IFC-Bridge Fast Track Project

Report WP1: Requirements analysis

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Content

1 Overview and methodology

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

WP1 intended to define the scope of the project and the requirements of the IFC-Bridge extension. Given the restricted project duration, it was necessary to focus on common and widespread bridge types and to include only those use cases that provide a high value to the end users and require reasonable efforts for defining and validating the necessary IFC extensions.

As a basis for defining the IFC-Bridge extensions, the international project team identified the most important uses cases of the data exchange processes in infrastructure projects. The point of departure for this process had been provided by the outcomes of the IFC-Infra overall architecture process.

The defined list of use cases is not intended to be exhaustive. Instead, the most important use cases have been selected from interviews with experts having practical experience in bridge projects. In addition, the input from several national initiatives was taken into account:

- China: CRBIM project
- France: MIN^{n}D project
- Germany: IFC-Bridge Expert Group
- Nordic Chapter: IFC-Bridge Expert Group
- USA: FHWA project

The basic requirements for the IFC-Bridge extension have been derived from the identified use cases, by focusing on geometry representations and semantic descriptions. They have been distilled into three proposed Model View Definitions (MVDs) which are going to be developed throughout the project.

2 Bridge types covered

The following bridge types, based on their structural system, have been identified as the most common and widespread across the world. These bridge types are considered to be in-scope of this project. The developed IFC-Bridge extensions will be validated using examples of these bridge types.

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

The following bridges types are also expected to be covered by IFC and the IFC-Bridge extension, however they will not be 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 will be placed on realizing the necessary data structures for modeling prestressing systems.

3 Use cases

The following IFC-Bridge use cases have been identified by the project team by analyzing the outcomes of the national bridge projects and through discussions with the international expert panel. The table shows the priority of each use case and the complexity involved with defining the necessary data structures. This analysis formed the basis for subsequent decisions regarding the scope of the project; indicated by the color of the first column: green is in scope and red is out of scope.

No	**Use case**	**Description**	**Purpose**	**IFC exchange scenario**	**Required geometry representation**	**Required semantic information**	**Priority**	**Complexity**	**MVD**
🟩 1	Initial State Modeling	initial data (terrain, soil, existing structures etc.) from various sources (including GIS) are brought into BIM space and exchanged using IFC	GIS (and other) data provides the basis for the design task	GIS & other sources to design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc),	Major design parameters, Material (soil classification), accuracy and reliability of initial data	high	low	Bridge Reference View
🟩 2	Import of alignment and major road / railway parameters	alignment information is imported from roadway/railway design tool into bridge modeler	Alignment provides the basis for bridge design	From roadway / railway design system into bridge modeling system	Alignment and cross-sections	Maximum Speeds, Loads etc.	high	low	Alignment-based Bridge Reference View
🟩 3	Technical Visualization	3D technical visualization of the bridge project	Communication of design solutions to third parties, including the public	Design application to Visualization app.	Triangulated Face Sets	Bridge Breakdown Structure Object Types Material (opt) Colors (opt) Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View

No	**Use case**	**Description**	**Purpose**	**IFC exchange scenario**	**Required geometry representation**	**Required semantic information**	**Priority**	**Complexity**	**MVD**
4	Coordination / Collision detection	Coordination of domain-specific sub-models	Transfer and combine models to detect interferences (clashes)	Design application to Design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Component types Classification Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View
5	4D Construction Sequence Modeling	4D technical visualization of the construction phases	Organization of construction site and construction activities	Design application to 4D scheduling application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Temporal information	high	low	Bridge Reference View
6	Quantity Take-Off	Determine quantities (volumes and surfaces) from the model	Basis for cost estimation and cost calculation	Design application to QTO application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Material, Classifications Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View
7	Progress Monitoring	Transfer information about the progress of the construction project	Track and document the progress of the construction project	Surveying application to visualization application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Temporal information	high	low	Bridge Reference View
8	As-built vs. as-planned comparison	Compare the built structure against the as-planned model (Geometric Control)	Check the quality of the construction (on site)	Design application to field application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Classification Tolerance values Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
9	Handover to asset management	use the model to support operation and maintenance of the bridge,	use the model for inspection, damage detection, condition rating, condition prediction, maintenance planning	Design application to asset management system	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Classification Material Maintenance information	high	medium	Bridge Asset Management View
10	Handover to GIS for spatial analysis	Handover the bridge design to GIS for environmental analysis and/or asset mgmt.	GIS systems provide functionality for environmental analysis and can be used for asset management	Design application to GIS system	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Major design attributes	high	low	Alignment-based Bridge Reference View
11	Design to Design (reference model)	Use bridge model from early design phase as a reference for creating a more detailed bridge model in the detailed design ohase, limited modifiability required	Models are exchanged across different design phases, model from earlier phase is used us background / reference model for next phase	Design application to design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Classification Material Component types Relationships between entities (IfcRelConnects...)	high	medium	Alignment-based Bridge Reference View

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
12	Design-to-Design (full model logic)	Exchange of fully parametric description of bridge between two distinct design applications	within the same design phase, design models are exchanged between different design applications, model remains fully modifiable, all model logic is transferred	Design application to design application	Advanced BRep (NURBS), Fully parametric model information containing model logic, constraints and dependencies	All information entered in the design application	medium	high	Bridge Design Transfer View
13	Design-to-Construction	Handover from Design Phase to Construction Phase	Bridge Model is handed over from designer to Contractor for bidding and for actual construction	Design application to Tendering application and/or Review application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Material information Product information etc.	high	medium	Alignment-based Bridge Reference View
14	Structural Analysis incl. Structural Dynamics, Fluid-Structure Interaction, etc.	Structural analysis of bridges, tunnels, retaining walls	Ensure stability of the structures	Design application to structural analysis application	Procedural Description (Sweep and CSG) and/or Analytical Model	Loads, Material properties	medium	medium - high	Bridge Structural View

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
15	Code Compliance Checking	Check design of bridge for compliance with local codes and regulations	Compliance checking conducted by regulation authorities	Design application to checking application	Procedural description (Alignment, Sweep Geometry, CSG, BRep)	Information regarding the applying regulations (dimensions, distances, materials, etc.)	medium	high	?
16	Drawing generation and exchange	Exchange technical drawings derived from the model	Submission to owner / regulation authorities	Design application to Submission	2D representation	All information relevant for drawing representation (line styles, symbolic representations, etc.)	low	high	?
17	Prefabrication and manufacturing	Usage of model information for control / steering of prefabrication machines.	Partially automated construction of bridge components	Design application to machine	Procedural description (Alignment, Sweep Geometry, CSG, Advanced BRep)	(specific)	low	medium	?

Table 1In and out of scope use cases for the IFC-Bridge project

4 In-scope / Out-of-scope decisions

Based on a careful analysis of the benefits of the individual uses cases and the complexity and effort involved with defining the necessary data structures, the project team decided to prioritize the following use cases for explicit consideration when designing the IFC-Bridge extension:

- Initial State Modeling
- Import of major road / railway parameters
- Technical Visualization
- Coordination / Collision 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

Due to their overly high complexity, the following use cases are out of scope of this fast-track project:

- Design to Design (Full model logic)
- Structural analysis
- Code Compliance Checking
- Drawing generation and exchange
- Prefabrication and manufacturing

It is emphasized that the exclusion from the fast-track project does not mean that these use cases cannot be covered by future extensions of IFC-Bridge.

It has to be noted in particular, that the full design-to-design use case which incorporates the model's design logic, is excluded here as it would require software vendors to adapt modeling functionality, which is not deemed practical for reasons of competitive advantage, compatibility, and cost/benefit. Currently, there is no well-defined industry need that would justify this effort.

5 Geometry

As can be seen in Figure 1, the in scope use cases require a limited amount of geometry representations. These geometry representations should sufficiently describe how to build components of bridges, including explicit geometry based on boundary representation (B-Rep) and/or implicit geometry based on swept solids. Tessellated geometry is also supported for components and uses that do not involve construction. The IFC-Bridge development can therefore focus on a limited set of geometry representations.

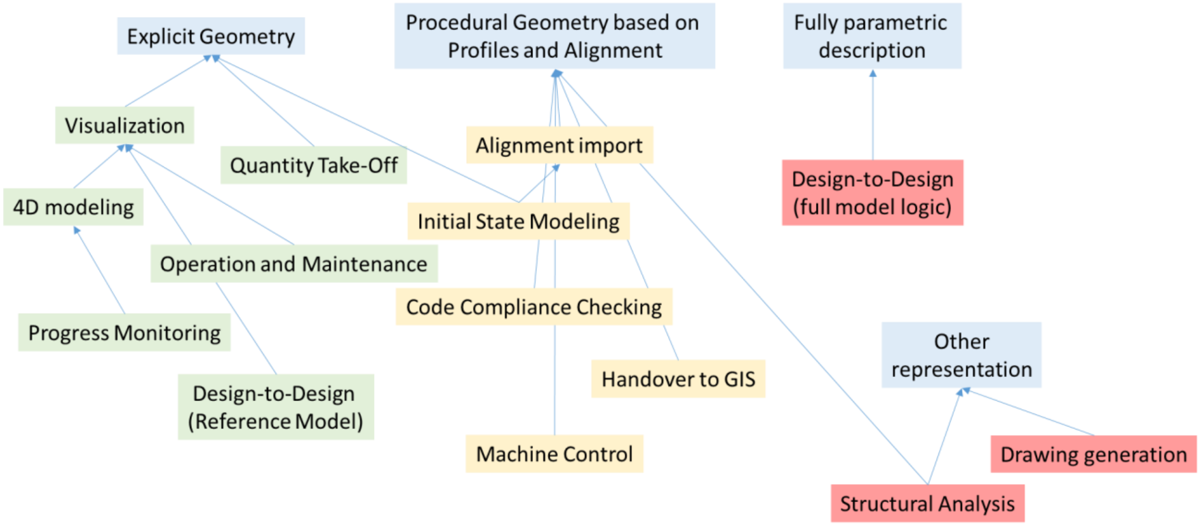

Figure 1 Dependencies between use cases based on required geometry representations.

Many of the required use cases demand the usage of sweeps for representing the superstructure elements, rebar and the prestressing systems. It has been well agreed by the project team that the usage of triangulated face sets is not appropriate for these elements, due to the loss in accuracy and the excessive increase in data size (see Table 1 for more information). The use of swept solids is a strong demand for realizing a number of exchange scenarios (see Figure 2).

The entity *IfcSectionedSolidHorizontal,* introduced in IFC 4.1 by the IFC Alignment and IFC Infra Overall Architecture projects, plays an important role in these exchanges. The entity allows for sweeping along an alignment with potentially varying cross sections, where the cross-section's y-vector is kept pointing in the global z direction. This action cannot be accomplished with other *IfcSweptAreaSolid* subtypes. *IfcSectionedSolidHorizontal* has been introduced for modeling elements of infrastructure facilities, such as roadway layers and bridge decks, using parameters consistent with representations typically used in construction plans. *IfcSectionedSolidHorizontal* will be applied in this sense in the IFC-Bridge extensions and will be included in the Bridge Model View Definitions (see Chapter 8).

Depending on how the element is built, both *IfcSweptAreaSolid* and *IfcSectionedSolid-Horizontal* are needed to define alignment-based geometry. In the case of casting in place, the global z direction can easily be defined on site. However, if the element is precast in a plant, in a horizontal formwork, a profile perpendicular to the sweeping path is required.

6 Requirements resulting from Asset Management

The buildingSMART International InfraRoom has conducted a project on Infrastructure Asset Managers BIM Requirements. The results have been published in report TR1010 which is available on the bSI website[1].

The IFC-Bridge project team took the outcomes into consideration when defining the requirements for the IFC-Bridge extension. The following table lists the individual requirements and how the IFC-Bridge extension is able to meet them.

