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IFC-Bridge Fast Track Project

Report WP2: Conceptual Model

Status: DRAFT
Date: 2018-04-12

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1 Overview and methodology

The IFC-Bridge project aims at extending the IFC data model in order to allow the precise description of the semantics and geometry of bridges. It was initiated by the bSI Infra Room as a fast track project with a project duration of two years.

The scope of the bridge conceptual model has been derived from the WP1 report: Requirements analyses for the IFC-Bridge fast track extension.

Only the most common bridge types are considered to be in-scope of this project:

- Slab Bridge
- Girder Bridge
    - Slab-Girder Bridge
    - Box-girder bridge
- Frame Bridge
- Rigid Frame Bridge
- Culvert

However, it is expected that also the following bridge types will be covered reasonably well by IFC with the extension provided by this project, even though they are not subject to validation tests:

- Truss bridge
- Arch bridge
- Cantilever bridge
- Cable-stayed bridge
- Suspension bridge

From a material viewpoint, the following bridge types are covered:

- Reinforced Concrete bridges
- Prestressed Concrete bridges
- Steel/Concrete Composite bridges
- Steel girder bridges
- Steel bridges

Particular emphasis is put on the necessary data structures for modeling pre-stressing systems.

In terms or use cases, the following ones in scope of this IFC-Bridge fast track project:

- Initial State Modeling
- Import of major road / railway parameters
- Technical Visualization
- Coordination / Collison Detection
- 4D Construction Sequence Modeling

- Quantity Take-Off
- Progress Monitoring
- As-built vs. as-planned comparison
- Handover to asset management
- Handover to GIS for spatial analysis
- Design to design (reference model)
- Design to Construction

Further bridge types and use cases will be covered by future extensions of IFC-Bridge.

The recommendations for IFC infrastructure extension development outlined in IFC Infra Overall Architecture Project (TR: Documentation and Guideline) have also been observed when developing the bridge conceptual model using UML notation.

2 Basic conceptual breakdown

A bridge, like any infrastructure project can be broken down in different manners. Following the general IFC modelling principles, three main types of breakdown structure considered (Figure 1):

- spatial breakdown structure
- element breakdown structure
- system breakdown structure

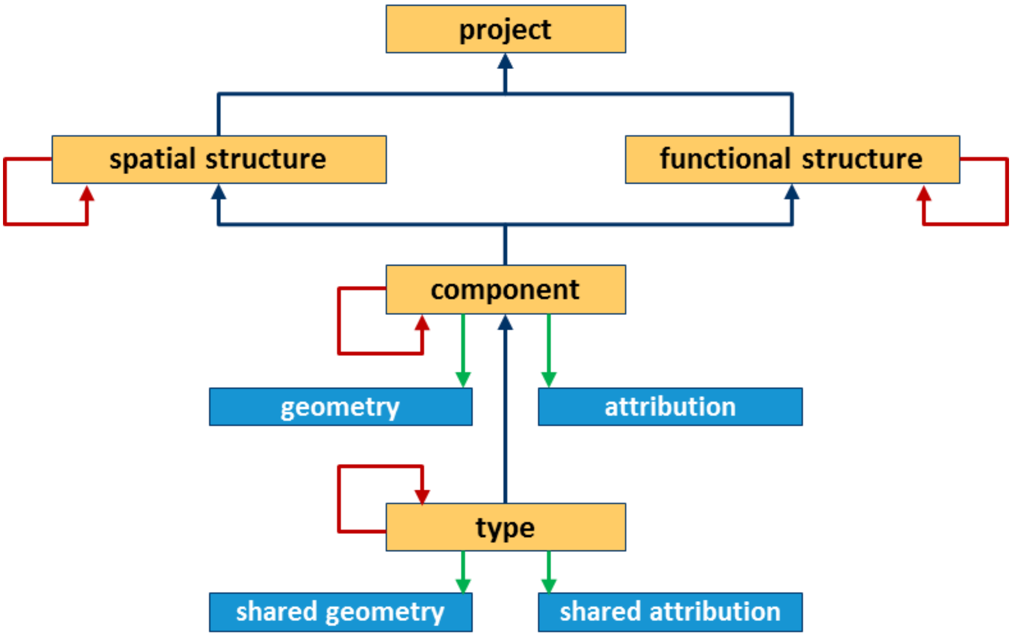

Figure 1 Three main breakdown structures in IFC.

According to this principles, each infrastructure project shall have a hierarchical spatial breakdown structure (Project: Site / Bridge / …) - with at least one level of hierarchy. All physical components (Slab / Beam / Column/ …) shall be contained in exactly once in spatial hierarchy, either directly via containment relationship, or through hierarchical component breakdown using aggregation relationships (top level component being always contained in spatial hierarchy). Physical elements may also belong to functional systems (Structural / Drainage / Signage / …) via grouping relationships (non- hierarchical). In addition, components may have their geometry and properties derived from types (e.g. drain well defined once as a type and installed a number of times in different locations in the model as components); in principle, also spatial elements and systems may have defined types. All these may have dynamic association of properties (RelDefinesByProperties) to complement the statically defined object attributes.

3 Package view

The relevant concepts for Bridge modeling have been organized in the following modules:

- General concepts
- Geometry representation and positioning
- Spatial structure
- Physical elements
- Physical distribution elements
- Systems

In each module, documented in chapter 4, new concepts proposed by IFC-Bridge project are in red text (e.g. 4.3.3 Bridge); all others are adopted from IFC 4.1 as existing concepts, to be used as such or with updated semantic definition and in some cases with new proposed predefined types (also in red text) and potentially with new property sets.

3.1 General Concepts

In General concepts, the fundamental concepts and assumptions applying to Bridge modelling (in IFC-Bridge project context) are explained.

No new concepts or new predefined types are proposed in this module.

3.2 Geometric representation

In Geometric representation, the general concepts for modelling the shape of any spatial or physical element and their position in a Bridge model are explained.

One new concept proposed:

- RelPositions subtype of *RelConnects*

No new predefined types are proposed in existing concepts.

3.3 Spatial elements

In Spatial elements, the concepts for representing built facilities and capturing the spatial hierarchy in Bridge models are explained,

New concepts proposed:

- *Facility - (abstract) subtype of SpatialStructureElement*
- FacilityPart - subtype *of SpatialStructureElement*
- Bridge - subtype of *Facility*

No new predefined types are proposed in existing concepts.

3.4 Physical elements

In Physical elements, the concepts for representing all physical components and their parts comprising built facilities and bridge in particular are explained, except those comprising distributions systems of any kind (explained in Physical distribution elements).

New concept proposed:

- Bearing - subtype of *BuildingElement*
- VibrationDamper - subtype of *ElementComponent*
- TendonConduit - subtype of *ReinforcingElement*

New predefined types are proposed in existing concepts:

Beam: • GIRDER_SEGMENT • DIAPHRAGM • PIERCAP • HATSTONE • CORNICE • EDGEBEAM	Column: • PIERSTEM • PIERSTEM_SEGMENT • STANDCOLUMN	Covering: • COPING • PAVING
Member: • STIFFENING_RIB • ARCH_SEGMENT • SUSPENSION_CABLE • SUSPENDER • STAY_CABLE	Plate: • FLANGE_PLATE • WEB_PLATE • STIFFENER_PLATE • GUSSET_PLATE • SPLICE_PLATE • COVER_PLATE • BASE_PLATE	Slab: • APPROACH_SLAB • SIDEWALK • WEARING
Wall: • RETAININGWALL	ElementAssembly: • ABUTMENT • PIER • PYLON • CROSS_BRACING • DECK	VibrationIsolator: • BASE
BuildingElementPart: • APRON •	DiscreteAccessory: • EXPANSION_JOINT_DEVICE	MechanicalFastener: • COUPLER
ReinforcingBar: • SPACEBAR	SurfaceFeature: • DEFECT	ProjectionElement:

		• BLISTER • DEVIATOR •
GeographicElement: SOIL_BORING_POINT		

3.5 Physical distribution elements

In Physical distribution elements, the concepts for representing all physical components and their parts comprising distributions systems of any kind in built facilities and bridge in particular are explained.

No new concepts or new predefined types are proposed in this module.

3.6 Systems

In Systems, the concepts for grouping objects for a purpose of describing a system or an asset group are explained.

No new concepts or new predefined types are proposed in this module.

4 Concepts

4.1 General Concepts

This section refers to the basic concepts and overall context for modelling a bridge.

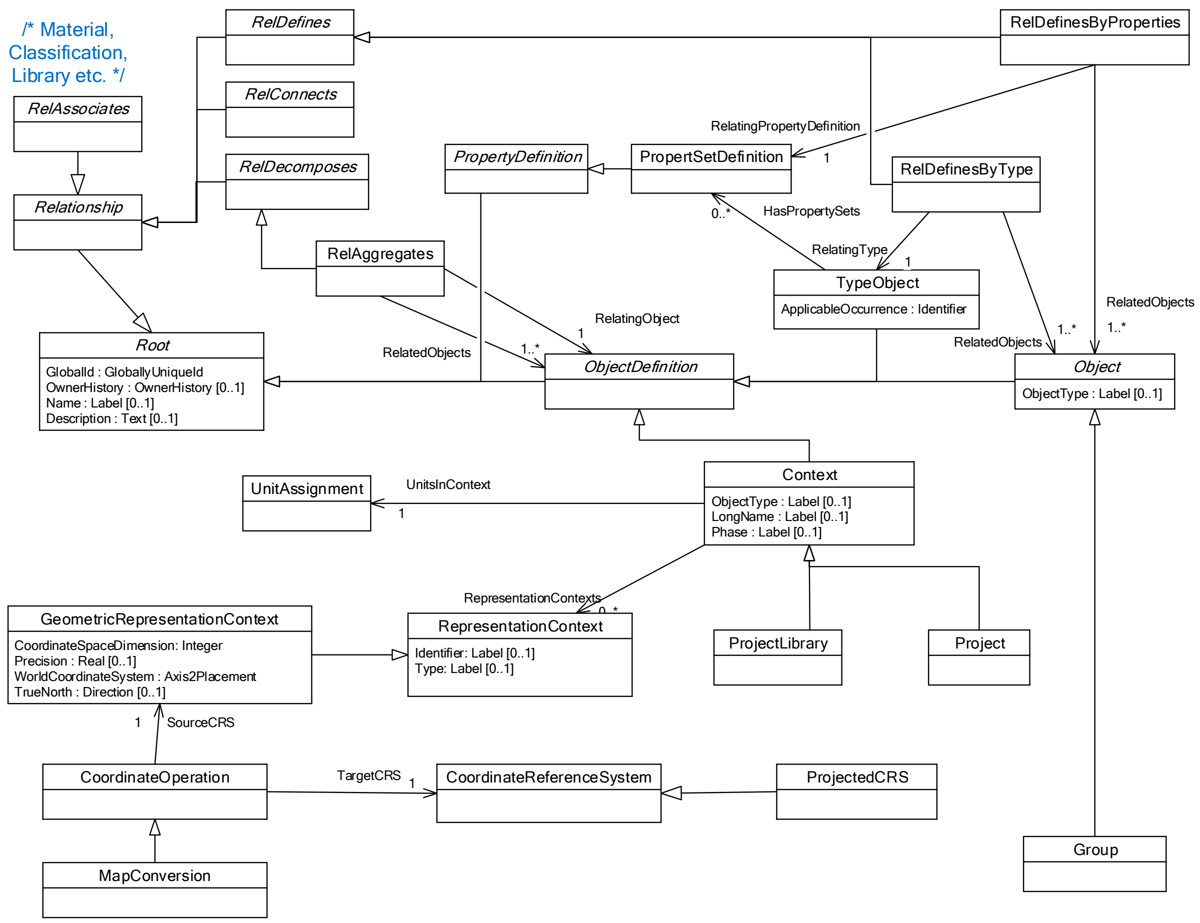

Figure 2 General concept for Bridge model.

4.1.1 Project

Project provides the root instance and the context for all other information items included in a Bridge model to be exchanged or shared. As a type of Context, it declares the units of measure for the model, as well as the geometric representation context for including shape representations in terms of the project coordinate system and the coordinate space dimension, and optionally the map conversion between the project coordinate system and the geospatial coordinate reference system. Project may also declare type libraries or property definition libraries to be used in the project.

Every Bridge model shall have one Project-instance, referencing the root of the spatial structure, either Site (where the Bridge is located) or Bridge (in case Site is not provided); the reference is established by RelAggregates relationship.

4.1.2 UnitAssignment

UnitAssignment indicates a set of units which may be assigned. Within an UnitAssigment each unit definition shall be unique; that is, there shall be no redundant unit definitions for the same unit type such as length unit or area unit.

NOTE A Project has a unit assignment which establishes a set of units which will be used globally within the project, if not otherwise defined. Other objects may have local unit assignments if there is a requirement for them to make use of units not within the project global unit assignment.

4.1.3 GeometricRepresentationContext

The GeometricRepresentationContext defines the context that applies to several shape representations of products within a project. It defines the type of the context in which the shape representation is defined, and the numeric precision applicable to the geometric representation items defined in this context.

The main representation context may also provide the true north direction.

In addition, the project engineering coordinate system (often referred to as the world coordinate system in CAD) can have an offset from a global point of origin, using the WorldCoordinateSystem attribute.

NOTE The offset can be used to provide better numeric stability if the placement of the bridge is far away from the origin. In most cases however it would be set to origin: (0.,0.,0.) and directions x(1.,0.,0.), y(0.,1.,0.), z(0.,0.,1.).

If an geographic placement is provided using MapConversion then the WorldCoordinateSystem attribute is used to define the offset between the zero point of the local engineering coordinate system and the geographic reference point to which the MapConversion offset relates. In preferred practice, both points (also called "project base point" and "survey point") should be coincidental. However, it is possible to offset the geographic reference point from the local zero point.

4.1.4 MapConversion

The map conversion deals with transforming the local engineering coordinate system, often called world coordinate system, into the coordinate reference system of the underlying map.

NOTE The MapConversion does not handle the projection of a map from the geodetic coordinate reference system.

The map conversion allows to convert the local origin of the local engineering coordinate system to its place within a map (easting, northing, orthogonal height) and to rotate the x-axis of the local engineering coordinate system within the horizontal (easting/northing) plane of the map.

NOTE The z axis of the local engineering coordinate system is always parallel to the z axis of the map coordinate system.

The scale factor can be used when the length unit for the 3 axes of the map coordinate system are not identical with the length unit established for this project (see Project.UnitsInContext); if omitted, the scale factor 1.0 is assumed.

4.1.5 Object

An Object is the generalization of any semantically treated thing or process. Objects are things as they appear in instantiated models - i.e. occurrences (as opposed to types, represented by TypeObject).

Objects include physically tangible items such as wall or beam, physically existing items such as spaces, or conceptual items such as alignments. It also stands for processes such as work tasks, for controls such as cost items, or for actors such as persons involved in the design process.

In addition to attributes for identification and description (inherited from Root), Object has ObjectType attribute intended to be used:

- to store the user defined value for all subtypes of Object, where a PredefinedType attribute is given, and its value is set to USERDEFINED.
- to provide a type information (could be seen as a very lightweight classifier) of the subtype of Object, if no PredefinedType attribute is given. This is often the case, if no comprehensive list of predefined types is available.

Objects are independent pieces of information that might contain or reference other pieces of information. There are several relationships in which objects can be involved:

- Association to external/internal resource information - an association relationship that refers to external/internal sources of information, such as classifications, data dictionaries or libraries.
- Assignment of other objects - an assignment relationship that refers to other types of objects.
- Aggregation of other objects - an aggregation relationship that establishes a whole/part relation.
- Assignment of a type - a definition relationship RelDefinesByType that uses a type definition to define the common characteristics of this occurrences, potentially including the common shape representation and common properties of all object occurrences assigned to this type.

- Assignment of a partial type - a definition relationship RelDefinesByObject that uses a component of a type definition (a part of a type, called the "declaring part") to define a component of an occurrence (part of occurrence, called the "reflected part"). This is also referred to as a "deep copy". The common characteristics of all parts in the occurrence are defined by parts in the type.
- Assignment of property sets - a definition relationship RelDefinesByProperties that assigns property set definitions to the object occurrence.

4.1.6 TypeObject

The object type defines the specific information about a type, being common to all occurrences of this type. A TypeObject gets assigned to the individual object instances (the occurrences) via RelDefinesByType relationship.

An object type is represented by a set of property set definitions. The attached property sets describe the available alpha-numeric information about the object type, and are used to define all common properties that apply to all object occurrences of the same type.

NOTE If a property having the same name is used within the PropertySet assigned to an TypeObject (and subtypes) and to an occurrence of that type, then the occurrence property overrides the type property.

Object types may be exchanged without being already assigned to objects. An object type may have an indication of the library (or catalogue) from which its definition originates. This association is handled by the inherited HasAssociations relationship pointing to RelAssociatesLibrary.

