0.)
Room Space Boundary 6 (#9964)	"2nd Level" Physical External	Room (#3988)	North Wall Window (#2381)	Origin: (0.,19.04,2.91) X: (0.951,0.309,0.) Z: (0.,1.,0.) P1: (4.65,3.51,0.) P2: (5.12,2.09,0.) P3: (3.69,1.63,0.) P4: (3.22,3.05,0.)
Continue to the next page				

Verdict Criteria Summary for all Space Boundaries relating to "Room" (Continued)				
	Attributes: Name Physical/Virtual Ext. / Int.	Related Space	Related Building Element	Connection Geometry: Origin relative to LCS of Space XYZ direction Points defining the outer bound of the space boundary (from origin of LCS)
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.,19.04,0.) P4: (0.,19.04,0.)
Room Space Boundary 10 (#4056) TO Room Space Boundary 106 (#5152)	"2nd Level" Physical External	Room (#3988)	Curve Wall (#2506)	Origin: (9.52,19.04,6.) X: (0.,0.,1) Z: (0.,1.,0.) P1: (0.,0.,0.) P2: (-6.,0.,0.) P2: (-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