Requirement from Infra Asset Managers BIM Requirements report	**IFC Bridge fulfilment of requirements**
Unique identification	Each IFC-Bridge model will be able to carry a unique identifier represented by the attribute name of an IfcBridge entity.
Network, geospatial, linear location	IFC provides capabilities for geospatial referencing, a local coordinate system can be used for the BIM model IfcAlignment provides means for linear placement Support for the network perspective has to be provided by IfcRoad and IfcRailways
Functional Requirement	IfcBridge will provide attributes and properties for capturing functional requirements
Dimensions	IFC-Bridge explicitly describes dimensions in terms such as height, width etc. explained in relation to respective object type.
System breakdown into Deck, Superstructure, Substructure	IFC-Bridge will provide a flexible spatial breakdown structure
Support of local/national/regional classification schemes	The IFC data model allows individual elements of a BIM model to be associated with any given classification (see Overall Architecture Report)
Support of local/national/regional Object Type Libraries	The IFC data model allows to connect any given Object Type Libraries with individual elements of a BIM model. To this end Linked Data approaches can be applied (see Overall Architecture Report).
Support of local/national/regional or project-specific property sets	The IFC data model allows to add user-defined property sets in an flexible manner.
Simple 3D geometry for Bridge Asset Management	The Bridge Asset Management Handover MVD will demand explicit geometry (excluding NURBS) allowing primarily visualization and management.
Support of inspection activities	The IFC-Bridge extension will support adding photographs and inspection results to individual components of a bridge model.
Support of sensor data	The IFC model allows to represent sensors and integrate their values by referring to external data sets.

Table 2 Fulfilment of Infra Asset Managers BIM requirements by the IFC Bridge project

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[1] Infra Asset Managers BIM Requirements report available here: https://buildingsmart-1xbd3ajdayi.netdna-ssl.com/wp-content/uploads/2018/01/18-01-09-AM-TR1010.pdf

7 Process Map and Exchange Scenarios

In order to identify the exchange requirements and associate them with dedicated data exchange scenarios the following process map has been defined (according to the IDM standard). Due to the large variety in national project setups and contractual models, the process map can only be seen as an example. Nevertheless, the defined exchange scenarios have a generic character and have, therefore, been a basis for the IFC-Bridge development.

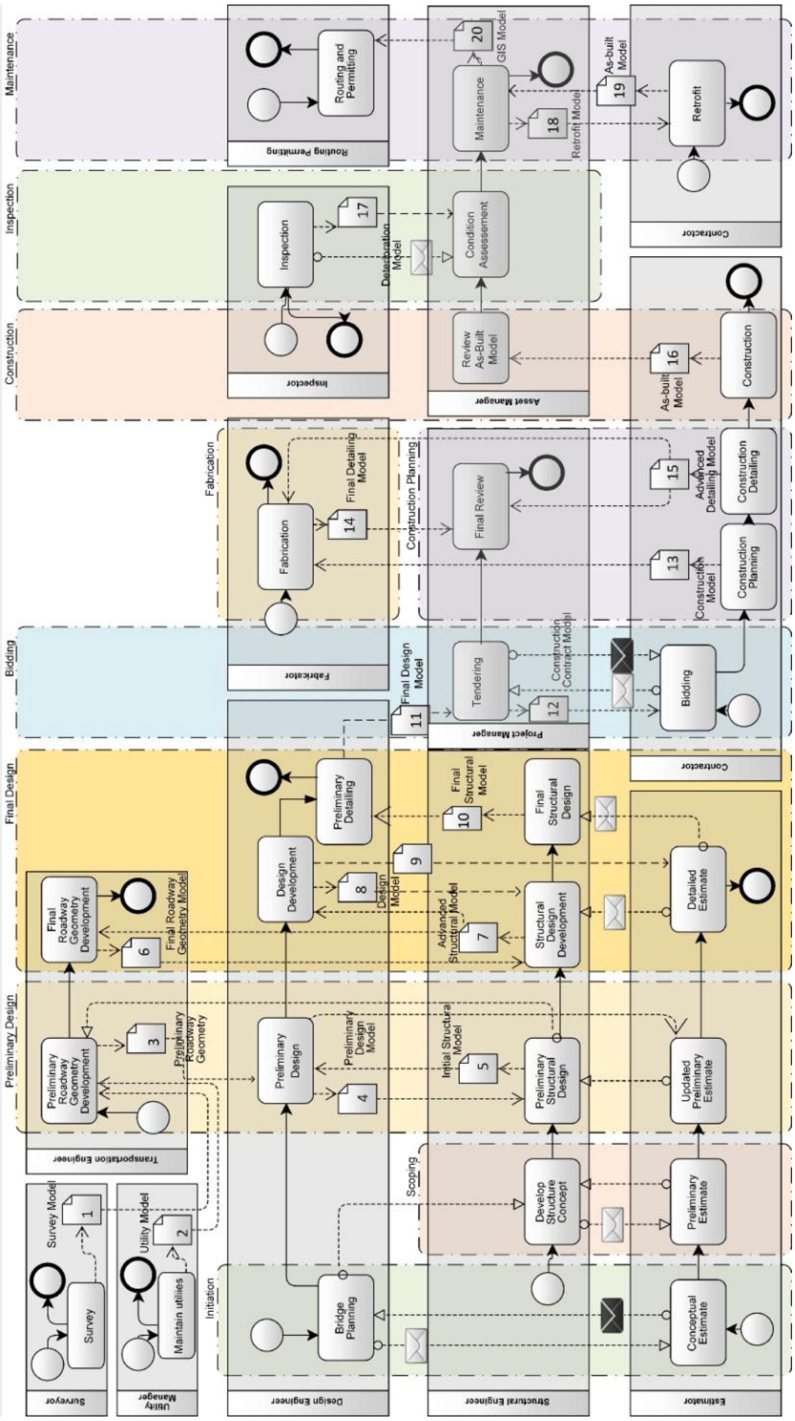

Figure 2: Process Map based on the US FHWA BrIM project process map

Exchange Scenario	Description	IFC-Bridge Use Case (Section 3)	MVD
1	Survey Model: Handover to Preliminary Design	Use Case 1: Initial State Modeling	ARV
2	Utility Model: Handover to Preliminary Roadway Design	Out of scope → IFC-Road	-
3	Preliminary Roadway Model: Handover to Preliminary Design	Use Case 2: Import of alignment and road parameters	DTV
4	Preliminary Design Model: Handover to Preliminary Structural Design	Use Case 11: Design-to-design (reference model)	DTV
5	Initial Structural Model: Handover to design development	Use 14: Structural analyis → Out of scope	-
6	Final Roadway Geometry Model: Handover to (Structural) Deisgn Devlopment	Use Case 2: Import of alignment and road parameters	ARV
7	Advanced Structural Model: Handover to Design Development	Use 14: Structural analyis → out of scope	-
8	Final Design Model: Handover to Structural Design Development	Use Case 11: Design-to-design (reference model)	DTV
9	Final Design Model: Handover to Detailed Estimate	Use case 6: Quantity Take-off	RV
10	Final Structural Model: Handover to Preliminary detailing	Use Case 11/12: Design-to-design	RV/DTV
11	Final Design Model: Handover to Tendering	Use case 6: Quantity Take-off Use Case 13: Design-to-construction	RV/ARV
12	Construction Contract Model Handover to Bidding	Use case 6: Quantity Take-off	RV/ARV
13	Construction Model: Handover to Fabrication	Use Case 13: Design-to-construction Use case 17: Prefabrication	DTV
14	Final Detailing Model Handover to Final Review	Use case 3: Technical Vizualization Use case 4: Coordination	RV/ARV
15	Advanced Detailing Model: Handover to Final Review / Fabrication	Use Case 13: Design-to-construction Use case 17: Prefabrication	ARV/DTV
16	As-built model: Handover to Asset Manager	Use Case 9: Handover to asset management	AMV
17	Deterioration Model: Handover to Condition Assessment	Use case 9: Handover to asset management	AMV
18	Retrofit Model: Handover to constructor	Use Case 13: Design-to-construction	DTV
19	Updated As-built Model: Handover to Asset Mangement	Use Case 9: Handover to asset management	AMV
20	Operation Model Handover to GIS system	Use Case 10: Handover to GIS	ARV

Table 3 Corresponding IFC Bridge use cases and proposed MVD per exchange scenario

8 Model View Definitions

In order to reduce the complexity of the data model developments, the use cases were mapped to the following basic Model View Definitions (see Table 2 and Table 3 for more information):

- Bridge Reference View (Bridge RV)
- Alignment-based Bridge Reference View (Bridge ARV)
- Bridge Design Transfer View (Bridge DTV)
- Bridge Asset Management Handover View (Bridge AMV)

The decision was taken to align both the Bridge Reference View and the Bridge Design Transfer View with the existing views in IFC4, but extend them where necessary to capture the specifics of bridges.

Figure 3, depicted on the next page, lists the differences in terms of the geometry representations supported between the IFC4 Reference view (IFC4 RV), the IFC4 Design Transfer View (IFC4 DTV., the Bridge Reference View (Bridge RV), the Bridge Alignment-based Reference View (Bridge ARV) and the Bridge Design Transfer View (Bridge DTV).

The basic differentiation between RV and DTV is also applied to the Bridge MVDs, the most important differences are:

- *IfcCSGSolid* (Constructive Solid Geometry = Boolean Operations on Solids) is not supported by the Bridge RV, but by the Bridge DTV.
- the support of *IfcFacetedBrep* and *IfcAdvancedBrep* is only realized in the Bridge DTV.
- *IfcPolygonalFaceSet* representation must be used for representing BRep geometry in RV.
- Curved surfaces (NURBS) are not supported by RV.

The Alignment-based Reference View (Bridge ARV) extends the IFC4 Reference View by supporting *IfcAlignment* and *IfcSectionedSolidHorizontal* for positioning and geometry creation. The reason for introducing the additional MVD lies in the importance of alignment for linear infrastructure. Standard IFC viewers typically do not support alignment, but should still be able to visualize bridge models. Therefore, the basic Bridge RV will not demand *IfcAlignment* be supported, but will rely on explicit geometry and on Cartesian coordinates for positioning.

Following is still under development and still requires further investigation in the next project phases:

- development of geometric and semantic aspects may bring forward other differences between Bridge RV, Bridge ARV and Bridge DTV.
- details of the Bridge Asset Management Handover View are still to be decided.