4.1.7 RelAggregates

The aggregation relationship RelAggregates is a special type of the general composition/decomposition (or whole/part). The aggregation relationship can be applied to all subtypes of ObjectDefinition. There are three ways of aggregation typically used Bridge model: aggregation of spatial hierarchy into Project context, aggregation of SpatialStructureElements into spatial hierarchy, and aggregation of physical elements. In case of aggregation of physical elements into a physical aggregate, there are three common scenarios (depending on the use case), particularly with bridge girders:

- Geometry at main part (e.g. steel Beam with ExtrudedAreaSolid geometry);
- No geometry at main part, but at components (e.g. steel Beam aggregated into Plate for flanges and web where each Plate has ExtrudedAreaSolid geometry);
- Geometry at both main part and aggregated parts where boolean subtraction is implicit (e.g. concrete Beam with ExtrudedAreaSolid geometry aggregated into multiple ReinforcingBar with SweptDiskSolid geometry).

Decompositions imply a dependency, implying that the whole depends on the definition of the parts and the parts depend on the existence of the whole.

4.1.8 RelDefinesByProperties

The RelDefinesByProperties defines the relationships between property set definitions and objects. Properties are aggregated in property sets. Property sets can be either directly assigned to occurrence objects using this relationship, or assigned to an object type and assigned via that type to occurrence objects.

NOTE The assignment of a PropertySet to a TypeObject is not handled via this objectified relationship, but through the direct relationship HasPropertySets at TypeObject.

The RelDefinesByProperties is an N-to-N relationship, as it allows for the assignment of one or more property sets to one or more objects. Those objects then share the same property definition.

4.1.9 RelDefinesByType

The DefinesByType defines the relationship between an object type and its occurrences as objects. The RelDefinesByType is a 1-to-N relationship, as it allows for the assignment of one type information to a single or many objects. Those objects then share the same object type, and the property sets and properties assigned to the object type. In case of TypeProduct and Product (subtypes of TypeObject and Object), also shape representation is shared.

The RelDefinesByType links the ObjectType with the Object occurrence(s), both of which may define properties by assigning PropertySets (ObjectType attribute HasPropertySets and Object via RelDefinedsByProperties). There are several scenarios to define the same property set on the object type definition and object occurrence:

- All properties for all object occurrences of a common object type have the same value - then only the object type definition has a property set assigned.
- All properties for all object occurrences are different, that is there are no common property values for the object type definition - then each of the object occurrence has a property set assigned.
- Some properties within the same property set have common values and are assigned to the object type definition and some are occurrence specific and assigned (with potentially different values) to the object occurrences - then:
    - The sum of all properties within a given property set applicable to an object occurrence is the union of properties assigned to the object type definition plus the properties assigned to the object occurrence.
    - If the object occurrence has a property with the same Property.Name in a PropertySet, as the corresponding object type definition, then the occurrence property value overrides the type property value.

4.2 Geometric representation

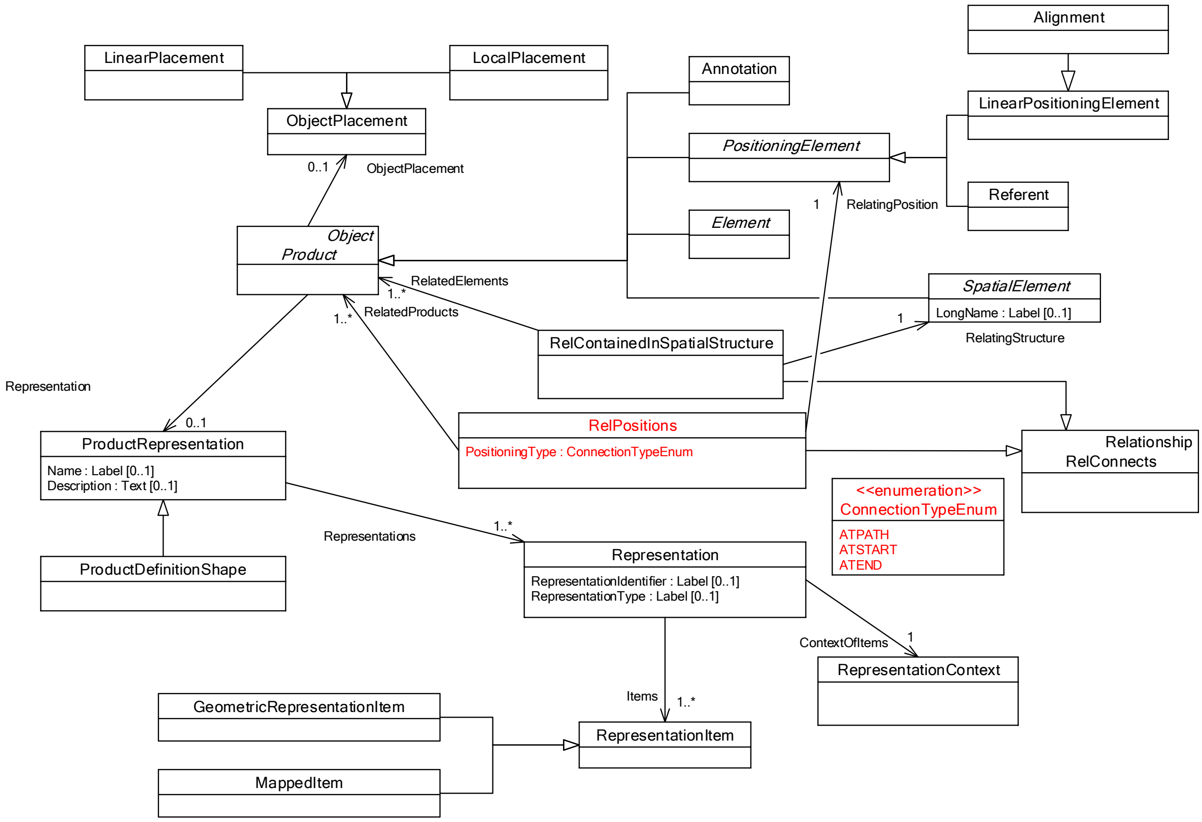

Figure 3 Geometric shape and positioning concepts for Bridge model.

4.2.1 Product

All elements under Product, most notably all spatial structure elements (derived from SpatialElement) and all physical components (derived from Element) can have a location ObjectPlacement and geometric representations (however, not mandatory) as ProductDefinitionShape .

For placing a single object of fixed dimensions relative a reference curve, the entity IfcLinearPlacement may be used to position a single element at position (distance, lateral offset, vertical offset) that is relative to an IfcCurve, and an optional orientation relative to the tangent of the horizontal curve and vertical curve. It is also possible for IfcAlignment objects to be positioned relative to other IfcAlignment objects using IfcLinearPlacement, however such usage may be restricted by implementation agreements to ensure wider compatibility.

For placing an object for which the geometry is defined relative to a reference curve, the entity IfcLocalPlacement may be used to position the element at the origin, and geometry may use IfcSectionedSolidHorizontal, IfcSweptDiskSolid, or any other construct that may make reference to reference curves (e.g. IfcAlignmentCurve).

All of Products may also be decomposed into parts (or aggregated from parts). Products can be designated for permanent use or temporary use, an example for the latter is formwork.

For IFC models, products have customarily represented the “Final” state of an object to be constructed. For some scenarios, there is also the need to define “Existing” state, particularly for terrain where earthwork may comprise a substantial portion of a construction project and there is a need to calculate cut and fill. Then there are other scenarios that define multiple “alternate” states of objects under consideration where several possibilities are identified to be analyzed (e.g. for structural analysis software) or identified as allowable for procurement (e.g. for government contracts requiring at least 3 alternates to be proposed for any proprietary product). Capturing this information could be done in several ways, such as having additional geometric representations with specific identifiers, or as separate objects that could also have property sets, quantities, part compositions and types on their own right. To support such scenario, while maintaining compatibility with software not having such concept, and providing the greatest flexibility and interoperability, it is proposed that the relationship IfcRelAssignsToProduct may be used to link such alternate states, with IfcRelAssignsToProduct.Name identifying the particular meaning, such as “Existing” to mean existing conditions. Such relationship would be entirely optional for all IFC Bridge model views, and would be consistent with current use where alternate representations are linked to physical elements such as structural analysis members.

Figure 4 illustrates the concept of alternates related to other IFC objects.

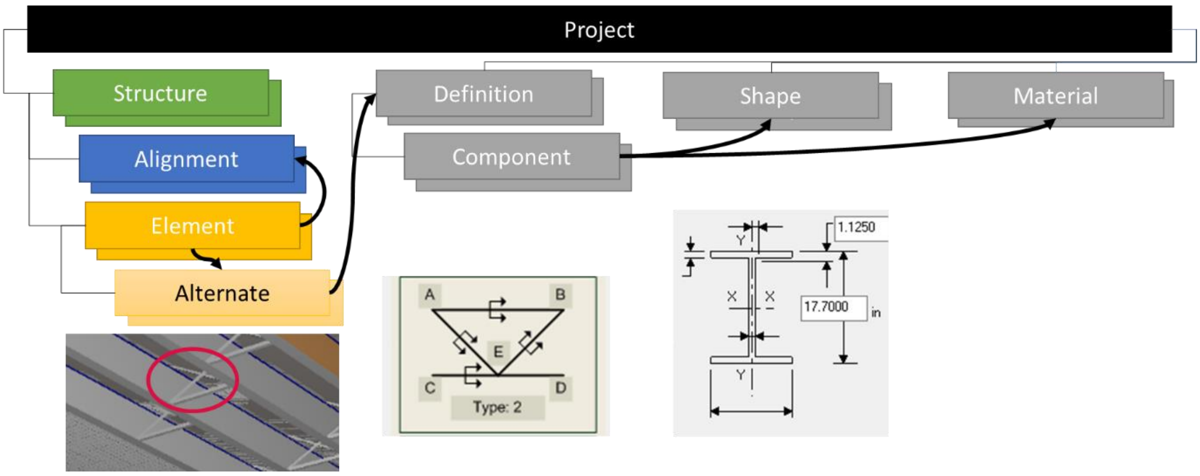

Figure 4: Product alternates

4.2.2 PositioningElement

The definition for positioning and annotating elements that are used to position other elements relatively.

EXAMPLE A grid is a positioning element to position building components mainly in vertical structures, an alignment is a linear positioning element to position geographic and civil elements mainly in infrastructure works.

EXAMPLE An alignment is a linear positioning element for using a linear referencing method to position other items. See ISO 19148 “Linear referencing” for general information about linear referencing methods and expressions.

4.2.3 LinearPositioningElement

The LinearPositioningElement is an abstract concept class describing positioning according to a curve; it has a non-abstract subclass Alignment.

4.2.4 Alignment

An alignment is used to define a reference system to position elements mainly for linear construction works, such as roads, railways, bridges, and others. The relative positioning along the alignment is defined by the linear referencing methodology.

Two alternatives for the use of Alignment have been considered. Either it takes the central place in project structure organizing the referenced products or the main structure remains centered on the dedicated spatial structure element such as IfcBuilding, IfcBridge etc. If we use Alignment as the main organizing structure (taking the role of IfcBuilding), positioning of elements would be achieved by means of stationing (Referents) along the alignment (linear referencing) and referencing in general spatial structures such as roads or bridges or physical elements such as traffic signs. Inside spatial structures local placement can be used with the Referent serving as the origin of the Cartesian coordinate system. Such a concept would rely mostly on existing relationships such as RelNests for Referents assigned to Alignment. A new relationship similar to RelContainedInSpatialStructure which derives from RelConnects would serve to specify the relationship between the Referent and the Product it positions.

Objects for which placement or geometry is defined relative to alignments (or grids) may be related using the proposed relationship RelPositions, which is a subtype of RelConnects, consisting of the following attributes:

RelatingPosition : PositioningElement;

RelatedProducts : SET[1:?] OF Product;

PositioningType : ConnectionTypeEnum; /* ATPATH, ATSTART, ATEND */

The referenced entities PositioningElement and Product would also gain inverse attributes to navigate to the relationship, enabling referential integrity and more readable formats (e.g. XML). RelatedProducts refers to Product (rather than just Element) to also support positioning spatial structures (e.g. bridges, traffic lanes) and other positioning elements (e.g. Referent, Alignment). The relative positioning is provided by the ObjectPlacement subtype, and geometry is provided by Representation.

The presence of such relationship then allows for modification scenarios where alignments may change and dependent objects may then have placement and geometry adjusted accordingly. Such relationship is similar in functionality as RelConnectsPathElements, where the adjustment of a wall, beam, or column can then be propagated to connected walls, beams, or columns.

Figure 5 illustrates positioning relationships where referents are used to indicate point-positions at supports. The spatial structure inheritance hierarchy and element containment relationships remain the same for compatibility with existing software, while the IfcRelPositions relationship designates dependencies between objects and positioning elements. The relationship IfcRelPositions works similarily to IfcRelConnectsPathElements, but defines a link between positioning elements (IfcAlignment, IfcReferent, or IfcGrid) and any product (e.g. physical element, spatial element, or another positioning element).

For Alignment Reference model view, this positioning information reflects dependencies shown on plan sets. For Alignment Design-Transfer model view, such relationship can be used by applications to maintain consistency if adjustments are made, in the same way that IfcWall/IfcWallStandardCase has such capability in the design transfer view.

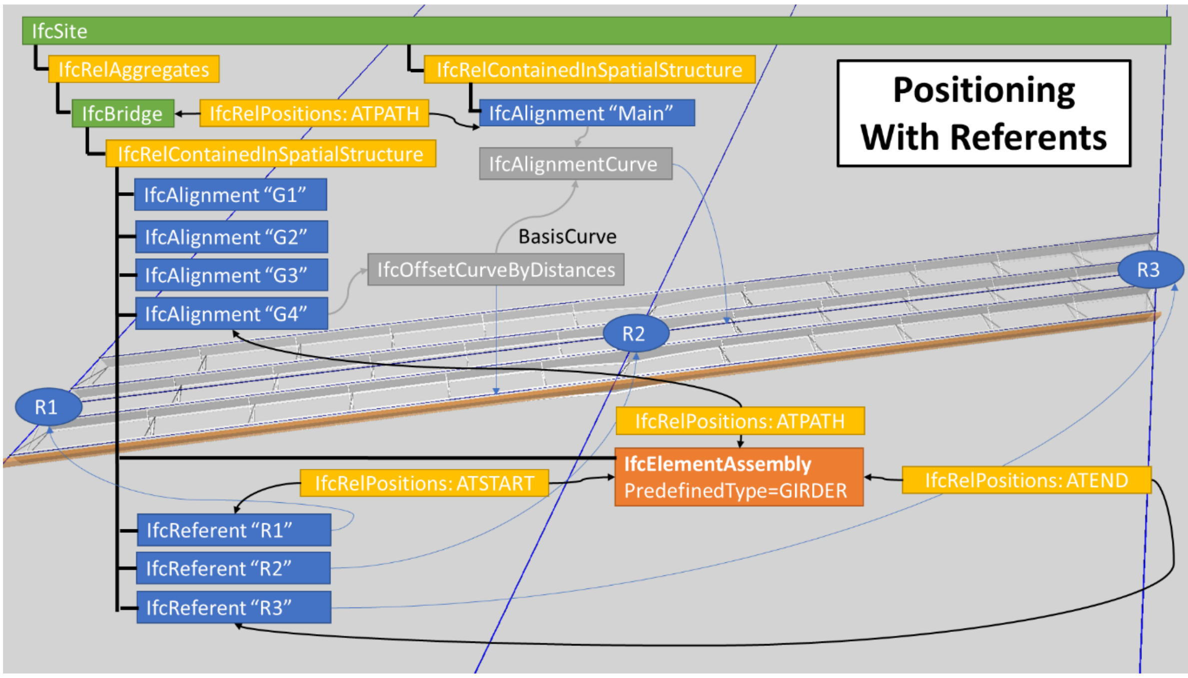

Figure 5: Positioning with referents

Figure 6 illustrates positioning relationships where alignments are used at supports to designate skew lines for which girders, decks, piers, and abutments are aligned. For scenarios where there is skew at supports, then other elements may follow suit for positioning.

In the figure, the right-most girder ("G4") is highlighted in orange, and is positioned along the "G4" alignment, which is defined relative to the "Main" alignment following the centerline of the bridge.

Not shown in the diagram, cross-bracing in certain locations may be defined relative to skew lines. Bridge deck segments may also be defined with positioning relationships to the main alignment and skew lines at each end, for which resulting geometry may then be derived.

It is anticipated that such positioning relationships would be optional for alignment reference view, but required for alignment design transfer view.