	IFC4 RV	Bridge RV	Bridge ARV	IFC 4 DTV	Bridge DTV
IfcSolidModel	x	x	x	x	x
IfcCsgSolid				x	x
IfcManifoldSolidBrep				x	x
IfcAdvancedBRep				x	x
IfcAdvancedBRepWithVoids					
IfcFacetedBrep				x	x
IfcFacetedBrepWithVoids					
IfcSweptAreaSolid	x	x	x	x	x
IfcExtrudedAraSolid	x	x	x	x	x
IfcExtrudedAreaSolidTapered				x	x
IfcFixedReferenceSweptAreaSolid				x	x
IfcRevolvedAreaSolid	x	x	x	x	x
IfcRevolvedAreaSolidTapered				x	x
IfcCurveSweptAreaSolid				x	x
IfcSweptDiskSolid	x	x	x	x	x
IfcSweptDiskSolidPolygonal					
IfcSectionedSolid			**x**		**x**
IfcSectionedSolidHorizontal			**x**		**x**
IfcTesselatedItem	x	x	x	x	x
IfcTesselatedFaceSet	x	x	x	x	x
IfcTriangulatedFaceSet	x	x	x	x	x
IfcPolygonalFaceSet	x	x	x	x	x
IfcCurve	x	x	x	x	x
IfcBoundedCurve	x	x	x	x	x
IfcAlignmentCurve			**x**		**x**
IfcOffsetCurve					**x**
IfcOffsetCurveByDistances					**x**
IfcDistanceExpression			**x**		**x**
IfcOrientationExpression			**x**		**x**
IfcLinearPlacement			**x**		**x**
IfcPositioningElement	x	x	x	x	x
IfcAlignment			**x**		x
IfcAlignment2DHorizontal			**x**		x
IfcAlignment2DVertical			**x**		x
IfcAlignment2DSegment			**x**		x
IfcAlignment2DVerticalSegment			**x**		x
IfcAlignment2DHorizonalSegment			**x**		x

Figure 3: Comparison of the geometry supported by the IFC4 Model View for Bridges and the proposed Bridge MVDs[2]

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[2] full list of the IFC 4 MVDs: http://www.buildingsmart-tech.org/specifications/ifc-view-definition/ifc4-reference-view/comparison-rv-dtv

9 Next Steps

In the next Work Package (WP2), the project team will identify the object types and attributes that are required for describing bridges from a semantic viewpoint in a way that is satisfying the use cases identified in WP1. To this end, a bridge taxonomy is created defining all necessary terms used in the context of bridge engineering. On the basis of the taxonomy, a mapping of the identified concepts to existing or new IFC entities is defined. This allows to specify new data structures (where necessary) as well as the Model View Definitions as discussed above.

Annex 1: Data Requirements

Data requirements have been defined for components of a bridge to reflect parameters required for supported use cases. Representative bridge projects have been used as input, where data found in these representative examples is captured as requirements, using parameters in the same form. For example, if a component (e.g. a pier) is described in construction plans for a representative bridge using a radius for a dimension, and referencing repetitive structures multiple times, then it is expected that the digital representation would follow suit. Similarly, if required material properties are conveyed by referencing an external grade or standard (rather than discrete engineering values such as compressive strength, etc.), then the digital representation would also follow suit.

In the sections that follow, data requirements are shown in tables indicating the field name, proposed mapping in the IFC schema, definition of the field, and whether it applies to the Bridge Reference View (R) and/or Bridge Design Transfer View (T).

Color conventions are used to indicate the use of a field as follows:

Color	Meaning
Red	Identifies the data (i.e. primary key)
Orange	References data described in another table (i.e. foreign key)
Yellow	Required data specific to the object.
Green	Optional data specific to the object.

Table 4 Color conventions for field use

It is important to note that such requirements are intended to represent the minimum amount of information needed to sufficiently support the stated use, and such requirements would be enforced by checking and verification tools. Applications may certainly include additional information, and users may also require additional information. For example, the IFC data model provides a field called “Description” for most data types which can capture informal data – this specification doesn’t impose any requirement for this field as the use is not defined in any specific way that would apply to all projects, though software vendors are encouraged to support such additional fields where there is a fit.

This section has been organized into categories of elements:

- as partitioned by regulatory agencies (e.g. US: FHWA MAP-21 which requires explicit distinction of substructure/superstructure/deck for analysis and inventory purposes),
- with subcategories mapping to how elements are typically modelled within software from industry leaders (e.g. US: Autodesk Infraworks, Bentley ProStructures, Trimble Structures),
- and associations (e.g. US: AASHTO).

1 General Conditions

This section refers to the overall context, positioning, and site conditions where a bridge is located.

1.1.1 Project

All data sets shall consist of a single IfcProject instance, which identifies the overall project, provides defaults for units, and holds a graph of references to all data within scope.

Field	Definition	R	T
Name	The name or code identifying the project within the owning agency.	■	■
Length Unit	Default unit for length. For imperial, inches are recommended. SI Meters are the default if not provided.	■	■
Angle Unit	Default unit for angles. Degrees are recommended, and are the default if not provided.	■	■
Mass Unit	Default unit for mass. For imperial, pounds are recommended. SI Kilograms are the default if not provided.	■	■
Temperature Unit	Default unit for temperature. For imperial, fahrenheit is recommended. SI Celcius is the default if not provided.	■	■
Site	Site within project describing geospatial location and project boundaries.	■	■

Table 5 Requirements for Element Project

1.1.2 Site

Data sets shall include at least one site. The site may define existing and proposed terrain within vicinity of the bridge project and contain alignment(s), bridge(s) and potentially other structures such as the road/rail supported by the bridge. Boring points may be included as objects contained within the site.

To capture existing conditions as well as proposed conditions within the same model, a generic mechanism is proposed by assigning “alternate” objects to elements (via the IfcRelAssignsToProduct relationship), such that any construction element may have a final state (as expected by current software), along with optional alternate states which may capture existing, intermediate states, or arbitrary alternatives. It is expected that most software may only be able to capture final state conditions, however such generic assignment mechanism enables other software to fully define objects in other states with full capability of capturing multiple geometry representations and property sets. To identify meanings of specific alternates, the Name attribute of IfcRelAssignsToProduct may be used to qualify such relationship, with “Existing” proposed to mean the existing conditions.

It is anticipated that future elaboration may support specific time phasing using IfcTask relating to construction elements using IfcRelAssignsToProduct, where the start date, end date, and nature of work (e.g. construct, demolish) may be defined.

Field	Definition	R	T
Name	Name of the site for referencing purposes.	■	■
Bridge	Bridge structure(s) within site.	■	■
Elevation	The reference elevation for which all vertical coordinates are relative.	■	■
Surface Proposed	The ground surface of the site indicating final conditions.	■	■
Surface Existing	The ground surface of the site indicating existing conditions.		■
Boring Points	Boring points indicating soil layers and properties at discrete locations.		■

Table 6 Requirements for Element Site

1.1.3 Alignment

Horizontal and vertical alignment curves provide the underlying placement for all components in a bridge plan.

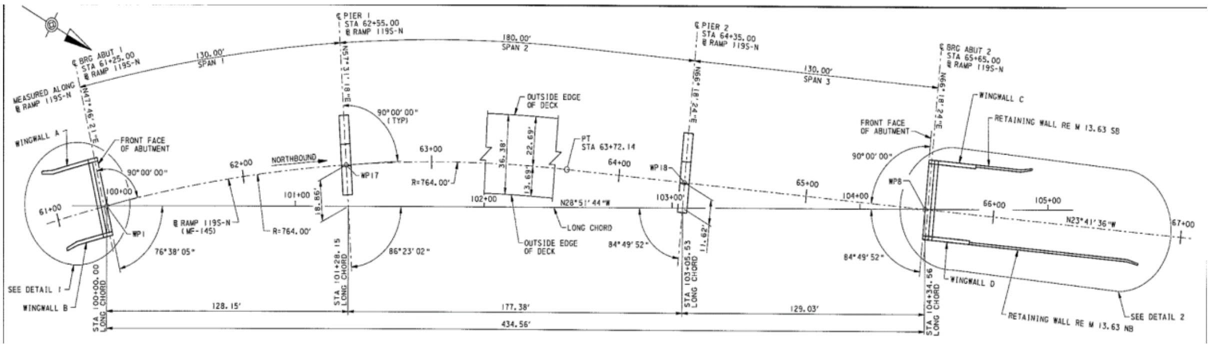


Figure 4 Bridge alignment plans

Field	Definition	R	T
Name	Name of the alignment used for referencing purposes.		■
Axis	Alignment shall define an axis curve, which may consist of a horizontal alignment curve only, a horizontal curve and vertical curve, an offset curve for capturing derivate alignments such as for a girder line, a polyline for capturing existing conditions at approximate intervals, or a line for capturing transverse alignments such as for positioning piers.		■
Containment	Alignment shall be contained within the site.		■
Placement	Alignment shall be placed at the global origin.		■

Table 7 Requirements for Element Alignment

1.1.4 Bridge

Each bridge structure is captured within a definition describing the span location of a bridge relative to an alignment.

The extents of the bridge are defined using an Axis curve, where IfcOffsetCurveByDistances would fit most scenarios – referencing an IfcAlignmentCurve with starting and ending distances along the curve, and typically no laterial or vertical offsets.

Field	Definition	R	T
Name	The name or code identifying the bridge within the owning agency.	■	■
Alignment	Reference to the alignment object used for positioning.	■	■
Axis	Alignment extent of the bridge defined as a sub-span of the overall alignment.	■	■
Components	Components within the bridge, including piers, abutments, girders, and decks. Placement of components is NOT relative to the bridge, but to the underlying alignment.	■	■

Table 8 Requirements for Element Bridge

1.1.5 Bridge Part

Components of bridges may be arbitrary decomposed into spatial parts that may be addressed separately, such as substructure, superstructure, and deck – similar in concept to IfcBuildingStorey, but without any implied sequence or direction.

Note: While bridge parts may also encapsulate phyical objects (e.g. piers), definitions for such physical objects should rely on IfcElement subtypes which provides for templating (IfcElementType subtypes), connectivity (IfcRelConnects subtypes), voiding (IfcRelVoidsElements), and other capabilities only possible with physical elements, for which spatial elements (IfcSpatialElement subtypes) do not support in the current IFC schema.

1.1.6 Soil Boring Point

Site grading is indicated using several geometric structures, for which contour lines or the elevation at any point may be derived. The IfcGeographicElement entity with PredefinedType set to SOILBORING (new) may be used to indicate soil borings at particular points.

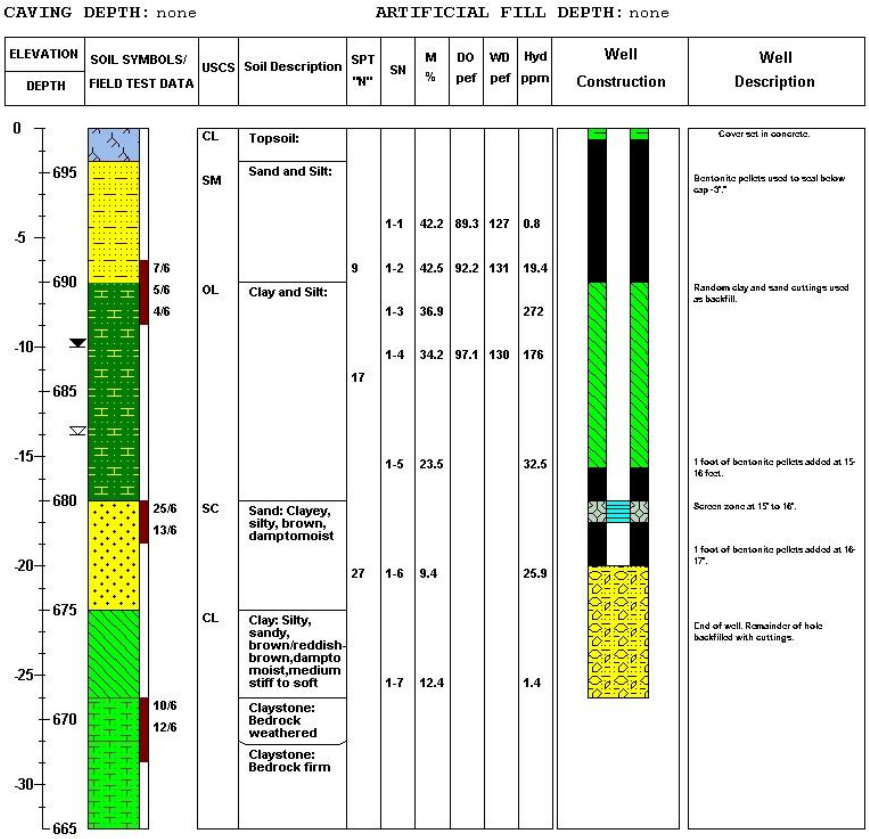


Figure 5 Example of soil boring point representation on plans

Soil boring information indicates the position of the test boring with longitudinal and lateral offsets relative to the alignment curve, and classification of soil between elevations for the specified depth of each boring.

Field	Definition	R	T
Name	Name of boring point for referencing purposes as would be found on construction plans.		■
Location	Location of boring point relative to the site, using linear placement or local placement.		■
Material Layers	Material layers describing soil conditions.		■

1.1.7 Material

Materials are defined on elements to be constructed (e.g. concrete), fabricated (e.g. steel girders), and that exist on site (e.g. soil borings), indicating material category, classification, and structural properties.

Field	Definition	R	T
Name	Material classification according to the respective authority (e.g. ASTM)	■	■
Category	Category of material, where if provided must be one of "Steel", "Concrete", "Wood", "Plastic", "Glass", "Earth".	■	■
Density	Material mass density.		■
Modulus of elasticity	A measure of the Young's modulus of elasticity of the material.		■
Modulus of rigidity	A measure of the shear modulus of elasticity of the material.		■
Thermal expansion coefficient	A measure of the expansion coefficient for warming up the material about one Kelvin.		■
Concrete compressive strength	[If Category=”Concrete”] The compressive strength of the concrete.		■
Steel yield strength	[If Category=”Steel”] A measure of the yield stress (or characteristic 0.2 percent proof stress) of the material.		■

Table 9 Requirements for Element Material

1.2 Substructure

The substructure of a bridge refers to elements that transfer loads into the ground.

1.2.1 Abutments

Abutments refer to substructures at the ends of a bridge. They may be composed of wing walls (on each side), head wall, stem wall, and cone.

Figure 6 Example of an abutment

1.2.2 Piers

Piers are decomposed into elements according to connectivity, indicating construction joints. Reinforcing may be indicated within inner elements such as footings, columns, members, and walls (see documentation at corresponding elements for usage); such reinforcing should reflect how it is to be placed at time of construction such that rebar connecting between elements is projected out of the element where it is initially placed.

Figure 7 Example of a pier

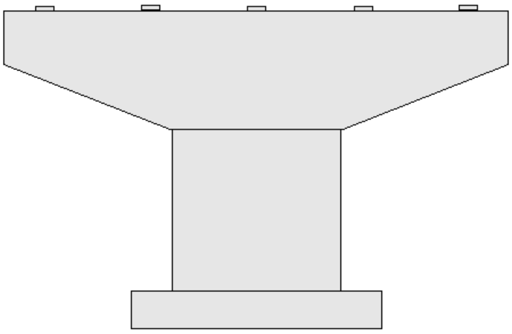


Figure 8 Cross sections of a pier

Abutments and piers are placed relative to the horizontal alignment curve (NOT the vertical alignment curve), with components placed according to Cartesian placement within. This reflects positioning as typically indicated on construction plans, where all dimension lines are based on Cartesian positioning relative to the position and orientation of the station along the horizontal alignment curve.

Field	Definition	R	T
Name	Name of pier for referencing purposes as would be found on construction plans.	■	■
Alignment	Reference to the alignment object used for positioning.	■	■
Location	Location of pier along alignment.	■	■

Pier Cap	Pier cap component, separated according to construction joint.	■	■
Pier Stem	Pier stem component(s), separated according to construction joint.	■	■
Footing	Footings in ground.	■	■
Piles	Piles supporting footings.	■	■

Table 10 Requirements for Element Piers

1.2.3 Pier Stems

Each pier may have one or more stems, separated laterally.

1.2.4 Pier Segments

Each pier stem may have one or more segments, separated by construction joint.

1.2.5 Pier Caps

Each pier may have a top that spans stem(s). If such cap is above a bearing, then it is modelled as part of the superstructure.

1.2.6 Retaining Walls

Retaining walls refer to wall structures for retaining soil.

Figure 9 Example of a retaining wall

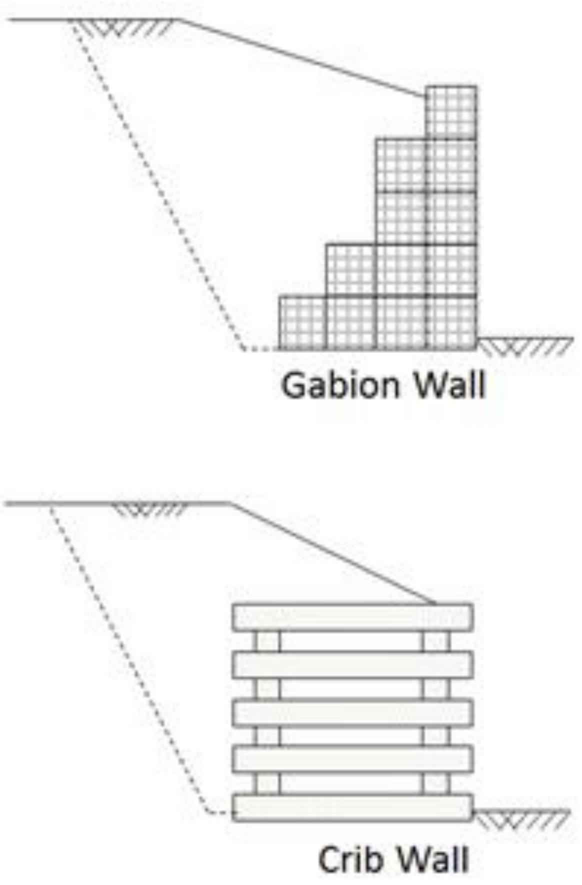
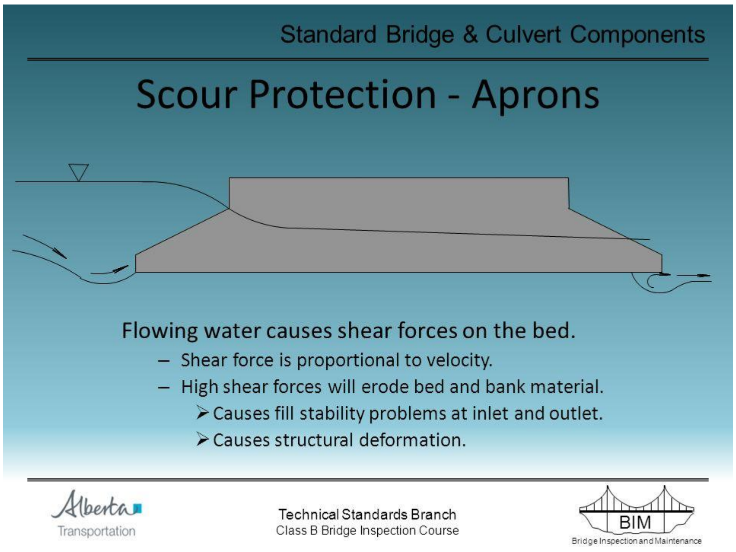


Figure 10 Types of retaining walls on plans

1.2.7 Apron

A bridge apron is a device to protect a river bank or river bed against scour; a shield (source: http://sdrc.lib.uiowa.edu/eng/bridges/WaddellGlossary/GlossA.htm).



Standard Bridge & Culvert Components

Scour Protection - Aprons

Flowing water causes shear forces on the bed.

- Shear force is proportional to velocity.
- High shear forces will erode bed and bank material.
  - Causes fill stability problems at inlet and outlet.
  - Causes structural deformation.

Figure 11 Example of an apron (source: Alberta Transportation)

1.2.8 Arch

An arch refers to a hyperbolic member that supports vertical loads at intervals along its span.

Figure 12 Example of an Arch

A springer refers to the base element supporting an arch.

Figure 13 Example of a springer

1.2.9 Footing

Footings are typically described geometrically by enclosed polygonal areas extruded vertically according to footing depth. For stepped footings, multiple extruded solids may be used, however they must not intersect.

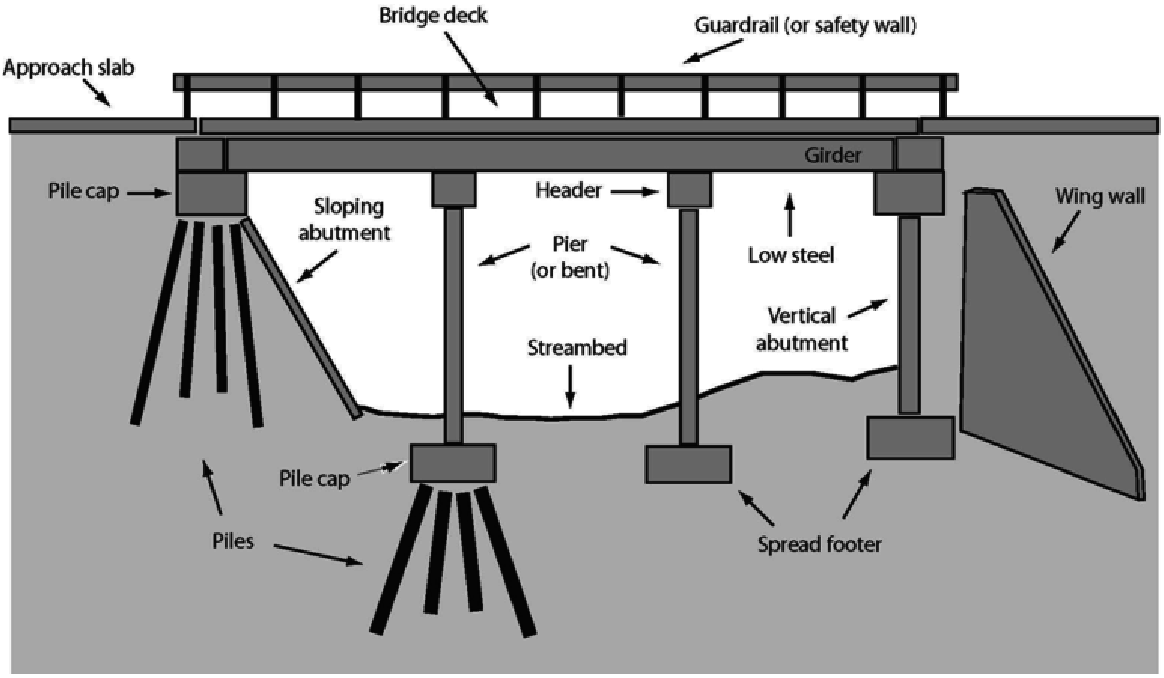


Figure 14 Example of a bridge, including footing

Piles supporting footings are linked according to a connection relationship.

Field	Definition	R	T
Name	Name of the footing for referencing purposes, as would be found on construction plans.		■
Material	Material properties of the footing, indicating concrete strength.		■
Geometry	Geometry of the footing typically described as footprint of polygons with constant height.		■
Piles	Connection to piles supporting footing.		■
Reinforcing	Reinforcing bars within footing.		

Table 11 Requirements for Element Footing

1.2.10 Pile

Piles are typically described geometrically by a circular profile extruded vertically according to pile depth. For multiple piles, mapped representation may be used to efficiently place piles of similar dimensions in multiple locations.