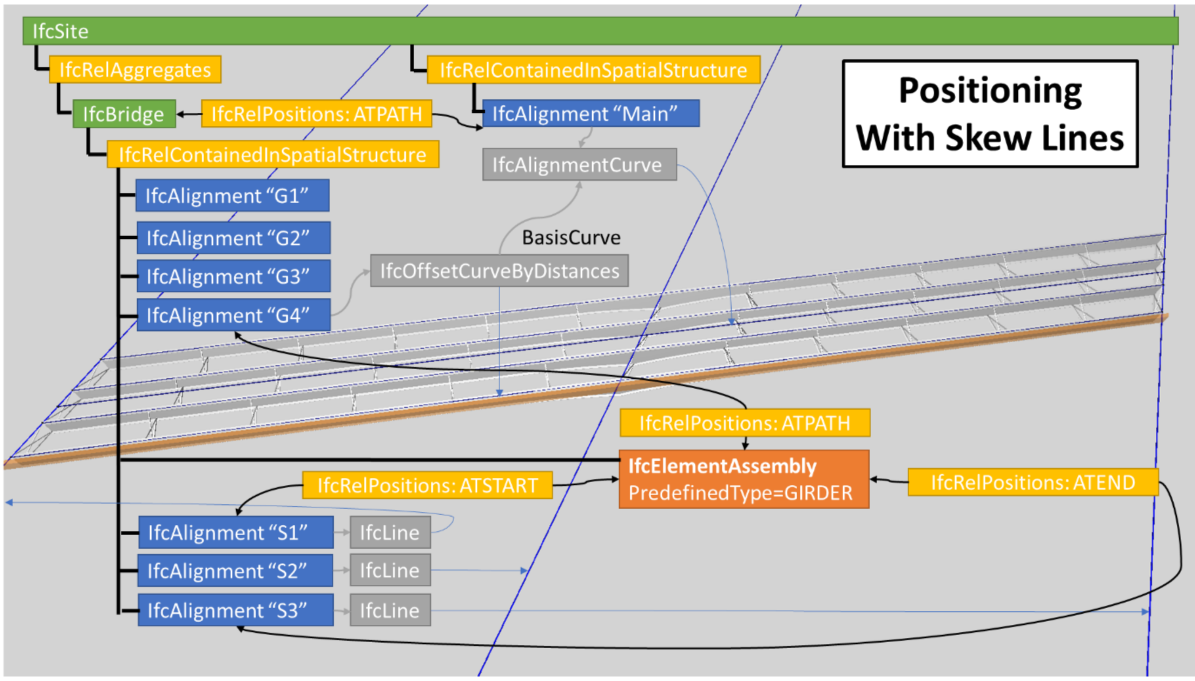

Figure 6: Positioning with skew lines

NOTE: Alternatively, rather than using IfcAlignment with IfcLine, IfcReferent could be used to accomplish the same by using IfcReferent.ObjectPlacement\IfcLinearPlacement.Orientation to reflect the skew angle) .

NOTE See ISO 19148 Geographic information – Linear referencing for general definitions about linear referencing.

A single alignment may have:

- a horizontal alignment defined in the x/y plane of the engineering coordinate system
- an accompanying vertical alignment, defined along the horizontal alignment in the distance along / z coordinate space
- a relative alignment, defined as a span within another alignment and/or at constant or variable offsets
- a 3D alignment, either computed from the horizontal and vertical alignment, or extracted from geospatial data.

Alignments may be aggregated into referents (Referent) or derivative alignments. Derivative alignments may be used to indicate dependent alignments, such as an alignment for a bridge that is relative to a parent alignment for a road, where the child Alignment may have Axis set to OffsetCurveByDistances that starts and ends at a span within the extent of the AlignmentCurve defined at the Axis of the parent Alignment.

Alignments may be assigned to groups using RelAssignsToGroup, where Group or subtypes may capture information common to multiple alignments or an alignment system.

Supported representations of Alignment.Axis are:

- AlignmentCurve as a 3D horizontal and vertical alignment (represented by their alignment segments)
- AlignmentCurve as a 2D horizontal alignment (represented by its horizontal alignment segments) without a vertical alignment
- OffsetCurveByDistances as a 2D or 3D curve defined relative to an AlignmentCurve or another OffsetCurveByDistances
- Polyline as a 3D alignment by a 3D polyline representation (such as coming from a survey)
- Polyline as a 2D horizontal alignment by a 2D polyline representation (such as in very early planning phases or as a map representation)
- Line (unbounded, reference point with direction): while AlignmentCurves are commonly used for longitudinal positioning, reference Lines can be used for lateral positioning, e.g. in Bridge model to indicate skew angle, for which piers and bearings are positioned along.

NOTE Although Axis is an Curve base type, only derived types AlignmentCurve, OffsetCurveByDistances, Line and Polyline are meant to be supported types. Derivative specifications may expand this set to include additional curve types.

4.2.5 Referent

Referent defines a position at a particular offset along an alignment curve. Referents may be used for several scenarios:

- positioning spatial and physical elements at common locations along an alignment curve (e.g. bridge piers)
- indicating transitions for cross-sections (e.g. beginning of curvature where road is relatively flat, maximum curvature having super-elevated cross-slope to accomodate design speed)
- indicating broken chainage where distance measurements reset or reverse directions
- indicating domain-specific design parameters (via property sets) at locations along an alignment curve.

4.2.6 Element

The Element and its subtypes represent all physical components (and their aggregations), and they can have associated Material definition (in case of tangible components).

The attribute Category is currently used to distinguish general categories of materials, such as steel or concrete. However, there is no standardization of this attribute currently. To enable such standardization, and preserve compatibility with existing usage of this attribute, it is proposed to add an additional attribute to Material, called PredefinedType, which is an enumeration to include at a minimum CONCRETE, STEEL, and TIMBER for the purposes of bridge construction, along with placeholders NOTDEFINED and USERDEFINED. Other general types may also be included, such as those defined at ConstructionMaterialResourceTypeEnum

Elements are physically existent objects, although they might be void elements, such as holes. Elements permanent parts of facility, or only temporary, as formwork scaffolding. Elements can be either pre-manufactured or built on site.

The elements can be logically contained by a spatial structure element that constitutes a certain level within a project structure hierarchy (site, bridge, facility part or space). This is done by using the ContainedInSpatialStructure relationship. An element can have material and quantity information assigned through the AssociatesMaterial and RelDefinesByProperties relationship.

Elements can also be connected by using RelConnects relationship to express a physical connection.

In addition an element can be declared to be a specific occurrence of an element type (and thereby be defined by the element type properties) using the RelDefinesByType relationship. An element can also be defined as an element assembly that is an aggregation of semantically and topologically related elements that form a complex product or part of a facility. Those element assemblies are defined using the RelAggregates relationship.

EXAMPLES of elements that typically are assemblies are a Stair, composed of Flights and Landings, or a Bridge abutment structure composed of Walls.

4.2.7 Annotation

An annotation is a graphical representation within the geometric (and spatial) context of a project that adds a note or meaning to the objects constituting the project model. Annotations include additional points, curves, text, dimensioning, hatching and other forms of graphical notes. It also include symbolic representations of additional model components, not representing products or spatial structures, such as survey points, contour lines or similar.

If available, the annotation should be related to the spatial context of the project, by containing the annotation within the appropriate level of the spatial structure (site, bridge, facility part, or space). This is handled by the RelContainedInSpatialStructure relationship.

The Annotation can provide specific 0D, 1D, and 2D geometric items as representation of the annotation, offering annotation point, curves, and surfaces. The following values shall be used for the ObjectType:

- 'Annotation point' is an annotation provided by a point that has additional semantic. The inherited attribute ObjectType should be used to capture the type of point annotation, some predefined values are:
    - 'SurveyPoint: A single survey point represented by a Cartesian point. A property set may add the conditions (method, accuracy, etc. to the survey point).
    - 'SurveyArea': A set of survey points represented by Cartesian point. These coordinates are determined relative to the coordinates of a reference point, which acts as the datum for the survey. Properties attached apply equally to all points. The difference in elevation of the survey points enables terrain to be determined.
- 'Annotation curve' is an annotation provided by a curve that has additional semantic. The inherited attribute ObjectType should be used to capture the type of curve annotation, some predefined values are:
    - 'ContourLine': A line of constant elevation typically used on geographic maps where the spacing of lines at constant intervals of elevation may be used as an indication of slope.
    - 'IsoBar': A line of constant pressure typically used on weather maps or to show pressure gradient in spaces, chambers or externally.
    - 'IsoLux': A line of constant illumination typically used to show the distribution of illumination levels and/or daylighting in a space or externally.
    - 'IsoTherm': A line of constant temperature typically used to show the distribution and effect of heating or cooling within a space or to show temperature distribution on a geographic map.
- 'Annotation surface' is an annotation provided by a surface that has additional semantic. The inherited attribute ObjectType should be used to capture the type of surface annotation, some predefined values are:
    - 'SurveyArea': A surface patch based on survey points.

4.3 Spatial elements

Spatial elements are intangible, but they can have a shape and a location in space. They can also have physical (tangible) elements contained in them, providing their boundaries or having other functions. They are often used also for creating the main breakdown structure for the project model (by subtype SpatialStructureElement and its subtypes).

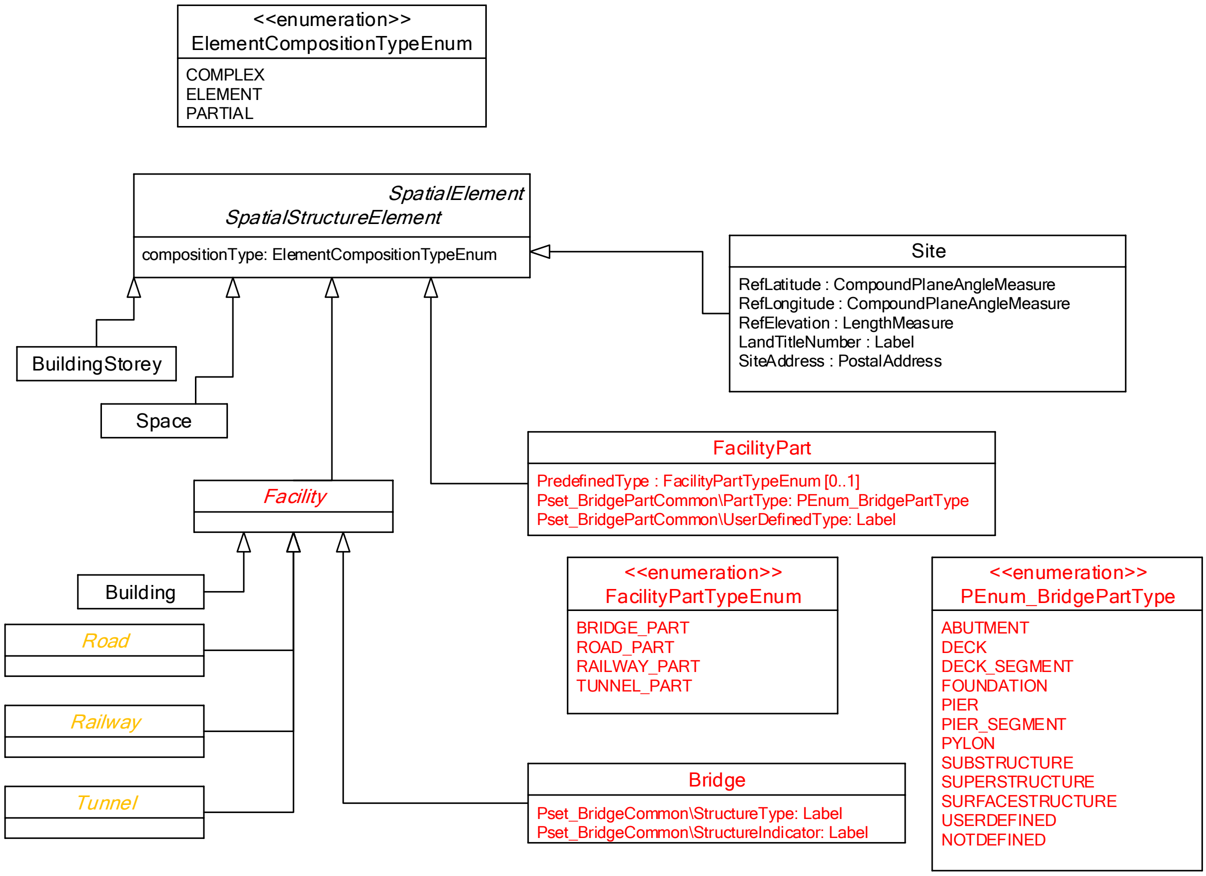

Figure 7 Spatial structure concepts for Bridge model.

4.3.1 SpatialElement

A spatial element is the generalization of all spatial elements that might be used to define a spatial structure or to define spatial zones.

- hierarchical spatial structure element as SpatialStructureElement
  - a spatial structure is a hierarchical decomposition of the project. That spatial structure is often used to provide a project structure to organize a building project.
  - a spatial project structure might define as many levels of decomposition as necessary for the building project. Elements within the spatial project structure are site, bridge, facility part and space
- spatial zone as SpatialZone
  - a spatial zone is a non-hierarchical and potentially overlapping decomposition of the project under some functional consideration.
  - a spatial zone might be used to represent a thermal zone, a lighting zone, a usable area zone.
  - a spatial zone might be used to represent a horizontal spatial structure as used in civil works.
  - a spatial zone might have its independent placement and shape representation.

4.3.2 SpatialStructureElement

A spatial structure element is the generalization of all spatial elements that might be used to define a spatial structure. This spatial structure is often used to provide a hierarchical project structure to organize project information.

A spatial project structure may define as many levels of decomposition as necessary for the project. Elements within the spatial project structure are at different levels of decomposition (even though decomposition may appear also within each level):

- Site (where facility/facilities is/are built)
- Facility as
  - Building
  - Bridge
- Decomposition of a facility, as
  - BuildingStorey in Buildings
  - FacilityPart in other types of Facility
- Space (primitive component in spatial structure).

4.3.3 Site

A site is a defined area of land, possibly covered with water, on which the project construction is to be completed. A site may be used to erect, retrofit or turn down built facilities or for other construction related developments.

NOTE Term according to ISO6707-1 vocabulary "area of land or water where construction work or other development is undertaken".

In addition to being the container for the objects in planned developments, a Site contains objects existing before the project starts. This includes the terrain and soil, the surrounding buildings and infrastructures, the utility networks and bodies of water.

A site may include a definition of the single geographic reference point for this site (global position using WGS84 with Longitude, Latitude and Elevation). The precision is provided up to millionth of a second and it provides an absolute placement in relation to the real world as used in exchange with geospatial information systems. If asserted, the Longitude, Latitude and Elevation establish the point in WGS84 where the point 0.,0.,0. of the LocalPlacement of IfcSite is situated.

The geometrical placement of the site, defined by the LocalPlacement, shall be always relative to the spatial structure element, in which this site is included, or absolute, i.e. to the world coordinate system, as established by the geometric representation context of the project. The world coordinate system, established at the Project.RepresentationContexts, may include a definition of the true north within the XY plane of the world coordinate system, if provided, it can be obtained at GeometricRepresentationContext.TrueNorth.

A project may span over several connected or disconnected sites. Therefore, site complex provides for a collection of sites included in a project. A site can also be decomposed in parts, where each part defines a site section. This is defined by the composition type attribute of the supertype SpatialStructureElements which is interpreted as follow:

- COMPLEX = site complex
- ELEMENT = site
- PARTIAL = site section

The Site is used to build the spatial structure of a built facility (that serves as the primary project breakdown and is required to be hierarchical).

4.3.4 Facility

A Facility (derived from SpatialStructureElement) may be a Building or a Bridge (or any other type of built facility defined in the future - Road, Railway and Tunnel are expected among the first ones to follow).

4.3.5 Bridge

A Bridge is civil engineering works that affords passage to pedestrians, animals, vehicles, and services above obstacles or between two points at a height above ground [ISO 6707-1:2014].

Bridge StructureType (in Pset_BridgeCommon) can be one from the following list, or otherwise defined in more special cases:

- BoxGirderBridge,
- ArchedBridge,
- SuspensionBridge,
- Cable-StayedBridge,
- CulvertBridge,
- GirderBridge,
- SlabBridge,
- CantiliverSlabBridge,
- BowStringBridge,
- LadderBridge,
- FrameworkBridge,
- PortalBridge.

Bridge may also have a StructureIndicator (in Pset_BridgeCommon) from the following list (which may be extended):

- Composite,
- Coated,
- Homogeneous.

Bridge composition type can be COMPLEX e.g. when there is a cable-stayed bridge (ELEMENT) in the middle and smaller girder bridges (ELEMENT) at the ends; if necessary, the girder bridges can be further broken down (PARTIAL).

4.3.6 FacilityPart

FacilityPart provides for spatial breakdown of built facilities (other than Buildings, broken down in BuildingStoreys). In a bridge, FacilityParts can represent the parts in breakdown structure according to local practices (e.g. Superstructure, Substructure, Foundation), and these can also be broken down further (e.g. Substructure as whole can be COMPLEX, while each abutment and pier would be ELEMENT, and a pier can be composed of separate towers (PARTIAL).

PredifedType of FacilityPart would have value BRIDGE_PART, with associated property set Pset_BridgePartCommon, where a property named PartType is provided for capturing the specific enumerated type of Bridge part (and property UserDefinedType for any type not in enumeration list):

- ABUTMENT
- DECK
- DECK_SEGMENT
- FOUNDATION
- PIER
- PIER_SEGMENT
- PYLON
- SUBSTRUCTURE
- SUPERSTRUCTURE
- SURFACESTRUCTURE
- USERDEFINED
- NOTDEFINED

4.4 Physical building elements

This section describes all the Elements that are used to physically construct built facilities, regardless of their function (architectural, structural, distribution or any other). These elements can be tangible (with associated material), or virtual (such as openings) in nature.