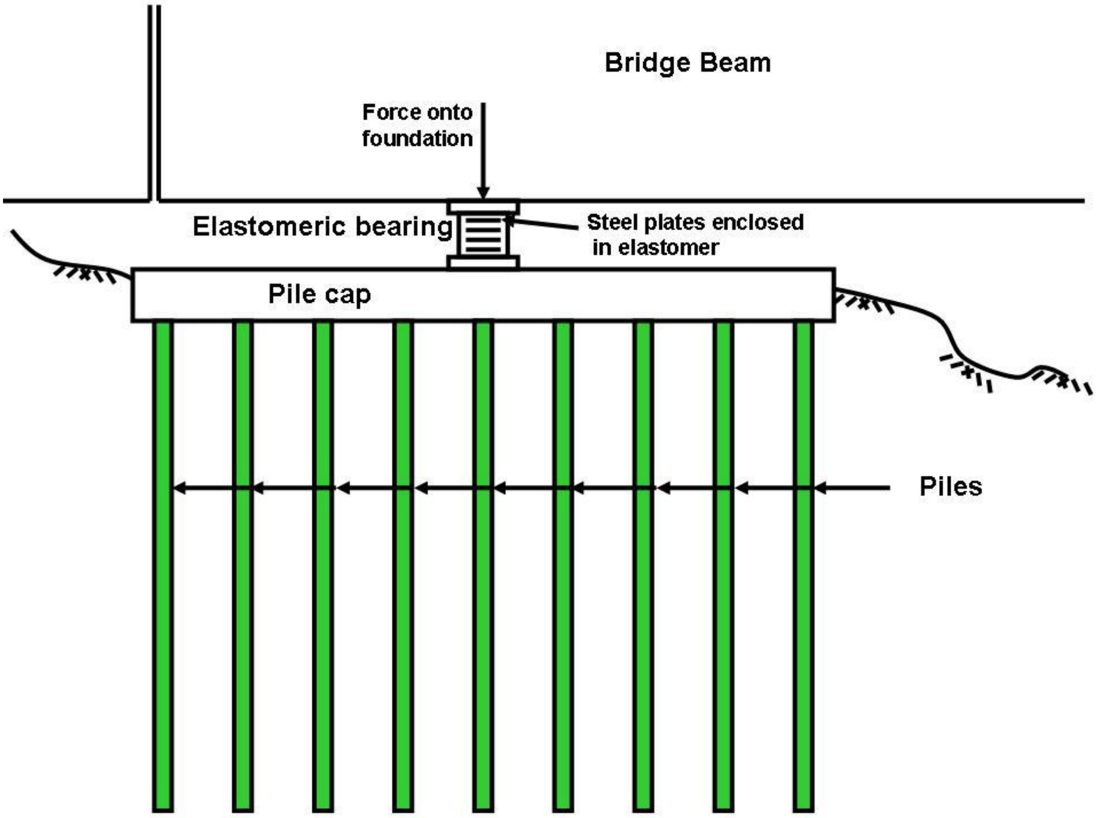


Figure 15 Drawing of Piles

Piles supporting footings are linked according to a connection relationship.

Field	Definition	R	T
Name	Name of pile arrangement for referencing purposes, as found on construction plans.		■
Material	Material of piles.		■
Cross Section	Cross section of piles, typically I-shape or hollow circle.		■
Placement	Cartesian positions of pile occurrences relative to enclosing pier or abutment structure.		■
Batter	Angle of incline indicated as a parameter. In case of inconsistency, the Placement takes precedence.		

Table 12 Requirements for Element Pile

1.2.11 Hat Stone

Hat Stone refers to a top course on an abutment or culvert.

Figure 16 Example of a hat stone

1.3 Superstructure

The superstructure of a bridge refers to those elements than span horizontally to carry loads onto substructures.

Field	Definition	R	T
Name	Name of the superstructure for organizational purposes.	■	■
Alignments	Alignment objects used longitudinally (e.g. for girders) or laterally (e.g. for floor beams).	■	■
Trusses	Truss lines.		
Girders	Girder lines.		■
Cross Frames	Cross frames between girder lines.		
Floor Beams	Floor beams between girder lines.		
Stringers	Stringers between floor beams.		

Table 13 Requirements for Element Superstructure

1.3.1 Girder

Bridge girders refer to horizontal support beams that span along the alignment of a bridge.

Figure 17 Example of bridge girders

For steel girders, this refers to each girder line, decomposed into beam segments.

For concrete box girders, this refers to the overall box girder, typically connected to the bridge deck via a keyed construction joint with adjoining reinforcing.

Field	Definition	R	T
Name	Name of the girder line for referencing purposes as would be found on construction plans.	■	■
Alignment	Reference to the alignment object used to position the girder line.	■	■
Axis	Axis curve defined as a sub-span with offsets relative to the alignment curve.		■
Type	Template defining general construction that may be used across projects.	■	■
Material	Common material that applies to all segments of the girder.		■
Segments	Segmented girders may be decomposed into segments for each continuous section.	■	■
Components	Built-up girders may be decomposed into plates (or members) for web, flanges, cover plates, longitudinal stiffeners, and vertical stiffeners.		

Table 14 Requirements for Element Girder

1.3.2 Girder Segment

Girder segments refer to discrete sections along a girder line. They may be modelled as one object that encapsulates the overall cross section (e.g. I-Shape steel, arbitrary precast profile), or as separate objects (e.g. steel flange plates, steel web plate). Each segment may have a constant cross section, a tapered cross section (linearly interpolated from start to end), a variable cross section (linearly interpolated at multiple points between start and end), or free-form geometry.

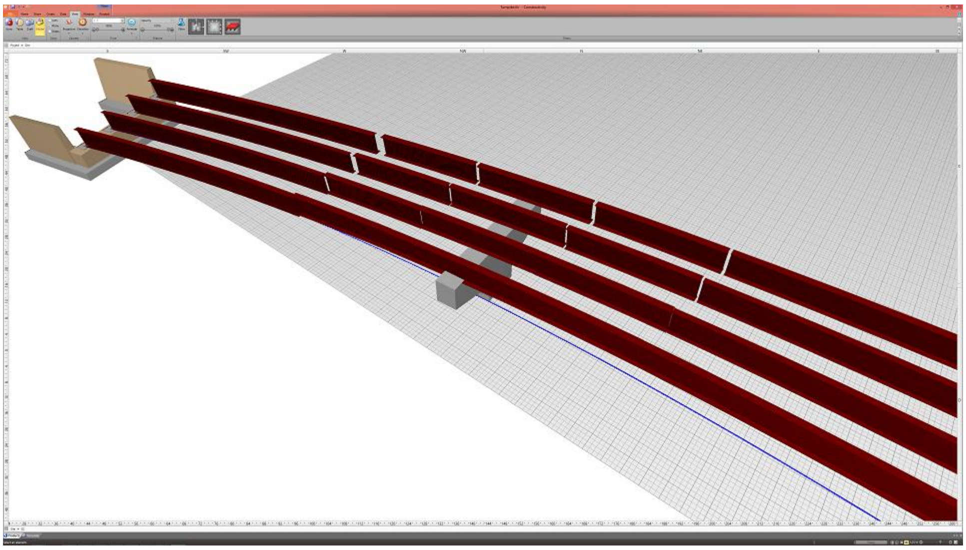


Figure 18 Bridge girder model (source: T. Chipman)

As shown in Figure 18, girders may be split into segments according to defined splices. The gaps in the illustration are exaggerated to show each segment.

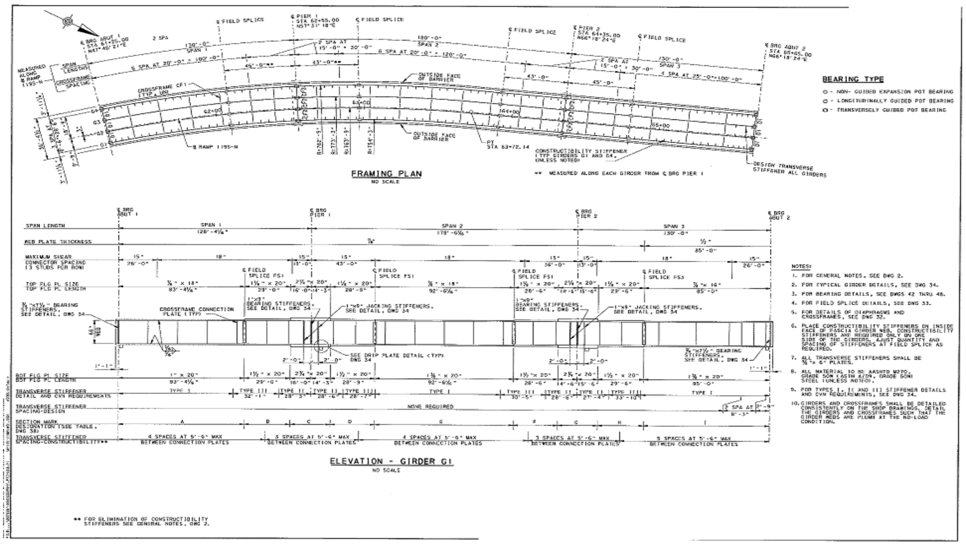


Figure 19 Bridge girder plans

Field	Definition	R	T
Name	Name of the girder segment for referencing purposes as would be found on construction plans.	■	■
Material	Material of the girder segment.	■	■
Solid Geometry	Geometry of the girder segment defined as a cross section that may be constant or variable (linearly or parabolic), swept along the alignment at starting and ending positions.	■	■
Connection Head	Relationship connecting head of girder segment with abutment or another girder segment, where realizing element refers to splice plates.		■
Connection Tail	Relationship connecting tail of girder segment with another girder segment or abutment, where realizing element refers to splice plates.		■
Connection Support	Relationship connecting girder segment to substructure, where realizing element refers to bearing if present.		
Reinforcing	For concrete girders, reinforcing embedded.		■
Tendons	For concrete girders, tendons embedded.		■
Stiffeners	For steel girders, web stiffeners placed at intervals along inside face(s) of web.		■
Shear Studs	For steel girders, shear studs placed at intervals along top flange.		■
Camber	For steel girders, camber ordinates for fabrication.		■

Table 15 Requirements for Element Girder

The connection between beams is represented using IfcRelConnectsWithRealizingElements, where the *RealizingElements* refers to IfcPlate elements for fastening plates on each side, IfcFastener for bolts, and IfcPlate for any flange transition plates. The reason for using this connection relationship specifically (as opposed to just placing the elements) is to be able to derive an IfcStructuralAnalysisModel that captures the beam connectivity.

1.3.3 Cross Frame

Bridge cross frames connect two girders laterally.

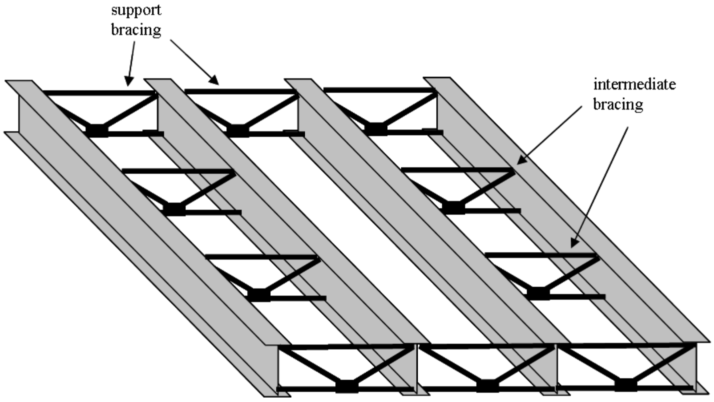


Figure 20 Diagram depicting cross frame

Cross-framing between girders may be described using templates of member configurations. Such cross framing is captured within components, using standard shapes (e.g. AISC in U.S.) where applicable. For curved alignments where girders are placed at different elevations, members must be placed relative to the girders at each side, for which positioning is defined relative to alignment curves.

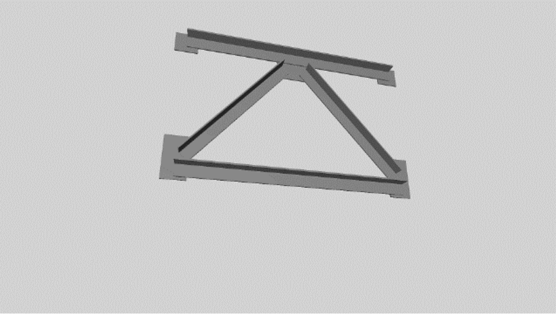


Figure 21 Bridge framing model

Such cross-framing is then instantiated as object occurrences according to repetition intervals, where each occurrence has unique connectivity relationships with corresponding girder segments.

Field	Definition	R	T
Name	Name of cross frame occurrence as would be identified on construction plans.	■	■
Plates	Plates used within cross frame.	■	■
Members	Members used within cross frame.	■	■
Position	Position of cross frame relative to alignment.	■	■
Girder Segment Left	Connection to girder on left as facing direction of alignment.		■
Girder Segment Right	Connection to girder on right as facing direction of alignment.		■

Table 16 Requirements for Element Cross Frame

1.3.4 Diaphragm

Diaphragms refer to sections of bridge girders immediately above supporting structures that provide additional lateral and vertical support.

Diaphragms are modeled similarly as concrete girder segments, except are distinguished according to a predefined type (e.g. IfcBeamTypeEnum.DIAPHRAGM), and have connections to underlying supports.

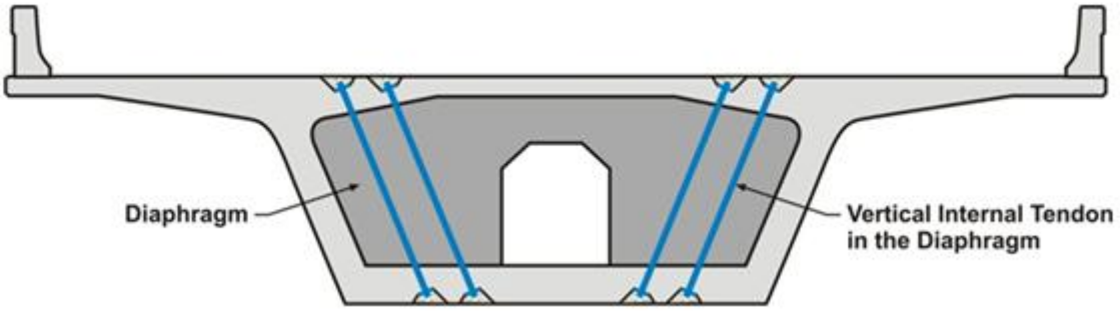


Figure 22 Diaphragm with a vertical internal tendon

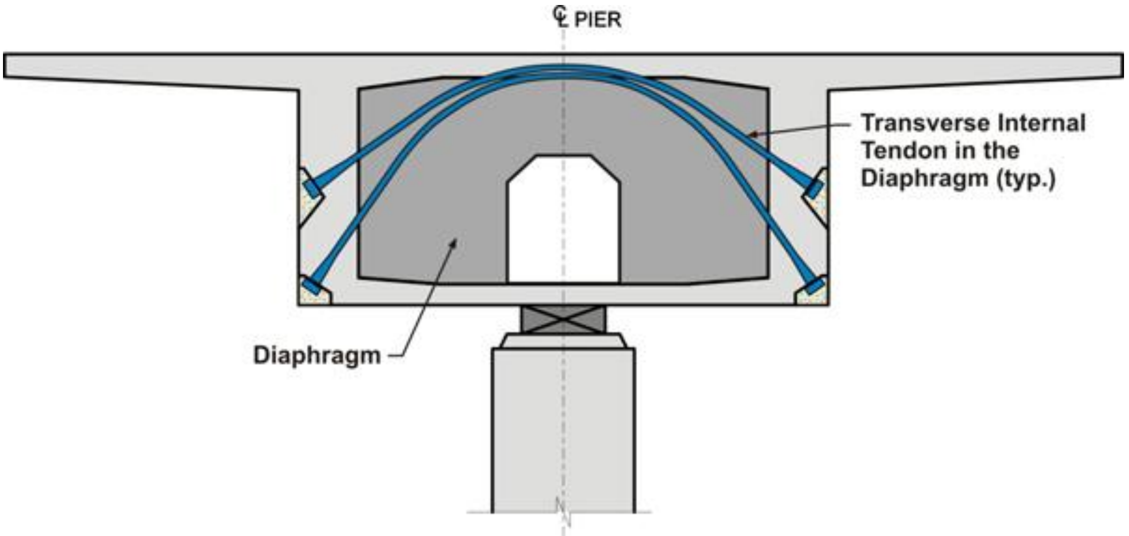


Figure 23 Diaphragm with a transverse internal tendon

Field	Definition	R	T
Name	Name of the diaphragm for referencing purposes as would be found on construction plans.	■	■
Material	Material of the girder segment.	■	■
Solid Geometry	Geometry defined as a cross section that may be constant or variable (linearly or parabolic), swept along the alignment at starting and ending positions.	■	■
Connection Head	Relationship connecting head of diaphragm with a girder segment.		■
Connection Tail	Relationship connecting tail of diaphragm with a girder segment.		■
Connection Support	Relationship connecting diaphragm to substructure, where realizing element refers to bearing if present.		
Reinforcing	For concrete diaphragms, reinforcing embedded.		■
Tendons	For concrete diaphragms, tendons embedded.		■

Table 17 Requirements for Element Diaphragm

1.3.5 Truss

Trusses refer to a framework of linear structural elements in tension and compression for supporting the span of a bridge superstructure.

Figure 24 Example of a truss

Within a truss, struts refer to compression elements, and ties refer to tension elements.

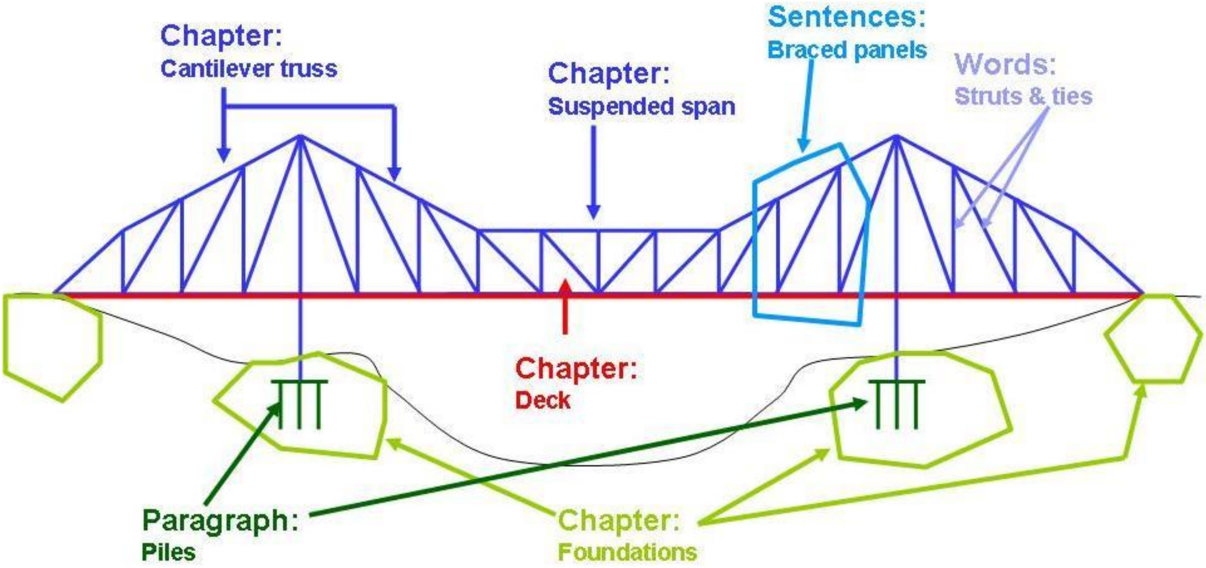


Figure 25 Struts and ties in a truss

Field	Definition	R	T
Name	1.3.5.1 Name of the truss for referencing purposes as would be found on construction plans.	■	■
Members	Members within truss, each having connections to gusset plates.		■
Gusset Plates	Gusset plates connecting truss memers		■
Connections	Relationships connecting truss to other superstructure elements		■

Table 18 Requirements for Element Truss

1.4 Deck

A bridge deck is comprised of those elements used for conveying traffic but do not perform structural functions of the superstructure.

1.4.1 Deck Span

Bridge deck spans represent the surface of a bridge. They may be decomposed into segments and components.

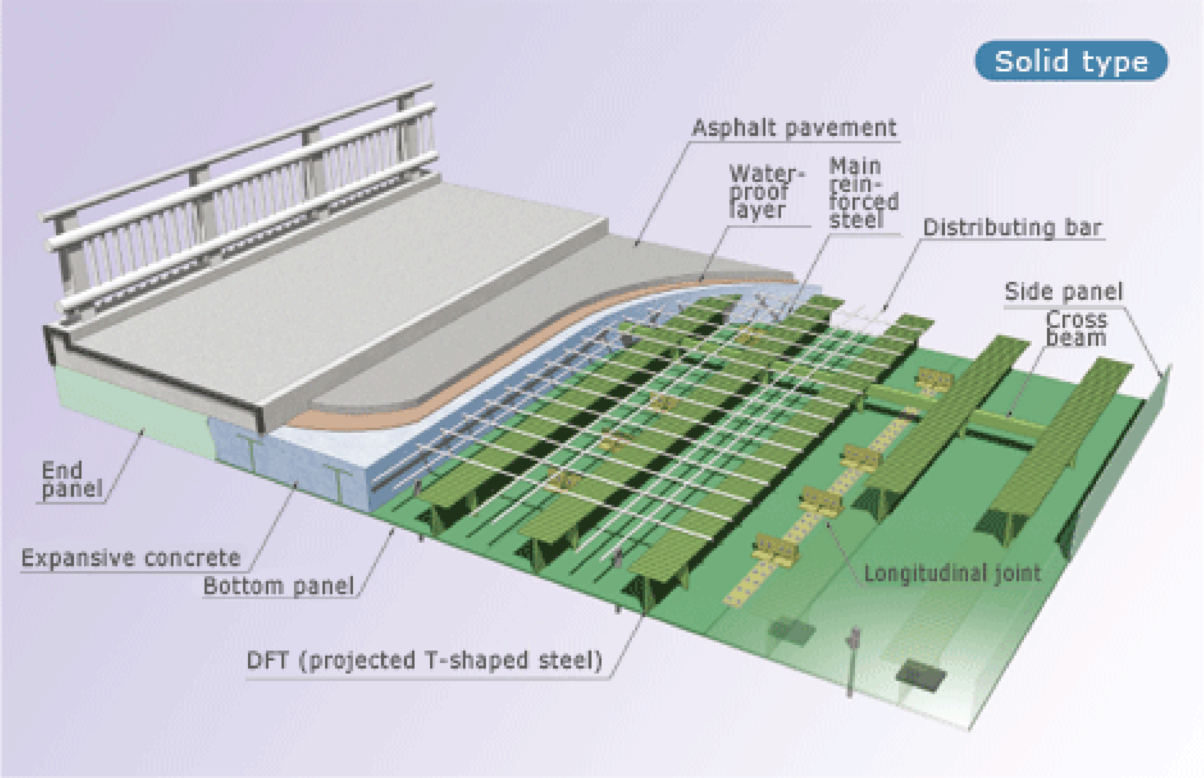


Figure 26 Example of a decomposed deck span

Field	Definition	R	T
Name	Name of the deck sequence.	■	■
Type	Template defining general construction that may be used across projects.	■	■
Material	Common material that applies to all segments of the bridge deck		■

Table 19 Requirements for Element Deck span

1.4.2 Deck Segment

This entity may be used to model segments of a bridge deck, separated by construction or expansion joint. Geometry for bridge decks is typically represented using IfcSectionedSolidHorizontal for defining a cross section that may potentially vary along an alignment.