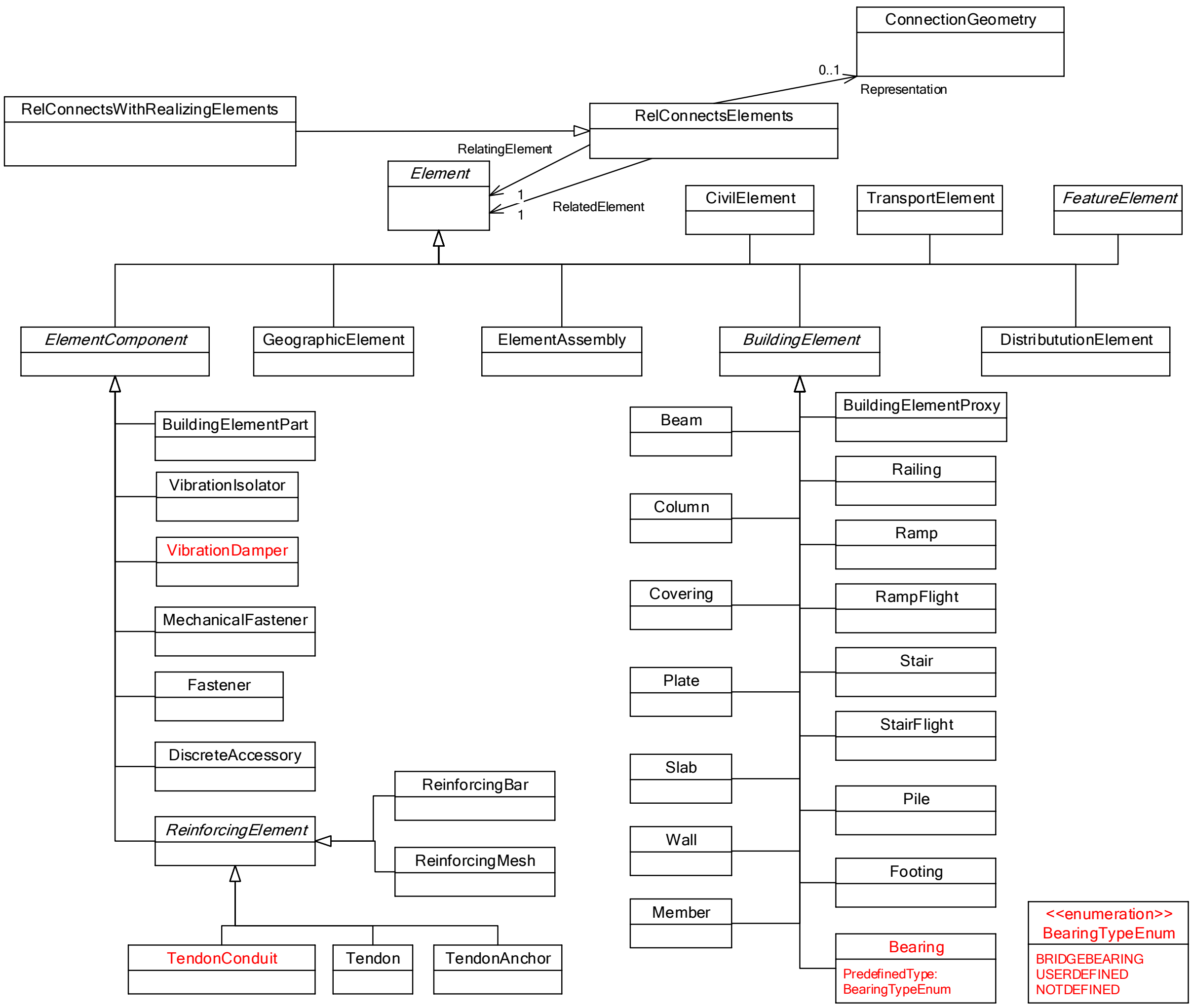

Figure 8 Physical elements for Bridge model.

4.4.1 BuildingElement

The BuildingElement comprises all elements that are primarily parts of the construction of a built facility, i.e., its structural and space separating system. Building elements are all physically existent and tangible things.

Typical examples of BuildingElements are (among others):

- building elements within a space separation systems
- building elements within an enclosure system (such as a facade)
- building elements within a fenestration system
- building elements within a load bearing system
- building elements within a foundation system

Types of building elements that can be instantiated in a Bridge model are explained below.

4.4.2 Bearing

Type of building element that is used to transmit loads from superstructure to substructure, and usually allowing movement (displacement or rotation) in one or more degrees of freedom. It is typically a mechanical component procured as a whole and installed on site, but in simple cases it may be built on site (composed of other building elements, element components, etc.).

The predefined types of Bearing, including bridge specific cases are:

- CYLINDRICAL A bearing consisting of a sliding material (such as PTFE) surfaced concave plate and mating stainless steel convex plate, which accommodate unidirectional rotation through sliding.
- ELASTOMERIC A pad bearing which carries vertical load by contact stresses between a sheet of sliding material (such as PTFE) and a mating surface that permits movements by sliding and accommodates rotation by deformation of the elastomer.
- GUIDE A plain bearing used to guide a machine element in its lengthwise motion, usually without rotation of the element.
- POT A bearing which carries vertical load by compression on an elastomeric disc confined in a steel cylinder and which accommodates rotations by deformations of the disc.
- RESTRAINT
- ROCKER A bearing which carries vertical load by direct contact between two metal surfaces and which accommodates movement by rolling of one surface with respect to the other.
- ROLLER A bearing which carries vertical load by direct contact between two metal surfaces and which accommodates movement by rolling of one surface with respect to the other.
- SLIDING A bearing which accommodates movement by slip of one surface over another.
- SPHERICAL A bearing consisting of a sliding material (such as PTFE) surfaced concave plate and mating stainless steel convex plate, which accommodate multidirectional rotation through sliding.
- USERDEFINED User-defined bearing element.
- NOTDEFINED Undefined bearing element.

The mechanical behaviour of a bearing may be defined by assigning an StructuralPointConnection, with an BoundaryNodeCondition indicating the degrees of freedom (using RelAssignsToProduct).

4.4.3 Beam

A Beam is a horizontal, or nearly horizontal, structural member that is capable of withstanding load primarily by resisting bending. However, it is not required to be load bearing.

Definition according to ISO 6707-1: structural member for carrying load(s) between or beyond points of support, usually narrow in relation to its length and horizontal or nearly so.

NOTE The representation of load-bearing beams in a structural analysis model is provided by subtypes of StructuralMember as part of an StructuralAnalysisModel.

NOTE For any other longitudinal structural member, not constrained to be predominately horizontal nor vertical, or where this semantic information is irrelevant, the Member should be used.

The camber of a beam may be defined by assigning an StructuralCurveMember with an StructuralLoadConfiguration indicating displacement coordinates with StructuralLoadSingleDisplacement. Multiple sets of camber ordinates may be provided that are qualified by the particular load case, where full dead load would typically be used for fabrication, and other scenarios used for other loading conditions such as during construction.

There are potentially two types of Beam occurrences in terms of geometric representation:

- Beam Standard Case used for all occurrences of beams, that have a profile defined that is swept along a directrix. The profile might be changed uniformly by a taper definition along the directrix. The profile parameter and its cardinal point of insertion can be fully described by the MaterialProfileSetUsage. These beams are always represented geometricly by an 'Axis' and a 'SweptSolid' or 'AdvancedSweptSolid' shape representation (or by a 'Clipping' geometry based on the swept solid), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialProfileSetUsage assigned. (Capturing rebar layout parametrically, see 4.4.29).
- Beam General Case used for all other occurrences of beams, particularly for beams with non-uniformly changing profile sizes along the sweep, or beams having only 'AdvancedBrep', 'Brep', 'SurfaceModel', or 'Tessellation' geometry.

The predefined types of Beam, including bridge specific cases are:

- BEAM A standard beam usually used horizontally.
- JOIST A beam used to support a floor or ceiling.
- HOLLOWCORE A wide often pre-stressed beam with a hollow-core profile that usually serves as a slab component.
- LINTEL A beam or horizontal piece of material over an opening (e.g. door, window).
- SPANDREL A tall beam placed on the facade of a building. One tall side is usually finished to provide the exterior of the building. Can be used to support joists or slab elements on its interior side.
- T_BEAM A beam that forms part of a slab construction and acts together with the slab which its carries. Such beams are often of T-shape (therefore the English name), but may have other shapes as well, e.g. an L-Shape or an Inverted-T-Shape.
- GIRDER_SEGMENT A segment of a girder (e.g. each span of a continuous girder)
- DIAPHRAGM End portion of a girder transmitting loads to supports and providing moment resistance to adjoining segment PIERCAP A transversal beam on top of a pier (on a single column or extending from one column of a pier to another column of the same pier).

- HATSTONE A beam on top of a retaining wall or a wing wall, preventing earth movement.
- CORNICE A non-loadbearing beam on the longitudinal edge of bridge slab, usually encasing installations.
- EDGEBEAM A beam on the longitudinal edge of bridge slab, usually concrete, providing additional stiffening and protection from the elements.
- USERDEFINED User-defined linear beam element.
- NOTDEFINED Undefined linear beam element.

4.4.4 BuildingElementProxy

The BuildingElementProxy is a proxy definition that provides the same functionality as other subtypes of BuildingElement, but without having a predefined meaning of the special type of building element, it represents.

Proxies can also be used as spatial place holders or provisions, that are later replaced by special types of elements.

One use of the proxy object is a provision for voids, i.e. where a particular volume of space is requested by an engineering function that might later be accepted or rejected. If accepted it is transformed into a void within a building element, like a wall opening, or a slab opening. The provision for voids is exchanged as an BuildingElementProxy with the PredefinedType = ProvisionForVoid. Such proxy shall have a swept solid geometry, where the profile of the swept solid lies on/near the surface of the referred building element and the extrusion depths is equal to or bigger then (in case of round or otherwise irregular element shape) the thickness of the building element. The appropriate property set should be attached.

In addition to the provision for voids, the building element proxy can also represent a provision for space, often the necessary space allocation for mechanical equipment that will be determined in a later design phase. The provision for space is exchanged as an BuildingElementProxy with the PredefinedType = ProvisionForSpace.

Other usages of BuildingElementProxy include:

- The BuildingElementProxy can be used to exchange special types of building elements for which the current specification does not yet provide a semantic definition.
- The BuildingElementProxy can also be used to represent building elements for which the participating applications can not provide a semantic definition.

4.4.5 Column

Column is a vertical structural member which often is aligned with a structural grid intersection or along an alignment, possibly with offsets. It represents a vertical, or nearly vertical, structural member that transmits, through compression, the weight of the structure above to other structural elements below. However, it is not required to be load bearing.

Definition according to ISO 6707-1: structural member of slender form, usually vertical, that transmits to its base the forces, primarily in compression, that are applied to it.

NOTE The representation of a column in a structural analysis model is provided by StructuralCurveMember being part of an StructuralAnalysisModel.

NOTE For any longitudial structural member, not constrained to be predominately horizontal nor vertical, or where this semantic information is irrelevant, the Member shall be used.

Two types of column occurrences in terms of geometric representation are possible:

- Column Standard Case used for all occurrences of columns, that have a profile defined that is swept along a directrix. The profile might be changed uniformly by a taper definition along the directrix. The profile parameter and its cardinal point of insertion can be fully described by the MaterialProfileSetUsage. These beams are always represented geometrically by an 'Axis' and a 'SweptSolid' or 'AdvancedSweptSolid' shape representation (or by a 'Clipping' geometry based on the swept solid), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialProfileSetUsage assigned. (Capturing rebar layout parametrically, see 4.4.29).
- Column General Case used for all other occurrences of columns, particularly for columns with changing profile sizes along the extrusion, or columns defined by non-linear extrusion, or columns having only 'Brep', or 'SurfaceModel' geometry.

The predefined types of Column, including bridge specific cases are:

- COLUMN A standard member usually vertical and requiring resistance to vertical forces by compression but also sometimes to lateral forces.
- PILASTER A column element embedded within a wall that can be required to be load bearing but may also only be used for decorative purposes.
- PIERSTEM An individual vertical part of a pier, may be a simple column, i.e. no breakdown into segments or separate structural parts such as flanges and web(s), or may be an aggregation of segments and/or parts.
- PIERSTEM_SEGMENT A vertical segment of a pier column.
- STANDCOLUMN A column transmitting vertical loads from superstructure to an arch below it.
- USERDEFINED User-defined linear element.
- NOTDEFINED Undefined linear element.

4.4.6 Covering

A covering is an element which covers some part of another element and is fully dependent on that other element. The Covering defines the occurrence of a covering type, that (if given) is expressed by the CoveringType.

NOTE Definition according to ISO ISO 6707-1: final coverings and treatments of surfaces and their intersections.

Coverings are elements with relationships to the covered element and the space on the other side, they may contain openings, assigned by RelVoidsElement, material information, assigned by RelAssociatesMaterial, and others.

EXAMPLE Coverings include wall claddings, floorings, suspended ceilings, moldings and skirting boards.

NOTE A more basic information about claddings, floorings, and ceilings of a space can be attached to Spaces using the Pset_SpaceCommon properties. Then only a name can be provided and the covering quantities would be interpreted from the space quantities.

Coverings can be assigned to:

- a Space, using the inverse relationship CoversSpaces pointing to RelCoversSpaces. In this case coverings may not have their own shape representation and no defined relationships to the building elements they cover. The space is accessible via RelCoversSpaces.RelatedSpace; it defines to which space a covering is facing towards.
- a RelSpaceBoundary, using the inverse relationship ProvidesBoundaries pointing to RelSpaceBoundary. In this case space has coverings that have an own shape representation and the space has defined space boundaries The space is accessible via RelSpaceBoundary.RelatingSpace.
- a BuildingElement or DistributionElement, using the inverse relationship CoversElements pointing to RelCoversBldgElements. The building or dstribution element is then accessible via RelCoversBldgElements.RelatingBuildingElement. In this case the covering does not relate to a space.

The predefined types of Covering, including bridge specific cases are:

- CEILING The covering is used to represent a ceiling.
- FLOORING The covering is used to represent a flooring.
- CLADDING The covering is used to represent a cladding.
- ROOFING The covering is used to represent a roof covering.
- MOLDING The covering is used to represent a molding being a strip of material to cover the transition of surfaces (often between wall cladding and ceiling).
- SKIRTINGBOARD The covering is used to represent a skirting board being a strip of material to cover the transition between the wall cladding and the flooring.
- INSULATION The covering is used to insulate an element for thermal or acoustic purposes.
- MEMBRANE An impervious layer that could be used for e.g. roof covering (below tiling - that may be known as sarking etc.) or as a damp proof course membrane; also, waterproofing material on a bridge structure (typically on top of bridge slab).
- SLEEVING The covering is used to isolate a distribution element from a space in which it is contained.
- WRAPPING The covering is used for wrapping particularly of distribution elements using tape.
- COPING A protective capping or covering of a wall or a parapet.
- PAVING Roadway surface (pavement,”blacktops”) as the topmost covering of a road usually asphalt, concrete or stone.

- USERDEFINED User defined type of covering.
- NOTDEFINED Undefined type of covering.

4.4.7 Door

The door is a building element that is predominately used to provide controlled access for people and goods. It includes constructions with hinged, pivoted, sliding, and additionally revolving and folding operations. A door may consist of a lining and one or several panels.

Definition according to ISO 6707-1: construction for closing an opening, intended primarily for access with hinged, pivoted or sliding operation.

In bridge structures, a specific type of a door is AccessPanel, providing access to otherwise closed compartments in structures such as box girders.

4.4.8 Footing

A footing is a part of the foundation of a structure that spreads and transmits the load to the soil. A footing is also characterized as shallow foundation, where the loads are transferred to the ground near the surface.

Definition according to ISO 6707-1: stepped construction that spreads the load at the foot of a wall or column.

NOTE Slab foundations, also called slab-on-grade, are not instantiated as Footing but as Slab or as its subtype SlabStandardCase, SlabElementedCase with a predefined type of SlabTypeEnum.BASESLAB. Deep foundations, which transfer the loads to subsurface layers, are represented by Pile.

Footings, similarly to slabs may also be defined parametrically (rebar layout, see 4.4.29).

Predefined types of Footing are:

- CAISSON_FOUNDATION A foundation construction type used in underwater construction.
- FOOTING_BEAM Footing elements that are in bending and are supported clear of the ground. They will normally span between piers, piles or pile caps. They are distinguished from beams in the building superstructure since they will normally require a lower grade of finish. They are distinguished from STRIP_FOOTING since they are clear of the ground surface and hence require support to the lower face while the concrete is curing.
- PAD_FOOTING An element that transfers the load of a single column (possibly two) to the ground.
- PILE_CAP An element that transfers the load from a column or group of columns to a pier or pile or group of piers or piles.
- STRIP_FOOTING A linear element that transfers loads into the ground from either a continuous element, such as a wall, or from a series of elements, such as columns.

4.4.9 Member

A Member is a linear structural member designed to carry loads between or beyond points of support. It is not required to be load bearing. The orientation of the member (being horizontal, vertical or sloped) is not relevant to its definition (in contrary to Beam and Column).

NOTE The representation of a member in a structural analysis model is provided by StructuralCurveMember being part of an StructuralAnalysisModel.

Two types of member occurrences in terms of geometric representation are possible:

- Member Standard Case used for all occurrences of members, that have a profile defined that is swept along a directrix. The profile might be changed uniformly by a taper definition along the directrix. The profile parameter and its cardinal point of insertion can be fully described by the MaterialProfileSetUsage. These beams are always represented geometrically by an 'Axis' and a 'SweptSolid' or 'AdvancedSweptSolid' shape representation (or by a 'Clipping' geometry based on the swept solid), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialProfileSetUsage assigned.
- Member General Case used for all other occurrences of members, particularly for members with changing profile sizes along the extrusion, or members defined by non-linear extrusion, or members having only 'Brep', or 'SurfaceModel' geometry.

The predefined types of Member, including bridge specific cases are:

- BRACE A linear element (usually sloped) often used for bracing of a girder or truss.
- CHORD Upper or lower longitudinal member of a truss, used horizontally or sloped.
- COLLAR A linear element (usually used horizontally) within a roof structure to connect rafters and posts.
- MEMBER A linear element within a girder or truss with no further meaning.
- MULLION A linear element within a curtain wall system to connect two (or more) panels.
- PLATE A linear continuous horizontal element in wall framing, such as a head piece or a sole plate.
- POST A linear member (usually used vertically) within a roof structure to support purlins.
- PURLIN A linear element (usually used horizontally) within a roof structure to support rafters.
- RAFTER A linear elements used to support roof slabs or roof covering, usually used with slope.
- STRINGER A linear element used to support stair or ramp flights, usually used with slope.
- STRUT A linear element often used within a girder or truss.
- STUD Vertical element in wall framing.
- STIFFENING_RIB A linear element added to a flange or a web plate of a girder for local stiffening

- ARCH_SEGMENT Individual segment of an arch structure
- SUSPENSION_CABLE A suspended tendon, typically comprising steel wire, sheath, etc.
- SUSPENDER A vertical element suspending a structure (such as bridge deck) from a suspension cable or an arch.
- STAY_CABLE A sloped element suspending a structure (such as bridge deck) from a pylon.
- USERDEFINED User-defined linear element.
- NOTDEFINED Undefined linear element.

4.4.10 Pile

A pile is a slender timber, concrete, or steel structural element, driven, jetted, or otherwise embedded on end in the ground for the purpose of supporting a load. A pile is also characterized as deep foundation, where the loads are transfered to deeper subsurface layers.

NOTE Definition according to ISO 6707-1: slender structural member, substantially underground, intended to transmit force(s) into loadbearing strata below the surface of the ground.

NOTE Shallow foundations, which transfer the loads to the ground near its surface, are represented by Footing.

The predefined types of Pile are:

- BORED A bore pile.
- DRIVEN A rammed, vibrated, or otherwise driven pile.
- JETGROUTING An injected pile-like construction.
- COHESION A cohesion pile.
- FRICTION A friction pile.
- SUPPORT A support pile.
- USERDEFINED The type of pile function is user defined.
- NOTDEFINED The type of pile function is not defined.

4.4.11 Plate

A Plate is a planar and often flat part with constant thickness. A plate may carry loads between or beyond points of support, or provide stiffening. The location of the plate (being horizontal, vertical or sloped) is not relevant to its definition (in contrary to Wall and Slab).

NOTE Definition according to ISO 6707-1: thin, rigid, flat, metal product, of a thickness greater than that of a sheet.

Plates are normally made of steel, other metallic material, or by glass panels. However the definition of Plate is material independent and specific material information shall be handled by using AssociatesMaterial to assign a material specification to the Plate.

NOTE Although not necessarily, plates are often add-on parts. This is represented by the RelAggregates decomposition mechanism used to aggregate parts, such as Plate, into a container element such as ElementAssembly or CurtainWall.

NOTE The representation of a plate in a structural analysis model is provided by StructuralSurfaceMember being part of a StructuralAnalysisModel.

An instance Plate should preferably get its geometric representation and material assignment through the type definition by PlateType assigned using the RelDefinesByType relationship. This allows identical plates in a construction to be represented by the same instance of PlateType.

A plate may have openings, such as voids or recesses. They are defined by an OpeningElement attached to the plate using the inverse relationship HasOpenings pointing to RelVoidsElement. The position number of a plate as often used in steel construction is assigned through the attribute Element.Tag

Two types of plate occurrences in terms of geometric representation are possible:

- Plate Standard Case used for all occurrences of plates, that are prismatic and where the thickness parameter can be fully described by the MaterialLayerSetUsage. These plates are always represented geometrically by a 'SweptSolid' geometry (or by a 'Clipping' geometry based on 'SweptSolid'), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialLayerSetUsage assigned.
- Plate General Case used for all other occurrences of plates, particularly for plates with changing thickness, or plates with non planar surfaces, and plates having only 'SurfaceModel' or 'Brep' geometry.

The predefined types of Plate, including bridge specific cases are:

- CURTAIN_PANEL A planar element within a curtain wall, often consisting of a frame with fixed glazing.
- SHEET A planar, flat and thin element, comes usually as metal sheet, and is often used as an additional part within an assembly.
- FLANGE_PLATE A flange plate in linear members having box or I-profile (e.g. top or bottom flange plate in box-girder).
- WEB_PLATE A plate connecting flange plates in linear members having box or I-profile.
- STIFFENER_PLATE A transversal plate added to a flange or a web plate for local stiffening.
- GUSSET_PLATE a plate or bracket for strengthening an angle in framework (as in a building or bridge)
- COVER_PLATE A plate underneath a flange to provide additional load capacity
- SPLICE_PLATE A plate connecting two members joined at ends

- BASE_PLATE A plate used to spread load over a surface, such as underneath a bearing or column
- USERDEFINED User-defined linear element.
- NOTDEFINED Undefined linear element.

4.4.12 Railing

The railing is a frame assembly adjacent to human or vehicle circulation spaces and at some space boundaries where it is used in lieu of walls or to compliment walls. Designed to aid humans, either as an optional physical support, or to prevent injury or damage, either by falling or collision.

The predefined types of Railing, including bridge specific cases are:

- HANDRAIL A type of railing designed to serve as an optional structural support for loads applied by human occupants (at hand height). Generally located adjacent to ramps and stairs. Usually floor or wall mounted.
- GUARDRAIL A type of railing designed to guard human or vehicle from falling off a stair, ramp or landing where there is a vertical drop at the edge of such floors/landings, or to provide restraint to an errant road vehicle, installed on the central reserve of or alongside a road.
- BALUSTRADE Similar to the definitions of a guardrail except the location is at the edge of a floor, rather than a stair or ramp. Examples are balustrades at roof-tops or balconies system, or along a bridge or on top of a retaining wall.
- USERDEFINED User-defined railing element type.
- NOTDEFINED Undefined railing element, no type information available.

4.4.13 Ramp

A ramp is a vertical passageway providing a human or vehicle circulation link from one level to another at a different elevation. It may include several flights with landings as intermediate slabs. A ramp normally does not include steps.

NOTE Definition according to ISO 6707-1: Inclined way or floor joining two surfaces at different levels.

The Ramp shall either be represented:

- as a ramp assembly that aggregates all parts (ramp flight, landing, etc.) with own shape representations, or
- as a single ramp without decomposition including all shape representations directly at the ramp entity.

NOTE In case of a Ramp being the assembly of all parts of the ramp the aggregation is handled by the RelAggregates relationship, relating a Ramp with the related RampFlight and landings, Slab with PredefinedType=LANDING. Railings belonging to the ramp may also be included into the aggregation.

NOTE Some use cases may restrict the Ramp being an assembly to not have an independent shape representation, but to always require that the decomposed parts have a shape representation. In this case, at least the 'Body' geometric representations shall not be provided directly at Ramp if it is an assembly. The 'Body' geometric representation of the Ramp is then the sum of the 'Body' shape representation of the parts within the decomposition structure.

4.4.14 RampFlight

A ramp comprises a single inclined segment, or several inclined segments that are connected by a horizontal segment, referred to as a landing. A ramp flight is the single inclined segment and part of the ramp construction. In case of single flight ramps, the ramp flight and the ramp are identical.

NOTE A single flight ramp is represented by a Ramp instance without using aggregation and by utilizing the product shape representation directly at Ramp.

A RampFlight is an aggregated part of a Ramp realized through the RelAggregates relationship, the ramp flight is therefore included in the set of RelAggregates.RelatedObjects.

A RampFlight may connect zero, one or two slabs at different elevations. The connection relationship between the RampFlight and the Slab can be expressed using the RelConnectsElements relationship.

4.4.15 Slab

A slab is a flat horizontal, or nearly horizontal, component of the construction that may enclose a space vertically or provide structural support primarily by resisting bending. The slab may provide the lower support (floor) or upper construction (roof slab) in any part of a built facility.

NOTE Definition according to ISO 6707-1: thick, flat or shaped component, usually larger than 300 mm square, used to form a covering or projecting from a building.

Only the core or constructional part of this construction is considered to be a slab. The upper finish (flooring, roofing) and the lower finish (ceiling, suspended ceiling) are considered to be coverings. A special type of slab is the landing, described as a horizontal section to which one or more stair flights or ramp flights connect.

NOTE There is a representation of slabs for structural analysis provided by a proper subtype of StructuralMember being part of the StructuralAnalysisModel.

NOTE An arbitrary planar element to which this semantic information is not applicable or irrelevant shall be modeled as Plate.

A slab may have openings, such as floor openings, or recesses. They are defined by an OpeningElement attached to the slab using the inverse relationship HasOpenings pointing to RelVoidsElement.

Three types of slab occurrences in terms of geometric representation are possible:

- Slab Standard Case used for all occurrences of slabs, that are prismatic and where the thickness parameter can be fully described by the MaterialLayerSetUsage. These slabs are always represented geometrically by a 'SweptSolid' geometry (or by a 'Clipping' geometry based on 'SweptSolid'), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialLayerSetUsage assigned. (Capturing rebar layout parametrically, see 4.4.29).
- Slab Elemented Case used for occurrences of slabs which are aggregated from subordinate elements, following specific decomposition rules expressed by the mandatory use of RelAggregates relationship.
- Slab General Case used for all other occurrences of slabs, particularly for slabs with changing thickness, or slabs with non planar surfaces, and slabs having only 'SweptSolid' or 'Brep' geometry.

The predefined types of Slab, including bridge specific cases are:

- FLOOR The slab is used to represent a floor slab or a bridge deck.
- ROOF The slab is used to represent a roof slab (either flat or sloped).
- LANDING The slab is used to represent a landing within a stair or ramp.
- BASESLAB The slab is used to represent a floor slab against the ground (and thereby being a part of the foundation). Another name is mat foundation.
- APPROACH_SLAB is part of bridge abutment providing transition from embankment to the bridge
- WEARING The slab is used to represent a wearing surface.
- SIDEWALK The slab is used to represent a sidewalk
- USERDEFINED User-defined slab.
- NOTDEFINED Undefined slab type.

4.4.16 Stair

A stair is a vertical passageway providing a human circulation link from one level to another at a different elevation. It includes one or several stepped flights, with landings as intermediate slabs.

NOTE Definition according to ISO 6707-1: Construction comprising a succession of horizontal stages (steps or landings) that make it possible to pass on foot to other levels.

The Stair shall either be represented:

- as a stair assembly entity that aggregates all parts (stair flight, landing, etc. with own representations), or
- as a single stair entity without decomposition including all representation directly at the stair entity.

NOTE In case of a Stair being the aggregate of all parts of the stair the aggregation is handled by the RelAggregates relationship, relating a Stair with the related StairFlight and landings, Slab with PredefinedType=LANDING. Railings belonging to the stair may also be included into the aggregation.

NOTE Some use cases may restrict the Stair being an assembly to not have an independent shape representation, but to always require that the decomposed parts have a shape representation. In this case, at least the 'Body' geometric representations shall not be provided directly at Stair if it is an assembly. The 'Body' geometric representation of the Stair is then the sum of the 'Body' shape representation of the parts within the decomposition structure.

4.4.17 StairFlight

A stair flight is an assembly of building components in a single "run" of stair steps (not interrupted by a landing). The stair steps and any stringers are included in the stair flight. A winder is also regarded a part of a stair flight.

A StairFlight is normally aggregated by a Stair through the RelAggregates relationship, the stair flight is then included in the set of RelAggregates.RelatedObjects. A StairFlight normally connects zero, one or two slabs at different elevations. The connection relationship between the StairFlight and the Stair can be expressed using the RelConnectsElements relationship.

4.4.18 Wall

The wall represents a vertical construction that may bound or subdivide spaces. Wall is usually a vertical, or nearly vertical, planar element, often designed to bear structural loads. A wall is however not required to be load bearing.

NOTE Definition according to ISO 6707-1: vertical construction usually in masonry or in concrete which bounds or subdivides a construction works and fulfils a load bearing or retaining function.

NOTE There is a representation of walls for structural analysis provided by a proper subtype of StructuralMember being part of the StructuralAnalysisModel.

NOTE An arbitrary planar element to which this semantic information is not applicable (is not predominantly vertical), shall be modelled as Plate.

A wall may have openings, such as wall openings, openings used for windows or doors, or niches and recesses. They are defined by a OpeningElement attached to the wall using the inverse relationship HasOpenings pointing to RelVoidsElement.

NOTE Walls with openings that have already been modeled within the enclosing geometry may use the relationship RelConnectsElements to associate the wall with embedded elements such as doors and windows.

There are potentially three types of wall occurrences in terms of geometric representation:

- Wall Standard Case used for all occurrences of walls, that have a non-changing thickness along the wall path and where the thickness parameter can be fully described by a material layer set. These walls are always represented geometrically by an 'Axis' and a 'SweptSolid' shape representation (or by a 'Clipping' geometry based on 'SweptSolid'), if a 3D geometric representation is assigned. In addition they have to have a corresponding MaterialProfileSetUsage assigned. (Capturing rebar layout parametrically, see 4.4.29).

- Wall Elemented Case used for occurrences of walls which are aggregated from subordinate elements, following specific decomposition rules expressed by the mandatory use of RelAggregates relationship.
- Wall General Case used for all other occurrences of wall, particularly for walls with changing thickness along the wall path (e.g. polygonal walls), or walls with a non-rectangular cross sections (e.g. L-shaped retaining walls), and walls having an extrusion axis that is unequal to the global Z axis of the project (i.e. non-vertical walls), or walls having only 'Brep', or 'SurfaceModel' geometry.

The predefined types of Wall, including bridge specific cases are:

- MOVABLE A movable wall that is either movable, such as folding wall or a sliding wall, or can be easily removed as a removable partitioning or mounting wall. Movable walls do normally not define space boundaries and often belong to the furnishing system.
- PARAPET A wall-like barrier to protect human or vehicle from falling, or to prevent the spread of fires. Often designed at the edge of balconies, terraces or roofs, or along edges of bridges.
- PARTITIONING A wall designed to partition spaces that often has a light-weight, sandwich-like construction (e.g. using gypsum board). Partitioning walls are normally non load bearing.
- PLUMBINGWALL A pier, or enclosure, or encasement, normally used to enclose plumbing in sanitary rooms. Such walls often do not extent to the ceiling.
- SHEAR A wall designed to withstand shear loads. Examples of shear wall are diaphragms inside a box girder, typically on a pier, to resist lateral forces and transfer them to the support.
- SOLIDWALL A massive wall construction for the wall core being the single layer or having multiple layers attached. Such walls are often masonry or concrete walls (both cast in-situ or precast) that are load bearing and fire protecting.
- STANDARD A standard wall, extruded vertically with a constant thickness along the wall path.
- POLYGONAL A polygonal wall, extruded vertically, where the wall thickness varies along the wall path.
- ELEMENTEDWALL A stud wall framed with studs and faced with sheetings, sidings, wallboard, or plasterwork.
- RETAININGWALL A supporting wall used to protect against soil layers behind. Special types of a retaining wall may be e.g. Gabion wall and Grib wall. Examples of retaining walls are wing wall, headwall, stem wall, pierwall and protecting wall.
- USERDEFINED User-defined wall element.
- NOTDEFINED Undefined wall element.

4.4.19 ElementAssembly

The ElementAssembly represents complex element assemblies aggregated from several elements, such as discrete elements, building elements, or other elements.

EXAMPLE Steel construction assemblies, such as trusses and different kinds of frames, can be represented by the ElementAssembly entity. Other examples include slab fields aggregated from a number of precast concrete slabs or reinforcement units made from several reinforcement bars. Also bathroom units, staircase sections and other pre-manufactured or precast elements are examples of the general ElementAssembly entity.

NOTE The ElementAssembly is a general purpose entity that is required to be decomposed. Also other subtypes of Element can be decomposed (in some dedicated entities this is even presumed, such as Wall Elemented Case and Slab Elemented Case).

The assembly structure can be nested, i.e. an ElementAssembly could be an aggregated part within another ElementAssembly.

NOTE Some use cases may restrict the number of allowed levels of nesting.

The geometry of an ElementAssembly is generally formed from its components, in which case it does not need to have an explicit geometric representation. In some cases it may be useful to also expose an own explicit representation of the aggregate.

The predefined element assembly types, including bridge specific cases are:

- ACCESSORY_ASSEMBLY Assembled accessories or components.
- ARCH A curved structure.
- BEAM_GRID Interconnected beams, located in one (typically horizontal) plane.
- BRACED_FRAME A rigid frame with additional bracing members.
- GIRDER A beam-like superstructure, such as bridge main girder extending between abutments and piers built up of beams, braces (as Members) etc. - may also be an aggregation of girder segments.
- REINFORCEMENT_UNIT Assembled reinforcement elements.
- RIGID_FRAME A structure built up of beams, columns, etc. with moment-resisting joints.
- SLAB_FIELD Slabs, laid out in one plane.
- TRUSS A structure built up of members with (quasi) pinned joint.
- ABUTMENT A bridge abutment built up of walls, beams, slabs etc.
- PIER An intermediate support e.g. in a bridge, built up of walls, columns, beams etc.
- PYLON A vertical structure supporting cables in suspended or stayed structure
- CROSS_BRACING A Structural linear member or assembly of memebrs inside a box girder or between girders, typically on a pier, to resist lateral forces and transfer them to the support.
- DECK A platform (such as floor or bridge deck) built up of beams, slabs
- USERDEFINED User-defined element assembly.