Field	Definition	R	T
Name	Name of the deck segment for referencing purposes as would be found on construction plans.	■	■
Surface	For reference, surface geometry is only needed for visualization purposes.	■	■
Material	Material of the deck segment.		■
Solid Geometry	Geometry of the deck segment, including any haunches, defined as a cross section that may be constant or variable (linearly or parabolic), swept along the alignment at starting and ending positions.		■
Connection Head	Relationship connecting head of deck segment with abutment or another deck segment.		■
Connection Tail	Relationship connecting tail of deck segment with another deck segment or abutment.		■
Connection Girders	Relationship connecting deck segment to supporting girder(s).		■
Reinforcing	Reinforcing embedded within deck.		■
Drainage	Waste terminals embedded within deck.		■

Table 20 Requirements for Element Deck Segment

1.4.3 Parapet

This entity may be used to model barriers of constant cross-section, or architectural railings.

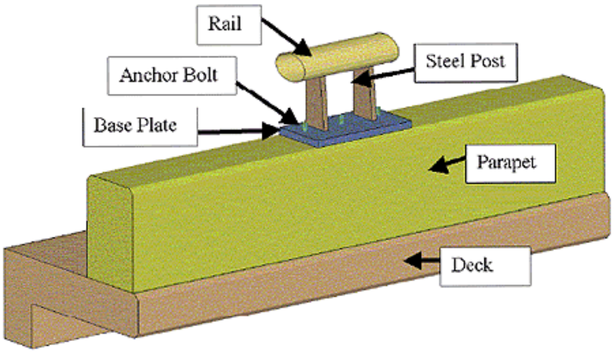


Figure 27 Example of a railing

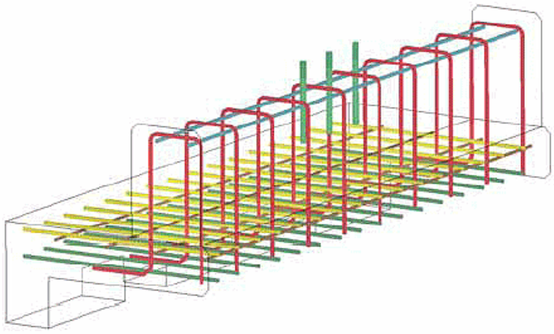


Figure 28 Example of a barrier constant cross-section

Barriers may be defined as a constant cross-section placed along the alignment at either edge of a bridge deck or anywhere in between.

Field	Definition	R	T
Name	Name of the parapet segment for referencing purposes as would be found on construction plans.	■	■
Material	Material of the parapet.	■	■
Solid Geometry	Geometry of the parapet segment defined as a cross section that may be constant or variable, swept along the alignment at starting and ending positions.	■	■
Connection Head	Relationship connecting head of parapet segment with abutment or another parapet segment.		■
Connection Tail	Relationship connecting tail of parapet segment with another parapet segment or abutment.		■
Deck	Relationship connecting parapet segment to supporting bridge deck.		■
Reinforcing	Reinforcing embedded within parapet.		■
Conduit	Conduit embedded within parapet.		■

Table 21Requirements for Element Parapet

1.4.4 Approach Slab

An approach slab refers to a slab providing transition between a bridge and road pavement, where an expansion joint allows for differential settlement, temperature changes, and freeze/thaw effects.

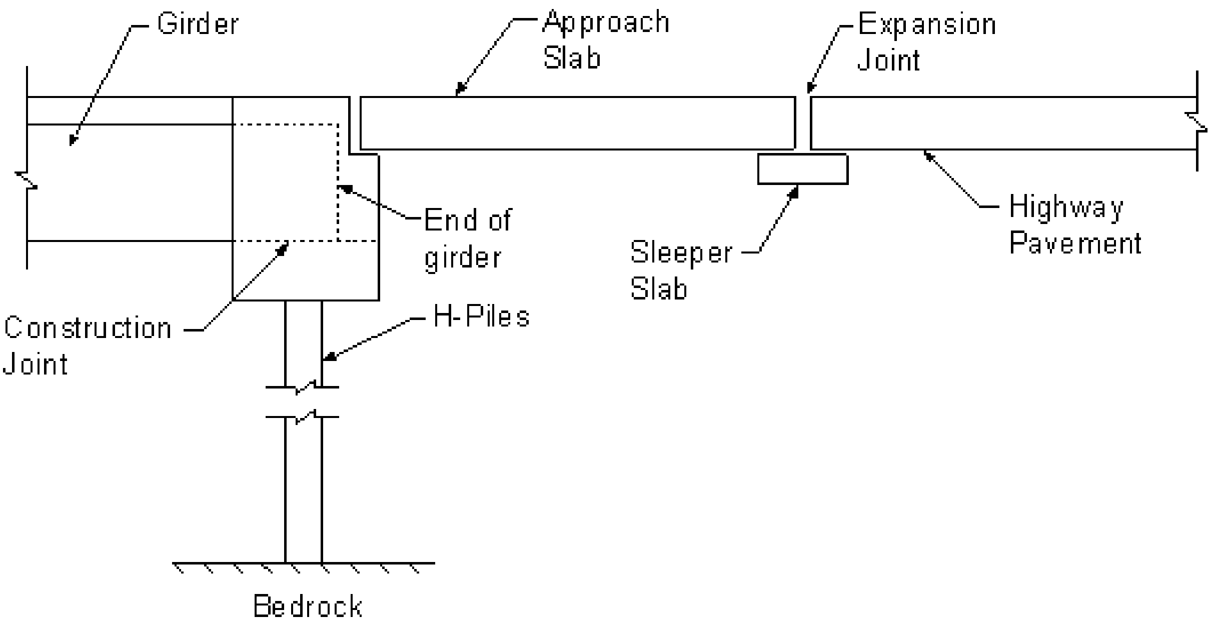


Figure 29 Example of an approach slab in plans

1.4.5 Cornice

A cornice is construction eveloping the sides of a bridge protecting the deck.

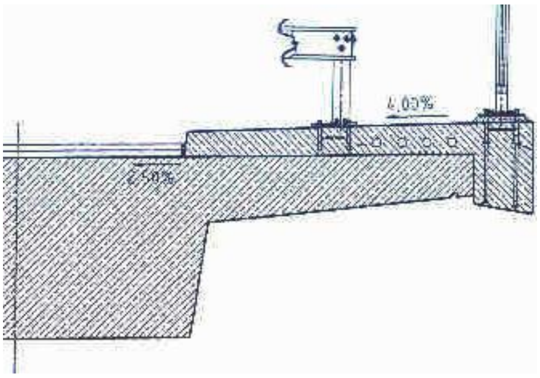


Figure 30 Example of a cornice in plans

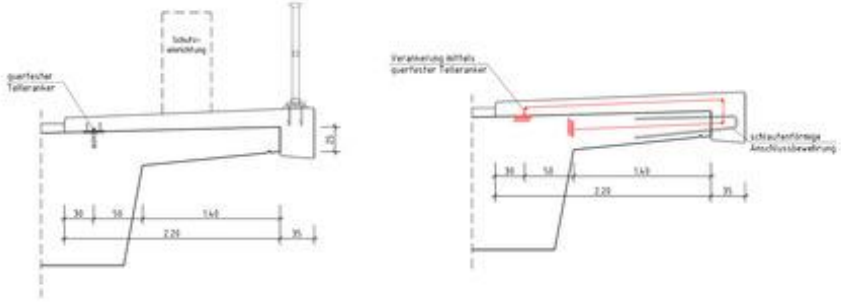


Figure 31 Example of a cornice in plans

1.4.6 Waterproofing

Waterproofing membranes are applied on top of deck segments.

Figure 32 Example of a waterproofing membrane

1.4.7 Roadway Surfaces

Roadway surface elements include pavement overlays and pavement treatments (e.g. rumble strips), and lane striping.

Figure 33 Example of a roadway surface

1.5 Mechanical Connections

Mechanical connections refer to elements providing connectivity with fixed or variable degrees of freedom.

1.5.1 Bearing

Bearings refer to elements connecting substructure elements to superstructure elements where movement is allowed along one or more degrees of freedom.

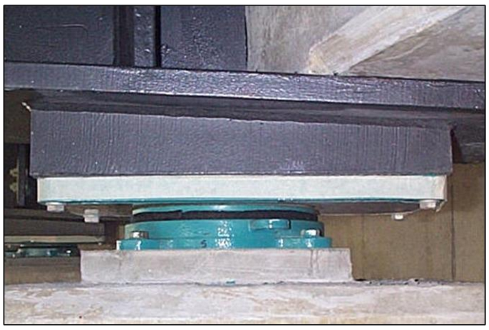


Figure 34 Example of a bearing

Figure 35 Example of a bearing

NOTE: a new entity will likely be introduced in the next phase of this project.

Field	Definition	R	T
Name	Name of bearing for referencing purposes as would be found on construction plans.	■	■
Type	Type of bearing, where common geometry and properties may be defined.	■	■
Mechanical Constraint	Indicates mechanical behavior of bearing for each degree of freedom with optional spring constant.	■	■
Connecting Support	Connection to abutment or pier supporting the bearing.	■	■
Connecting Girder	Connection to girder segment or diaphragm supported by the bearing.	■	■

Table 22 Requirements for Element Bearing

1.5.2 Joint

An expansion joint is an assembly connection between construction elements to allow for thermal differential expansions.

CIPEC WD Joint

Type: Cantilever
Benefits:
Excellent all-rounder;
Exceptionally robust;
Ideal for heavy traffic, user comfort and reducing noise;
Easy to maintain and remove.

Multiflex SX Joint

Type: Mat
Benefits:
Ideal for heavy traffic flow;
Effectively accommodates transverse, vertical and rotational movements;
Excellent user comfort;
Easy to install.

Freyssimod LW Joint

Type: Modular
Benefits:
Suitable for curved structures;
Easy installation, extremely durable and low maintenance;
Excellent in heavy traffic and water tight.

CIPEC WP Joint

Type: Cantilever
Benefits:
Exceptionally robust;
Provides excellent user comfort and noise reduction;
Can be adapted to suit the directional movement of the structure.

Figure 36 Example of expansion joints

A seam joint is a joint that joins two materials.