- NOTDEFINED Undefined element assembly.

4.4.20 ElementComponent

An element component is a representation for minor items included in, added to or connecting to or between elements, which usually are not of interest from the overall structure viewpoint. However, these small parts may have vital and load carrying functions within the construction. These items do not provide any actual space boundaries. Typical examples of ElementComponents include different kinds of fasteners and various accessories.

One or several instances of subtypes of ElementComponent should always be accompanied by a defining instance of a respective subtype of ElementComponentType. The type object holds shape and material information.

It is often desirable to model a number of same-shaped element components by means of a single occurrence object, e.g. several bolts within a connection or a row of reinforcement elements. This is possible by means of multiple mapped representation as documented below.

To express the multiplicity of element components also on a higher semantic level, a quantity set named Qto_ElementComponentPatternQuantities should be provided via RelDefinesByProperties and contain the number of pieces which are placed by a single ElementComponent instance.

Symbolic Representation

A symbolic representation is defined for a row of components or several rows of components within a single instance of ElementComponent. Such rows or arrays may contain possibly large numbers of individual pieces. The product definition shape consists of an ShapeRepresentation with the attribute values

- RepresentationIdentifier : 'Row'
- RepresentationType : 'GeometricCurveSet'

and one or several curves as geometric items. The curves represent where reference points of the pieces are located. For example, such reference points may be at the heads of mechanical fasteners or at the starting point of the extrusion axis of reinforcement bars. In case of straight components (bolts, nails, staples, straight reinforcement bars, or similar), the local placement of the ElementComponent shall be located and oriented such that the local z axis is parallel with the axes of the components. A Qto_ElementComponentPatternQuantities should denote the count of pieces in the row or array and their spacing.

4.4.21 VibrationDamper

A vibration damper is a device used to minimize the effects of vibration in a structure by dissipating kinetic energy. The damper may be passive (elastic, frictional, inertia) or active (in a system using sensors and actuators).

The predefined types are include:

- BENDING_YIELD A displacement dependent type damper in which the resistance force generated is determined by the plastic strain amount utilizing the plastic deformation of the steel material. The bending yield type is a damper, which yields steel material by bending.
- SHEAR_YIELD A displacement dependent type damper in which the resistance force generated is determined by the plastic strain amount utilizing the plastic deformation of the steel material. The shear yield type is a damper, which causes the steel material to yield for deformation in the direction perpendicular to the member.
- AXIAL_YIELD A displacement dependent type damper in which the resistance force generated is determined by the plastic strain amount utilizing the plastic deformation of the steel material. The axial yield type is a damper that yields energy by absorbing the steel material against deformation in the axial direction, that is, in the direction of expansion and contraction.
- FRICTION The friction type is a damper utilizing friction acting on the contact surface of a material.
- VISCOUS The viscous type is a damper that absorbs energy by utilizing the resistance of a viscous body.
- RUBBER The rubber mold is a damper that absorbs energy by utilizing deformation of laminated rubber. The difference between the seismic isolation bearing and the rubber type damper is whether or not to support the weight of the upper structures. The rubber damper does not transmit the weight of the upper structures to the sub structure.
- USERDEFINED User-defined vibration damper type.
- NOTDEFINED Undefined vibration damper type.

4.4.22 VibrationIsolator

A vibration isolator is a device used to minimize the effects of vibration transmissibility in a structure.

The predefined types include:

- COMPRESSION Compression type vibration isolator.
- SPRING Spring type vibration isolator.
- BASE Base isolator preventing transfer of energy from the ground to the structure.
- USERDEFINED User-defined vibration isolator type.
- NOTDEFINED Undefined vibration isolator type.

4.4.23 BuildingElementPart

BuildingElementPart represents major components as subordinate parts of a building element. Typical usage examples include precast concrete sandwich walls, where the layers may have different geometry representations. In this case the layered material representation does not sufficiently describe the element. Each layer is represented by an own instance of the BuildingElementPart with its own geometry description.

The kind of building element part is further specified by a corresponding instance of BuildingElementPartType, referred to by RelDefinesByType.

The predefined types include:

- INSULATION The part provides thermal insulation, for example as insulation layer between wall panels in sandwich walls or as infill in stud walls.
- PRECASTPANEL The part is a precast panel, usually as an internal or external layer in a sandwich wall panel.
- APRON A form of scour protection consisting of timber, concrete, riprap, paving, or other construction placed adjacent to abutments and piers to prevent undermining.
- USERDEFINED User-defined part.
- NOTDEFINED Undefined part.

4.4.24 DiscreteAccessory

A discrete accessory is a representation of different kinds of accessories included in or added to elements.

The predefined types with bridges specific cases include:

- ANCHORPLATE An accessory consisting of a steel plate, shear stud connectors or welded-on rebar which is embedded into the surface of a concrete element so that other elements can be welded or bolted onto it later.
- BRACKET An L-shaped or similarly shaped accessory attached in a corner between elements to hold them together or to carry a secondary element.
- SHOE A column shoe or a beam shoe (beam hanger) used to support or secure an element.
- EXPANSION_JOINT_DEVICE Assembly connection element between construction elements to allow for thermic differential expansions.
- USERDEFINED User-defined accessory.
- NOTDEFINED Undefined accessory.

4.4.25 Fastener

Representations of fixing parts which are used as fasteners to connect or join elements with other elements. Excluded are mechanical fasteners which are modeled by a separate class (MechanicalFastener).

The predefined types include:

- GLUE A fastening connection where glue is used to join together elements.
- MORTAR A composition of mineralic or other materials used to fill jointing gaps and possibly fulfilling a load carrying role.
- WELD A weld seam between parts of metallic material or other suitable materials.
- USERDEFINED User-defined fastener.
- NOTDEFINED Undefined fastener.

4.4.26 MechanicalFastener

A mechanical fasteners connecting building elements or parts mechanically. A single instance of this class may represent one or many of actual mechanical fasteners, for example an array of bolts or a row of nails.

The predefined types include:

- ANCHORBOLT A special bolt which is anchored into concrete, stone, or brickwork.
- BOLT A threaded cylindrical rod that engages with a similarly threaded hole in a nut or any other part to form a fastener. The mechanical fastener often also includes one or more washers and one or more nuts.
- DOWEL A cylindrical rod that is driven into holes of the connected pieces.
- NAIL A thin pointed piece of metal that is hammered into materials as a fastener.
- NAILPLATE A piece of sheet metal with punched points that overlaps the connected pieces and is pressed into their material.
- RIVET A fastening part having a head at one end and the other end being hammered flat after being passed through holes in the pieces that are fastened together.
- SCREW A fastener with a tapered threaded shank and a slotted head.
- SHEARCONNECTOR A ring connector that is accepted by ring keyways in the connected pieces; or a toothed circular or square connector that is pressed into the connected pieces.
- STAPLE A doubly pointed piece of metal that is hammered into materials as a fastener.
- STUDSHEARCONNECTOR Stud shear connectors are cylindrical fastening parts with a head on one end. On the other end they are welded on steel members for the use in composite steel and concrete structures.
- COUPLER A part connecting two rod or bars, such as reinforcement bars.
- USERDEFINED User-defined mechanical fastener.
- NOTDEFINED Undefined mechanical fastener.

4.4.27 ReinforcingElement

A reinforcing element represents bars, wires, strands, meshes, tendons, and other components embedded in concrete in such a manner that the reinforcement and the concrete act together in resisting forces.

NOTE Definition according to ISO 6707-1: rod(s), bar(s), fabric, fibres, wires and cable(s) added to give additional strength or support to a material or component.

One or several instances of subtypes of ReinforcingElement should always be accompanied by a defining instance of a respective subtype of ReinforcingElementType. The type object holds shape and material information.

4.4.28 ReinforcingMesh

A reinforcing mesh is a series of longitudinal and transverse wires or bars of various gauges, arranged at right angles to each other and welded at all points of intersection; usually used for concrete slab reinforcement. It is also known as welded wire fabric. In scope are plane meshes as well as bent meshes.

Placement and representation in general are inherited from the supertype ElementComponent. The representation map of a mapped 'Outline' representation should contain a representation of type 'Curve3D' which holds an Polyline. The representation map of a mapped 'Body' representation should contain a representation of type 'AdvancedSweptSolid' which holds multiple SweptDiskSolid (including subtype SweptDiskSolidPolygonal).

4.4.29 ReinforcingBar

A reinforcing bar is usually made of steel with manufactured deformations in the surface, and used in concrete and masonry construction to provide additional strength. A single instance of this class may represent one or many of actual rebars, for example a row of rebars.

Material profile sets may be used to indicate parametric layout of rebar, indicating cover, spacing, and repetition along all three axes, as explained below. For representing geometry for rebar, it is proposed to leverage existing definitions without creating any new parametric placement definitions at the level of geometry, but rather leverage material definitions for such parametric use.

For representing bars within a girder, having a potentially horizontally and vertically curved alignment, the entity SweptDiskSolid may be used, where the path of the sweep is defined using OffsetCurveByDistances. A single ReinforcingBar may then consist of a many SweptDiskSolid instances. MappedItem may be also used to repeat the same SweptDiskSolid, particularly for bridges that are straight or where curvature is not large enough to impact bar layout. Using MappedItem is more efficient for GPU rendering, as the same shape can be repeated many times, rather than capturing very slight variations due to curvature.

For representing spiral reinforcing, IfcPCurve may be used, where the BasisSurface is set to IfcCylindricalSurface, and ReferenceCurve is set to a 2D IfcPolyline with two points, starting at 0,0 from the reference surface, and extending to U, V where U equals the number of revolutions and V equals the vertical extent according to the parametrized surface.

Rebar may be exchanged with (a) geometry only; (b) parametric material definitions only; or (c) both, depending on the particular scenario.

With parametric material definitions provided, the geometry may be reconstructed by correlating MaterialProfile.Name with Element.Name, and traversing MaterialLayer.Components with Element.IsDecomposedBy, recursively. Longitudinal material offsets correlate with DistanceExpression.DistanceAlong; lateral material offsets correlate with DistanceExpression.LateralOffset; and vertical material offsets correlate with DistanceExpression.VerticalOffset

To capture rebar layout parametrically for beams as well as slabs, it is proposed to add several attributes to MaterialProfileWithOffsets and MaterialLayerWithOffsets:

- OffsetValues : OPTIONAL ARRAY[1:6] OF LengthMeasure; /* exists */
- SpanValues : OPTIONAL ARRAY[1:3] OF LengthMeasure;
- CountValues : OPTIONAL ARRAY[1:3] OF CountMeasure;
- Components : OPTIONAL LIST[1:?] OF MaterialDefiniiton;

The Components attribute enables an MaterialProfile to be decomposed into inner MaterialProfile's that are dependent upon such outer profile, such as rebar within a cross section. This is different than simply using multiple MaterialProfile's within an MaterialProfileSet, which is used for side-by-side cross sections such as the base and deck portions of a box girder cross section. Such nesting relationship then enables the inner rebar to be defined relative to the bounds of the outer profile. The order of the Components is significant, such that profiles or layers are stacked in the specified order.

Where such nesting is used, the existing OffsetValues attribute (for the inner MaterialProfile) may indicate the concrete cover on each end (distance between edge of profile and start of inner element(s). This attribute is expanded from 1:2 (indicating offsets only in longitudinal direction) to 1:6 (indicating offsets longitudinally, laterally, and/or vertically).

The SpanValues attribute may be used on an inner profile to indicate the minimum center-to-center distance between items (e.g. bars), where such pattern of bars then spans between the OffsetValues relative to the edges of the profile. Span values in the longitudinal direction may indicate the splice distance.

The CountValues attribute may be used to indicate a limiting number of intervals to repeat in the corresponding direction, or NIL to indicate spacing shall be repeated until reaching extents.

Such parametric definitions may be used to communicate rebar layout as typically indicated in construction plans with or without elaborating rebar into specific objects and geometry. If objects and geometry are also provided, then each MaterialProfile.Name may be correlated with Element.Name. Geometry for each element may be repeated using multiple MappedItem (for the case of straight rebar), multiple SweptDiskSolid,(for the case of curved longitudinal or lateral bars, each based on separate OffsetCurveByDistance), or other representation items.

Definitions for hooks or other such bending at ends may be provided by property sets for referencing standard bending shape codes.

This same mechanism may be leveraged for slabs where an outer MaterialLayer, may contain inner MaterialProfile's for indicating rebar in both horizontal directions. This mechanism may also be used in buildings for framed walls or floor slabs, where a layer is decomposed into stud/joist definitions as well as cavities, where such cavities may be further decomposed into layers for insulation.

The Figure 9 and Figure 10 below illustrate usage of MaterialProfileSet and MaterialProfileWithOffsets (concepts implemented as IFC entity instances) to indicate rebars within a cross section parametrically.

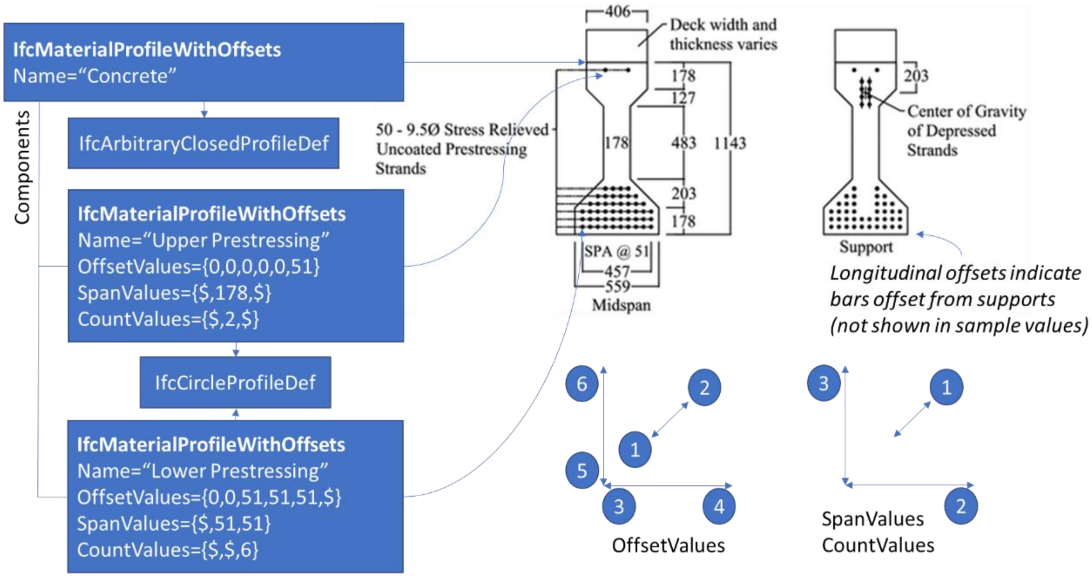

Figure 9 *Parametric rebar layout beam example in IFC model.*

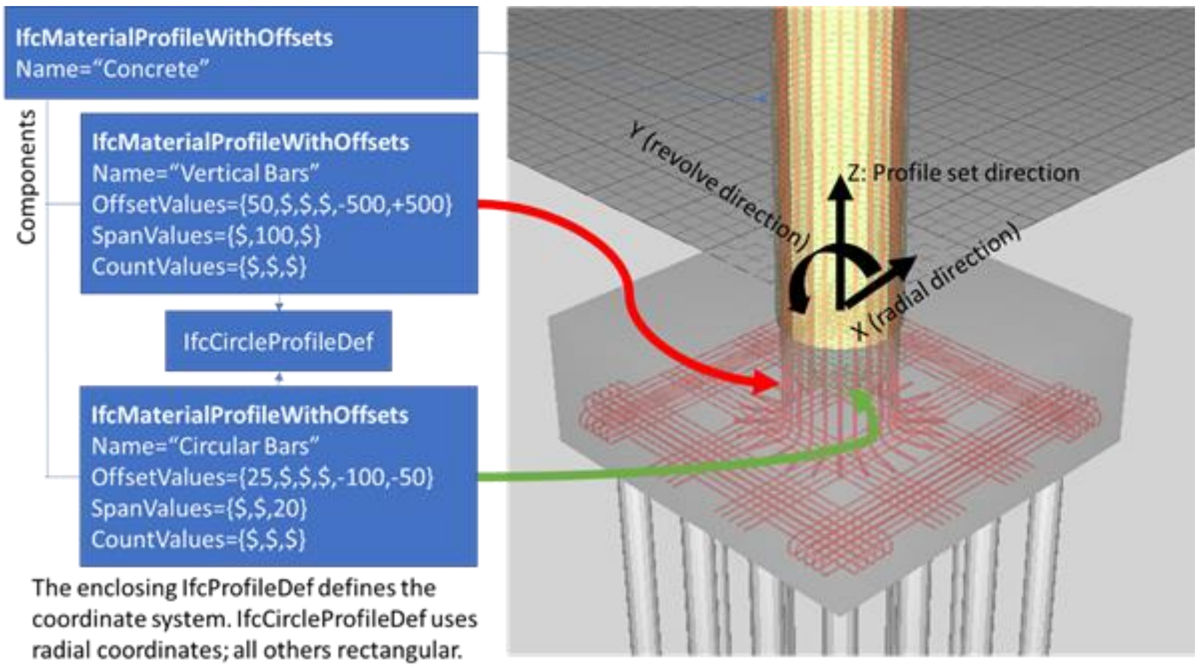

Figure 10 *Parametric rebar layout column and footing example in IFC model.*

Alternatively, using a new data structure may be more intuitive, rather than being consistent with the existing definitions, as follows. Yet another alternative which may simplify further would be to add additional attributes at MaterialProfile and MaterialLayer and remove the derived MaterialXXXXWithOffsets entities (MaterialProfileWithOffsets and similar for MaterialLayerWithOffsets).

Placement and representation in general are inherited from the supertype ElementComponent. The representation map of a mapped 'Body' representation should contain a representation of type 'AdvancedSweptSolid' which holds an SweptDiskSolid (including subtype SweptDiskSolidPolygonal).

The predefined types include:

- ANCHORING Anchoring reinforcement.
- EDGE Edge reinforcement.
- LIGATURE The reinforcing bar is a ligature (link, stirrup).
- MAIN The reinforcing bar is a main bar.
- PUNCHING Punching reinforcement.
- RING Ring reinforcement.
- SHEAR The reinforcing bar is a shear bar.
- STUD The reinforcing bar is a stud.
- SPACEBAR A stirrup in pre-stressing system to position TendonConduit.
- USERDEFINED The type of reinforcement is user defined.
- NOTDEFINED The type of reinforcement is not defined.

4.4.30 Tendon

A tendon is a steel element such as a wire, cable, bar, rod, or strand used to impart pre-stress to concrete when the element is tensioned.

NOTE Definition according to ISO 6707-1: steel bar(s) or groups of bars, strands or wires given a tensile stress that produces a compressive stress in pre-stressed concrete or masonry.

The geometry of the tendon should be explained. To be efficient, the cable follows the deck alignment and moves vertically up on the top of the piers and down in the middle of the span. Therefore the cable axis is defined relatively towards the deck alignment. The ShapeRepresentation should be 'AdvancedSweptSolid' geometry based on SectionedSolidHorizontal description including DistanceExpression, CircleProfileDef and AlignmentCurve, leading to a polyline describing the cable directrix.

Regarding the Structural Analysis model, the cable has to be transformed into loads applied at each CartesianPoint defining the polyline.

The predefined types include:

- BAR The tendon is configured as a bar.
- COATED The tendon is coated.

- STRAND The tendon is a strand.
- WIRE The tendon is a wire.
- USERDEFINED The type of tendon is user defined.
- NOTDEFINED The type of tendon is not defined.

4.4.31 TendonAnchor

A tendon anchor is the end connection for tendons in pre-stressed or post-tensioned concrete structure.

The predefined types include:

- COUPLER The anchor is an intermediate device which connects two tendons.
- FIXED_END The anchor fixes the end of a tendon.
- TENSIONING_END The anchor is used or can be used to prestress the tendon.
- USERDEFINED The type of tendon anchor is user defined.
- NOTDEFINED The type of tendon anchor is not defined.

4.4.32 TendonConduit

A TendonConduit represents the components of the conduit system for tendons embedded in concrete structure.

The predefined types for Bridges include:

- TENDON_SLEEVE
- COUPLING
- GROUT_VENT
- GROUT_INLET
- TRUMPET
- USERDEFINED,
- NOTDEFINED

4.4.33 FeatureElement

A feature element is a generalization of all existence dependent elements which modify the shape and appearance of the associated master element. The FeatureElement offers the ability to handle these shape modifiers as semantic objects.

NOTE The term "feature" has a predefined meaning in a context of "feature-based modeling" and within steel construction work. It is introduced here in a broader sense to cover all existence dependent, but semantically described, modifiers of an element's shape and appearance.

In contrary to the aggregation, as used in ElementAssembly, that defines the aggregate as a container element, that has equally treated parts, the feature concept introduced by FeatureElement defines the master element with subordinate parts as additions, or with voids or cut-outs as subtractions.

4.4.34 FeatureElementAddition

The FeatureElementAddition is associated to its master element by virtue of the objectified relationship RelProjectsElement in order to add material to the master. This relationship implies a Boolean 'union' operation between the shape of the master element and the shape of the addition feature.

The local placement for FeatureElementAddition is always defined in relation to the local placement of the element to which the feature element is added: the PlacementRelTo relationship of LocalPlacement shall point to the local placement of the same Element, which is used in the HasProjections.RelatingElement inverse attribute.

4.4.35 ProjectionElement

The projection element is a specialization of the general feature element addition to represent projections applied to building elements. It represents a solid attached to any element that has physical manifestation.

EXAMPLE A wall projection such as a pilaster strip is handled by ProjectionElement

An ProjectionElement has to be linked to an element (all subtypes of Element) by using the RelProjectsElement relationship. Its existence depends on the existence of the master element. The relationship implies a Boolean union operation between the volume of the projection element and the volume of the element.

The predefined types include:

- BLISTER Part of concrete where the anchor for pre-stressing tendon can be embedded.
- DEVIATOR Part of concrete where re-direction of an external pre-stressed tendon can be embedded.
- USERDEFINED User-defined projection element.
- NOTDEFINED Undefined projection element.

4.4.36 FeatureElementSubtraction

The FeatureElementSubtraction is specialization of the general feature element.

NOTE A single subtraction feature such as the subtype OpeningElement is assigned by a single subtraction relationship RelVoidsElement to one occurrence of Element. It establishes a 1:1 relationship between the opening and the element. An element may have several RelVoidsElement relationships, enabling several voids.

The voiding relationship between a master element and a subtraction feature is geometrically resolved by a Boolean difference operation.

The local placement for FeatureElementSubtraction is always defined in relation to the local placement of the building element from which the feature element substration is substracted:

the PlacementRelTo relationship of LocalPlacement shall point (if given) to the local placement of the same Element, which is used in the VoidsElements.RelatingElement inverse attribute.

4.4.37 OpeningElement

The opening element stands for opening, recess or chase, all reflecting voids. It represents a void within any element that has physical manifestation. Openings can be inserted into walls, slabs, beams, columns, or other elements.

There are two entities for opening elements in terms of geometry:

- Opening Standard Case is used for all openings that have a constant profile along a linear extrusion. They are placed relative to the voided elements and the extrusion direction is perpendicular to the plane of the element (horizontally for walls, vertically for slabs). Only a single extrusion body is allowed. It cuts through the whole thickness of the voided element, i.e. it reflects a true opening (the thickness of the opening is greater or equal to the thickness of the element).
- Opening General Element is used for all other occurrences of openings and in particular also for niches or recesses (the thickness of the recess is smaller than the thickness of the element).

The attribute PredefinedType should be used to capture the differences,

- the attribute is set to OPENING for an opening or
- the attribute is set to RECESS for a recess or niche.

If the value for PredefinedType is omitted, or the value is set to NOTDEFINED, no specific information of whether it is an opening or recess shall be assumed.

An OpeningElement may be filled by a Door (or a window), or another filling element by using the relationship RelFillsElements. Depending on the type of the ShapeRepresentation of the OpeningElement the voiding relationship implies:

- if the ShapeRepresentation. = 'Body', then the Body shape representation of the opening has to be subtracted from the body shape representation of the voided element - implicit Boolean difference operation.
- if the ShapeRepresentation. = 'Reference', then the Reference shape representation of the opening is not subtracted, it is provided in addition to the hole in the Body shape representation of the voided element.

4.4.38 VoidingFeature

A voiding feature is a modification of an element which reduces its volume. Such a feature may be manufactured in different ways, for example by cutting, drilling, or milling of members made of various materials, or by inlays into the formwork of cast members made of materials such as concrete.

The predefined types include:

- CUTOUT An internal cutout (creating an opening) or external cutout (creating a recess) of arbitrary shape. The edges between cutting planes may be overcut or undercut, i.e. rounded.
- NOTCH An external cutout of with a mostly rectangular cutting profile. The edges between cutting planes may be overcut or undercut, i.e. rounded.
- HOLE A circular or slotted or threaded hole, typically but not necessarily of smaller dimension than what would be considered a cutout.
- MITER A skewed plane end cut, removing material across the entire profile of the voided element.
- CHAMFER A skewed plane end cut, removing material only across a part of the profile of the voided element.
- EDGE A shape modification along an edge of the element with the edge length as the predominant dimension of the feature, and feature profile dimensions which are typically much smaller than the edge length. Can for example be a chamfer edge (differentiated from a chamfer by its ratio of dimensions and thus usually manufactured differently), rounded edge (a convex edge feature), or fillet edge (a concave edge feature).
- USERDEFINED A user-defined type of voiding feature.
- NOTDEFINED An undefined type of voiding feature.

4.4.39 SurfaceFeature

A surface feature is a modification at (onto, or into) of the surface of an element. Parts of the surface of the entire surface may be affected. The volume and mass of the element may be increased, remain unchanged, or be decreased by the surface feature, depending on the type of surface feature. However, any increase or decrease of volume is small compared to the total volume of the element.

The geometric representation of SurfaceFeature is given by ProductDefinitionShape, allowing multiple geometric representations.

The local placement for SurfaceFeature is defined by LocalPlacement, which defines the local coordinate system that is referenced by all geometric representations:

- In case of features which are part of an element type, absolute placement into the type object's implied coordinate system shall be used.
- In case of features which are voiding an element occurrence, the PlacementRelTo relationship of LocalPlacement shall point to the local placement of the respective element.

Different shape representations may be used, depending on the nature of the feature and information requirements:

- Symbolic representation, such as the two-dimensional bounding box of a tag.
- A geometric set representing the geometric items of a mark.

- Surface representations of the affected parts of the surface by means of ShellBasedSurfaceModel. The faces within the surface model may be included into a B-Rep model within a representation map of the parent element type.

The predefined types include:

- MARK A point, line, cross, or other mark, applied for example for easier adjustment of elements during assembly.
- TAG A name tag, which allows to identify an element during production, delivery and assembly. May be manufactured in different ways, e.g. by printing or punching the tracking code onto the element or by attaching an actual tag.
- TREATMENT A subtractive surface feature, e.g. grinding, or an additive surface feature, e.g. coating, or an impregnating treatment, or a series of any of these kinds of treatments.
- DEFECT Detected defect on the surface of an element, such as corroded or eroded area.
- USERDEFINED A user-defined type of surface feature.
- NOTDEFINED An undefined type of surface feature.

4.4.40 CivilElement

A CivilElement is a generalization of all major elements within civil engineering works that cannot be represented as BuildingElements, DistributionElements or GeographicElements.

4.4.41 GeographicElement

A GeographicElement is a generalization of all elements within a geographical landscape. It includes occurrences of typical geographical elements, often referred to as features, such as trees or terrain. Common type information behind several occurrences of GeographicElement is provided by the GeographicElementType.

The predefined types include:

- TERRAIN
- SOIL_BORING_POINT

4.4.42 RelConnectsWithRealizingElements

RelConnectsWithRealizingElements defines a generic relationship that is made between two elements that require the realization of that relationship by means of further realizing elements.

RelConnectsWithRealizingElements is a specialization of RelConnectsElements where the connecting operation has the additional attribute of (one or many) realizing elements that may be used to realize or further qualify the relationship. It is defined as a ternary relationship.

EXAMPLE It may be used to describe the attachment of one element to another where the attachment is realized by a 'fixing' element such as a bracket. It may also be used to describe the mounting of one element onto another such as the requirement for the mounting major plant items onto builders work bases and/or anti-vibration isolators.

The connection types for bridges include:

- TrussJoint: Joint between truss members.
- ExpansionJoint: Joint allowing movement, usually due to thermal expansion difference in structures, with DiscreteAccessory of type EXPANSION_JOINT_DEVICE as RealizingElement.
- EmbeddedPartsJoint: Joint for auxiliary parts to structure, with appropriate RealizingElements, such as DiscreteAccessories of type ANCHORPLATE, BRACKET or SHOE.
- ConstructionJoint: Joint for phasing of construction, typically in in-situ concrete structures.

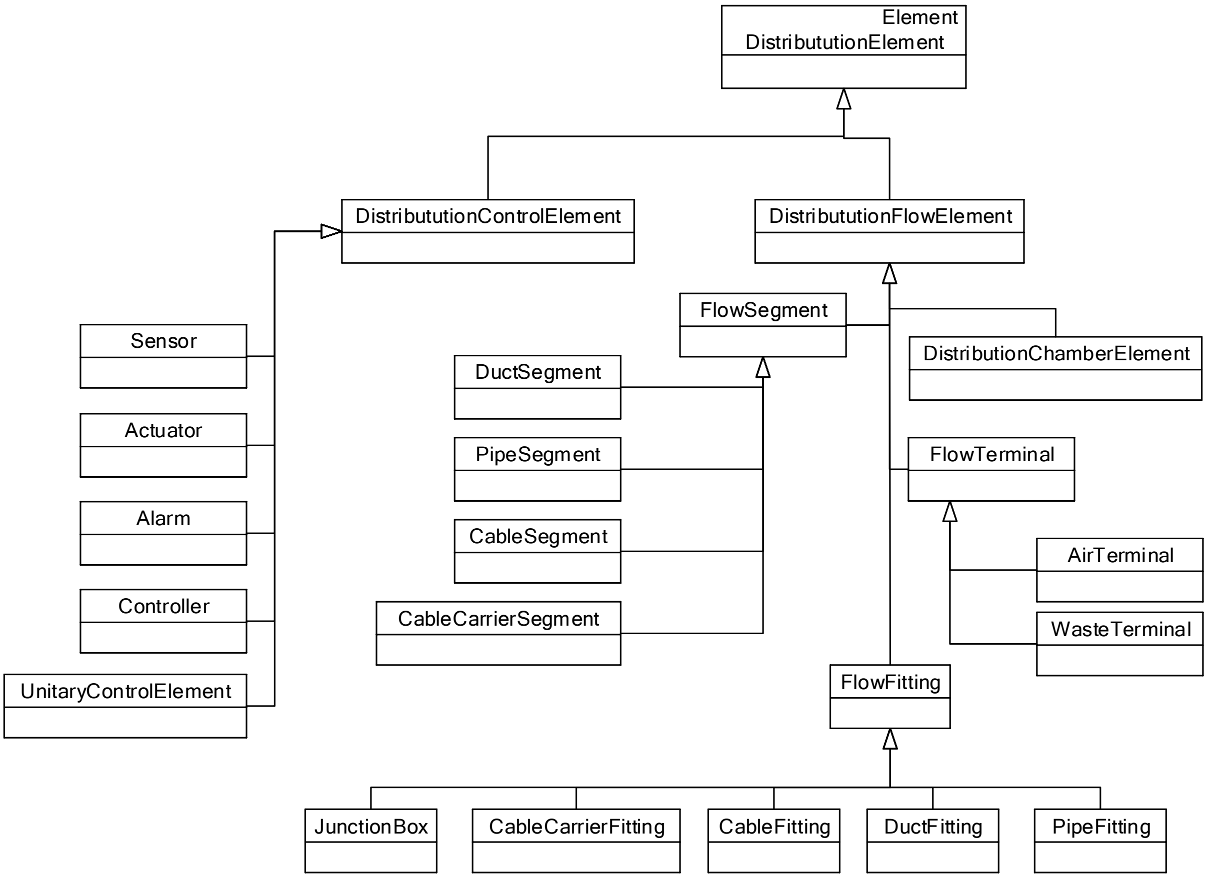

Figure 11 Physical distribution elements for Bridge model.

4.4.43 DistributionElement

This DistributionElement is a generalization of all elements that participate in a distribution system. Typical examples of DistributionElement's are (among others):

- building service elements within a heating systems
- building service elements within a cooling system
- building service elements within a ventilation system
- building service elements within a plumbing system

- building service elements within a drainage system
- electrical elements
- elements within a communication network elements
- within a sensor (monitoring) network

The DistributionElement is further specialized in the subtypes. Direct instantiation of DistributionElement without an assigned subtype of DistributionElementType provides the meaning of a distribution element proxy.

4.4.44 DistributionFlowElement

The distribution element DistributionFlowElement defines occurrence elements of a distribution system that facilitate the distribution of energy or matter, such as air, water or power.

EXAMPLE Examples of distribution flow elements are ducts, pipes, wires, fittings, and equipment.

4.4.45 FlowSegment

The distribution flow element FlowSegment defines the occurrence of a segment of a flow distribution system.

The FlowSegment defines a particular occurrence of a segment inserted in the spatial context of a project. The parameters defining the type of the segment and/or its shape are defined by the FlowSegmentType, which is related by the inverse relationship IsDefinedBy pointing to RelDefinesByType.

4.4.46 DuctSegment

A duct segment is used to typically join two sections of duct network.

The predefined types include:

- RIGIDSEGMENT A rigid segment is a continuous linear segment of duct that cannot be deformed.
- FLEXIBLESEGMENT A flexible segment is a continuous non-linear segment of duct that can be deformed and change the direction of flow.
- USERDEFINED User-defined segment.
- NOTDEFINED Undefined segment..

4.4.47 PipeSegment

A pipe segment is used to typically join two sections of a piping network.

The predefined types include:

- CULVERT A covered channel or large pipe that forms a watercourse below ground level, usually under a road or railway.

- FLEXIBLESEGMENT A flexible segment is a continuous non-linear segment of pipe that can be deformed and change the direction of flow.
- RIGIDSEGMENT A rigid segment is continuous linear segment of pipe that cannot be deformed.
- GUTTER A gutter segment is a continuous open-channel segment of pipe.
- SPOOL A type of rigid segment that is typically shorter and used for providing connectivity within a piping network.
- USERDEFINED User-defined segment.
- NOTDEFINED Undefined segment.

4.4.48 CableSegment

A cable segment is a flow segment used to carry electrical power, data, or telecommunications signals.

A cable segment is used to typically join two sections of an electrical network or a network of components carrying the electrical service.

The predefined types include:

- BUSBARSEGMENT Electrical conductor that makes a common connection between several electrical circuits. Properties of a busbar are the same as those of a cable segment and are captured by the cable segment property set.
- CABLESEGMENT Cable with a specific purpose to lead electric current within a circuit or any other electric construction. Includes all types of electric cables, mainly several core segments or conductor segments wrapped together.
- CONDUCTORSEGMENT A single linear element within a cable or an exposed wire (such as for grounding) with the specific purpose to lead electric current, data, or a telecommunications signal.
- CORESEGMENT A self contained element of a cable that comprises one or more conductors and sheathing.The core of one lead is normally single wired or multiwired which are intertwined.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type.

4.4.49 CableCarrierSegment

A cable carrier segment is a flow segment that is specifically used to carry and support cabling.

The predefined types include:

- CABLELADDERSEGMENT An open carrier segment on which cables are carried on a ladder structure.
- CABLETRAYSEGMENT A (typically) open carrier segment onto which cables are laid.
- CABLETRUNKINGSEGMENT An enclosed carrier segment with one or more compartments into which cables are placed.

- CONDUITSEGMENT An enclosed tubular carrier segment through which cables are pulled.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type.

4.4.50 FlowFitting

The distribution flow element FlowFitting defines the occurrence of a junction or transition in a flow distribution system, such as an elbow or tee. Its type is defined by FlowFittingType or its subtypes.

4.4.51 DuctFitting

A duct fitting is a junction or transition in a ducted flow distribution system or used to connect duct segments, resulting in changes in flow characteristics to the fluid such as direction and flow rate.

The predefined types include:

- BEND A fitting with typically two ports used to change the direction of flow between connected elements.
- CONNECTOR Connector fitting, typically used to join two ports together within a flow distribution system (e.g., a coupling used to join two duct segments).
- ENTRY Entry fitting, typically unconnected at one port and connected to a flow distribution system at the other (e.g., an outside air duct system intake opening).
- EXIT Exit fitting, typically unconnected at one port and connected to a flow distribution system at the other (e.g., an exhaust air discharge opening).
- JUNCTION A fitting with typically more than two ports used to redistribute flow among the ports and/or to change the direction of flow between connected elements (e.g, tee, cross, wye, etc.).
- OBSTRUCTION A fitting with typically two ports used to obstruct or restrict flow between the connected elements (e.g., screen, perforated plate, etc.).
- TRANSITION A fitting with typically two ports having different shapes or sizes. Can also be used to change the direction of flow between connected elements.
- USERDEFINED User-defined fitting.
- NOTDEFINED Undefined fitting.

4.4.52 PipeFitting

A pipe fitting is a junction or transition in a piping flow distribution system used to connect pipe segments, resulting in changes in flow characteristics to the fluid such as direction or flow rate.

Pipe fittings include elbows, junctions, manifolds, and plumbing boxes.

The predefined types include:

- BEND A fitting with typically two ports used to change the direction of flow between connected elements.

- CONNECTOR Connector fitting, typically used to join two ports together within a flow distribution system (e.g., a coupling used to join two duct segments).
- ENTRY Entry fitting, typically unconnected at one port and connected to a flow distribution system at the other (e.g., an outside air duct system intake opening).
- EXIT Exit fitting, typically unconnected at one port and connected to a flow distribution system at the other (e.g., an exhaust air discharge opening).
- JUNCTION A fitting with typically more than two ports used to redistribute flow among the ports and/or to change the direction of flow between connected elements (e.g, tee, cross, wye, etc.).
- OBSTRUCTION A fitting with typically two ports used to obstruct or restrict flow between the connected elements (e.g., screen, perforated plate, etc.).
- TRANSITION A fitting with typically two ports having different shapes or sizes. Can also be used to change the direction of flow between connected elements.
- USERDEFINED User-defined fitting.
- NOTDEFINED Undefined fitting.

4.4.53 CableFitting

A cable fitting is a fitting that is placed at a junction, transition or termination in a cable system.

- CONNECTOR A fitting that joins two cable segments of the same connector type (though potentially different gender).
- ENTRY A fitting that begins a cable segment at a non-electrical element such as a grounding clamp attached to a pipe.
- EXIT A fitting that ends a cable segment at a non-electrical element such as a grounding clamp attached to a pipe or to the ground.
- JUNCTION A fitting that joins three or more segments of arbitrary connector types for signal splitting or multiplexing.
- TRANSITION A fitting that joins two cable segments of different connector types.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type.

4.4.54 CableCarrierFitting

A cable carrier fitting is a fitting that is placed at junction or transition in a cable carrier system.

- BEND A fitting that changes the route of the cable carrier.
- CROSS A fitting at which two branches are taken from the main route of the cable carrier simultaneously.
- REDUCER A fitting that changes the physical size of the main route of the cable carrier.
- TEE A fitting at which a branch is taken from the main route of the cable carrier.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type.

4.4.55 JunctionBox

A junction box is an enclosure within which cables are connected.

Cables may be members of an electrical circuit (for electrical power systems) or be information carriers (in a telecommunications system). A junction box is typically intended to conceal a cable junction from sight, eliminate tampering or provide a safe place for electrical connection.

- DATA Contains cables, outlets, and/or switches for communications use.
- POWER Contains cables, outlets, and/or switches for electrical power.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type

4.4.56 DistributionChamberElement

A distribution chamber element defines a place at which distribution systems and their constituent elements may be inspected or through which they may travel.

An DistributionChamberElement is a formed volume used in a distribution system, such as a sump, trench or manhole. Instances of DistributionSystem or DistributionFlowElement may be related to the DistributionChamberElement enabling their location in or at the chamber to be determined.

- FORMEDDUCT Space formed in the ground for the passage of pipes, cables, ducts.
- INSPECTIONCHAMBER Chamber constructed on a drain, sewer or pipeline with a removable cover that permits visble inspection.
- INSPECTIONPIT Recess or chamber formed to permit access for inspection of substructure and services.
- MANHOLE Hamber constructed on a drain, sewer or pipeline with a removable cover that permits the entry of a person.
- METERCHAMBER Chamber that houses a meter(s).
- SUMP Recessed or small chamber into which liquid is drained to facilitate its collection for removal.
- TRENCH Excavated chamber, the length of which typically exceeds the width.
- VALVECHAMBER Chamber that houses a valve(s).
- USERDEFINED User-defined chamber type.
- NOTDEFINED Undefined chamber type.

4.4.57 FlowTerminal

The distribution flow element FlowTerminal defines the occurrence of a permanently attached element that acts as a terminus or beginning of a distribution system (such as an air outlet, drain, water closet, or sink). A terminal is typically a point at which a system interfaces with an external environment. Its type is defined by FlowTerminalType or its subtypes.

4.4.58 AirTerminal

An air terminal is a terminating or origination point for the transfer of air between distribution system(s) and one or more spaces. It can also be used for the transfer of air between adjacent spaces.

- DIFFUSER An outlet discharging supply air in various directions and planes.

- GRILLE A covering for any area through which air passes.
- LOUVRE A rectilinear louvre.
- REGISTER A grille typically equipped with a damper or control valve.
- USERDEFINED User-defined air terminal type.
- NOTDEFINED Undefined air terminal type.

4.4.59 WasteTerminal

A waste terminal has the purpose of collecting or intercepting waste from one or more sanitary terminals or other fluid waste generating equipment and discharging it into a single waste/drainage system.

A waste terminal provides for all forms of trap and waste point that collects discharge from a sanitary terminal and discharges it into a waste/drainage subsystem or that collects waste from several terminals and passes it into a single waste/drainage subsystem. This includes the P and S traps from soil sanitary terminals, sinks, and basins as well as floor wastes and gully traps that provide collection points.

- FLOORTRAP Pipe fitting, set into the floor, that retains liquid to prevent the passage of foul air
- FLOORWASTE Pipe fitting, set into the floor, that collects waste water and discharges it to a separate trap.
- GULLYSUMP Pipe fitting or assembly of fittings to receive surface water or waste water, fitted with a grating or sealed cover.
- GULLYTRAP Pipe fitting or assembly of fittings that receives surface water or waste water; fitted with a grating or sealed cover that discharges water through a trap.
- ROOFDRAIN Pipe fitting, set into the roof, that collects rainwater for discharge into the rainwater system.
- WASTEDISPOSALUNIT Electrically operated device that reduces kitchen or other waste into fragments small enough to be flushed into a drainage system.
- WASTETRAP Pipe fitting, set adjacent to a sanitary terminal, that retains liquid to prevent the passage of foul air.
- USERDEFINED User-defined type.
- NOTDEFINED Undefined type.

4.4.60 DistributionControlElement

DistributionControlElement defines elements of an automation control system. These are typically used to control distribution system elements to maintain variables such as temperature, humidity, pressure, flow, power, or lighting levels, through the modulation, staging or sequencing of mechanical or electrical devices. The three general functional categories of control elements are as follows:

- Impart control over flow control elements (FlowController) in a distribution system such as dampers, valves, or relays, typically through the use of actuation (Actuator).
- Sensing elements (Sensor) that measure changes in the controlled variable such as temperature, humidity, pressure, or flow.

- Controllers (Controller) typically classified according to the control action they seek to perform and generally responsible for making decisions about the elements under control.

Since DistributionControlElement and its subtypes typically relate to many different distribution flow elements (DistributionFlowElement), the objectified relationship RelFlowControlElements has been provided to relate control and flow elements as required.

The key distinction between DistributionFlowElement and DistributionControlElement is whether it is internal or external to the flow system, respectively. For example, the distinction between FlowMeter (subtype of DistributionFlowElement measuring a flow quantity) and FlowInstrument (subtype of DistributionControlElement measuring a flow quality), is based on this principal. A physical device that connects within the flow system in which it measures (having inlet/outlet pipes for the measured substance) follows the DistributionFlowElement hierarchy (and therefore FlowMeter which measures the flow internally). Otherwise, if it monitors/controls but does not connect inline within the flow system (it is external or is a component of another device), then it follows the DistributionControlElement hierarchy (and therefore FlowInstrument which may display various attributes through connected sensors).

4.5 Systems

4.5.1 System

Systems (derived from Group) do not have a location or geometric representations (only the physical components they are comprised of can have), but they may have relationship to spatial elements they serve.

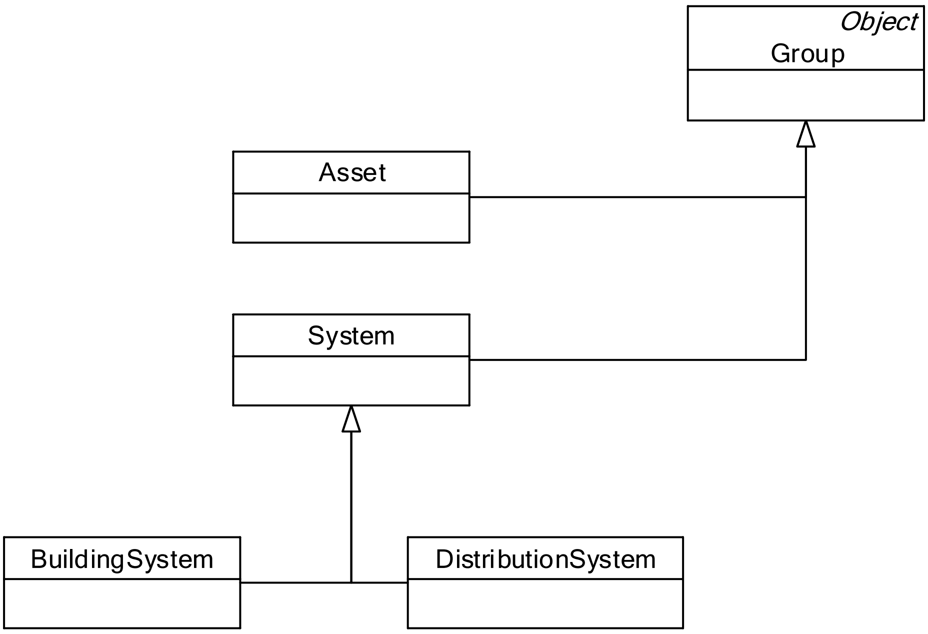

Figure 12 System concepts for Bridge model.

4.5.2 BuildingSystem

A building system is a group by which building elements are grouped according to a common function within the facility.

The group BuildingSystem defines the occurrence of a specialized system for use within the context of a building and finishing fabric. Important functionalities for the description of a building system are derived from supertypes:

- From System it inherits the ability to couple the building system via RelServicesBuildings to one or more SpatialElement subtypes as necessary.
- From Group it inherits the inverse attribute GroupedBy, pointing to the relationship class RelAssignsToGroup. This allows to group building elements (instances of BuildingElement subtypes, FurnishingElement subtype, ElementAssembly and TransportElement). The same object or object type can be included in zero, one or many groups. Grouping relationships are not hierarchical.
- From ObjectDefinition it inherits the inverse attribute DecomposedBy pointing to the relationship class RelAggregates. It provides the hierarchy between the separate (partial) building systems.

The predefined types include:

- FENESTRATION System of doors, windows, and other fillings in opening in a building envelop that are designed to permit the passage of air or light.
- FOUNDATION System of shallow and deep foundation element that transmit forces to the supporting ground.
- LOADBEARING System of building elements that transmit forces and stiffen the construction. Load-bearing system may be decomposed in subsystems such as ReinforcingSystem or PrestressingSystem.
- OUTERSHELL System of building elements that provides the outer skin to protect the construction (such as the facade).
- SHADING System of shading elements (external or internal) that permits the limitation or control of impact of natural sun light.
- TRANSPORT System of all transport elements in a building that enables the transport of people or goods.
- USERDEFINED
- NOTDEFINED

4.5.3 DistributionSystem

A distribution system is a network designed to receive, store, maintain, distribute, or control the flow of a distribution media. A common example is a heating hot water system that consists of a pump, a tank, and an interconnected piping system for distributing hot water to terminals.

The group DistributionSystem defines the occurrence of a specialized system for use within the context of building services or utilities for built facilities.

Important functionalities for the description of a distribution system are derived from supertypes:

- From System it inherits the ability to couple the distribution system via RelServicesBuildings to one or more SpatialElement subtypes as necessary.
- From Group it inherits the inverse attribute GroupedBy, pointing to the relationship entity RelAssignsToGroup. This allows to group distribution elements (instances of DistributionElement subtypes), and in special cases ports directly (instances of DistributionPort).
- From Object it inherits the inverse attribute DecomposedBy pointing to the relationship entity RelAggregates. It provides the hierarchy between the separate (partial) distribution systems. For example, an electrical main circuit may be aggregated into branch circuits.

The predefined types identifying the different types of distribution systems include:

- AUDIOVISUAL A transport of a single media source, having audio and/or video streams.
- COMMUNICATION
- CONTROL A system or network dedicated to control system usage.
- DATA A network having general-purpose usage.
- DRAINAGE Drainage collection system.
- ELECTRICAL A circuit for delivering electrical power.
- ELECTROACOUSTIC An amplified audio signal such as for loudspeakers.
- EXHAUST Exhaust air collection system for removing stale or noxious air from one or more spaces.
- FIREPROTECTION Fire protection sprinkler system.
- LIGHTING A circuit dedicated for lighting, such as a fixture having sockets for lamps.
- RAINWATER Rainwater resulting from precipitation which directly falls on a parcel.
- SIGNAL A raw analog signal, such as modulated data or measurements from sensors.
- STORMWATER Stormwater resulting from precipitation which runs off or travels over the ground surface.
- VENTILATION Ventilation air distribution system involved in either the exchange of air to the outside as well as circulation of air within a building.
- USERDEFINED
- NOTDEFINED

4.5.4 Asset

An asset is a uniquely identifiable grouping of elements acting as a single entity that has a financial value or that can be operated on as a single unit.

An asset is generally the level of granularity at which maintenance operations are undertaken. An asset is a group that can contain one or more elements. Whilst the financial value of a component or element can be defined, financial value is also defined for accounting purposes at the level of the asset.

There are a number of actors that can be associated with an asset, each actor having a role. Actors within the scope of the project are indicated using the RelAssignsToActor relationship in which case roles should be defined through the ActorRole class; otherwise principal actors are identified as attributes of the class. In the existence of both, direct attributes take precedence.

There are a number of costs that can be associated with an asset, each cost having a role. These are specified through the OriginalValue, CurrentValue, TotalReplacementCost and DepreciatedValue attributes.

5 ANNEX I: Example instance diagrams

Instance diagrams to be added.

6 ANNEX II: IFC Bridge conceptual model UML class diagrams

UML diagram in pdf file.