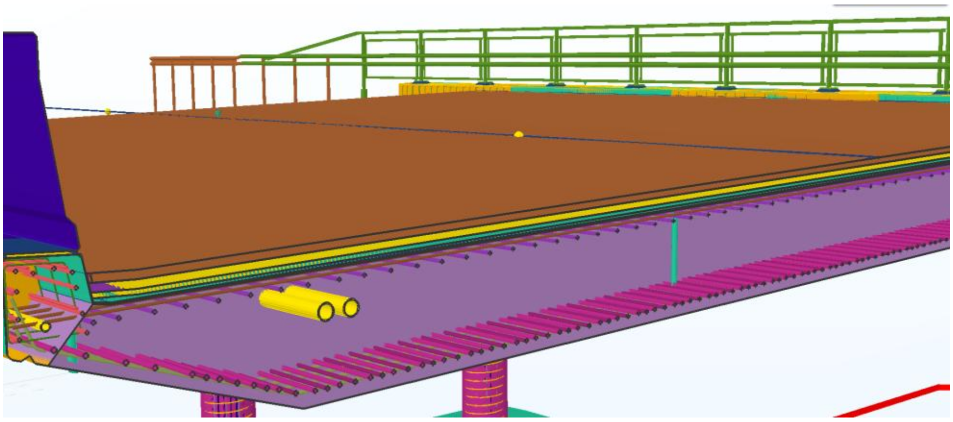


Figure 37 Model depicting a seam joint

A construction joint is one where fresh concrete has to be placed on or against concrete that has already hardened.[3]

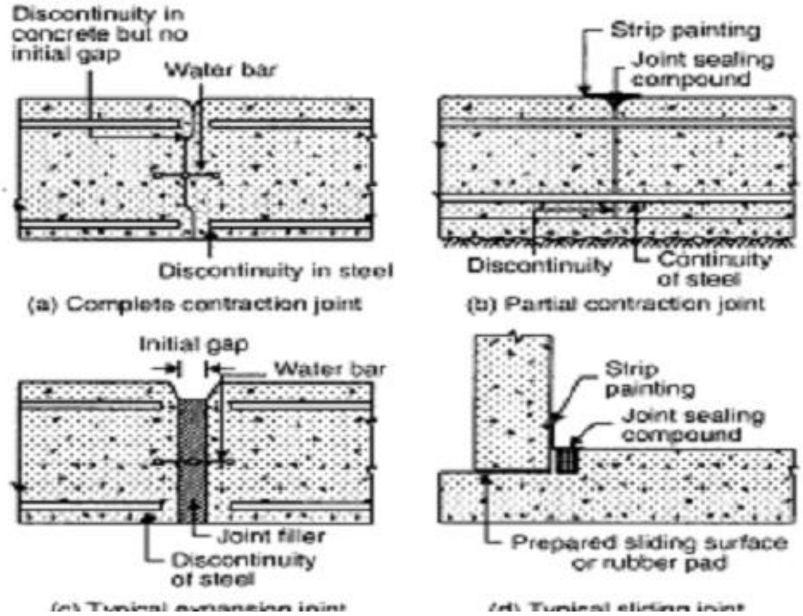


Figure 38 Example of construction joints on plans

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[3] source: https://addyst.blogspot.de/2015/02/construction-and-expansion-joints.html

Field	Definition	R	T
Name	2 Name of joint for referencing purposes as would be found on construction plans.	■	■
Type	Type of joint, where common geometry and properties may be defined.	■	■
Expansion Extent	Indicates the length available for expansion.	■	■
Connection Head	Reference to deck segment or pavement at head	■	■
Connection Tail	Reference to deck segment or pavement at tail	■	■

Table 23 Requirements for Element Joint

2.1.1 Shock Absorber

A shock absorber is a device designed to absorb shock impulses such as from earthquakes.

Figure 39 Example of a shock absorber (source: http://img.archiexpo.com/images_ae/photo-g/126411-6507243.jpg)

Figure 40 Example of a shock absorber

2.1.2 Beam Falling Prevention Device

- IFCBridgeElementAssembly
  - ✓ IfcBeamFallingPreventionDevice

Figure 41 Example of a beam falling prevention device (source: CRBIM)

2.2 Reinforcement and Prestressing

2.2.1 Rebar Array

Rebar is typically represented with one object instance corresponding to a set of rebar of the same dimensions, spaced at regular or irregular intervals.

Figure 42 Example of a rebar array

Field	Definition	R	T
Name	Name of rebar set for referencing purposes as would be found on construction plans.		■
Type	Type of rebar indicating common bar diameter and bending parameters.		■
Placement	Reference position of rebar within embedding element.		■
Pattern	Cover, spacing, and repetition along one or more axes.		
Geometry	Geometry of rebar indicated as mapped items.		

Table 24 Requirements for Element Rebar Array

2.2.2 Rebar Shape

This entity may be used to capture rebar sizes and bending shapes either parametrically or of fixed dimension.

For parametric definitions, the rebar size and/or material may be specified using a material profile set. If no material profile set is provided, then such information may be configurable by downstream usage of the definition (either a derived definition or an occurrence).

For bending shapes such as for stirrups or ties, the geometry may be defined using a polygonal swept disk, where a polyline indicates the transition points, and a fillet radius indicates how the rebar is to be bent at each transition point.The IFC4 Reference View uses an indexed poly curve (IfcIndexedPolyCurve) to represent the sequence of lines and arcs. For the purpose of representing spirals a polyline parameterized on a cylinder shall be used. IfcPcurve provides the required functinality.

For implicit parametric definitions of bending parameters, the BendingShapeCode and BendingParameters may be provided, where applications rely on their own database (e.g. ACI 318 in the United States) to interpret the code and parameters.

For explicit parametric definitions, constraints may be used to link the shape geometry of the swept disk solid to input parameters.

Field	Definition	R	T
Name	Name of rebar type for referencing purposes as would be found within rebar schedules in construction plans.		■
Material	Material properties of rebar.		■
Geometry	Bar shape defined by swept disc solid with bending radius, after applying all parameters.		■
Bar Diameter	Nominal diameter of rebar according to default units - for example, #7 would be 0.875 inches or 22.225 millimeters.		■
Bar Length	Length of rebar according to default units.		■
Bending Shape Code	Shape code per a standard (e.g. ACI 315 in U.S., ISO 3766, or a similar standard).		■
Bending Parameters	Bending shape parameters. Their meaning is defined by the bending shape code and the respective standard.		■
Bending Radius	The fillet that is equally applied to all transitions between the segments of the IfcPolyline, providing the geometric representation for *the Directrix*. If omited, no fillet is applied to the segments.		■

Table 25 Requirements for Element Rebar Shape

2.2.3 Prestressing system

Prestressing systems are used to strengthen bridge concrete structures and includes several entities.

The key one entity is an extrapolation of **IfcTendon**. The associated geometry has to be able to face bridge alignment. It may be defined as a constant cross-section placed along a polyline.

A bridge tendon can be located into the concrete structure (internal tendon), or located along the concrete structure (external tendon) and then connected to the concrete structure by **deviators**, or even, could be partly in the concrete and partly along the concrete structure.

At each end, the tendon is connected to the concrete structure through a **tendon anchor.** It is at the anchor that a jack is connected to tension de tendon. A tendon can be tensioned by one jack or by both, according to the tension losses along the cable, losses with are depending on the length and the geometry of the tendon.

A bridge tendon could be used to strengthen a given beam or to connect and strengthen the connection between two or more deck segments.

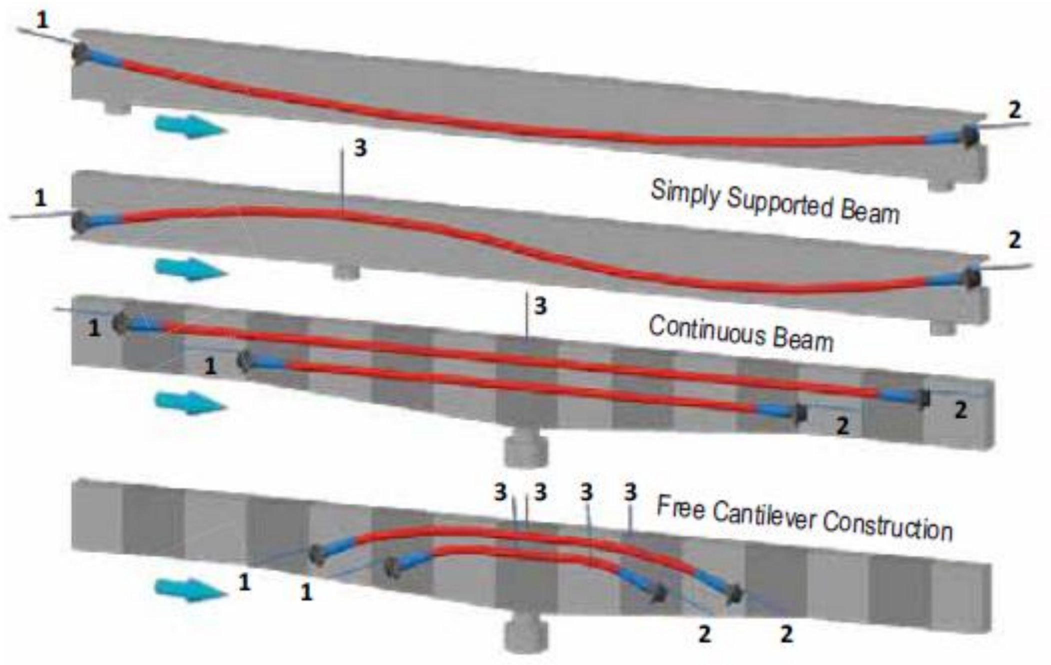

Figure 43 Tensioning system (source: VSL-strand-tensioning-systems.pdf)

2.2.4 Tendons

Prestressing systems include tensioning, anchorage, tendon, threading, and duct systems.

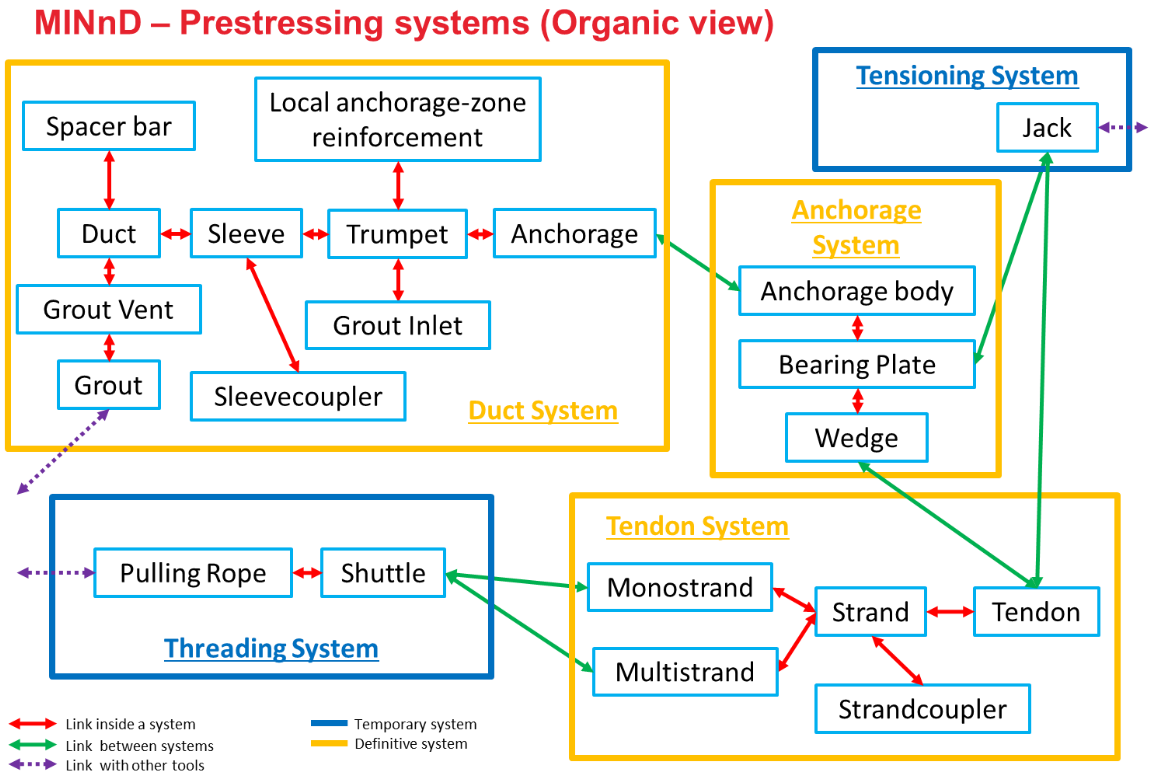

Figure 44 Diagram depicting an organic view of a prestressing system (source: MINnD project)

An anchor refers to an anchoring element for prestressing tendons.

Figure 45 Example of an anchor

Field	Definition	R	T
Name	Name of anchor for referencing purposes.		■
Geometry	Tendon anchor shape.		■
Connection Duct	Reference to tendon duct.		■
Connection Tendon	Reference to tendon strand.		■

Table 26 Requirements for Element Tendon anchor

A tendon refers to a tensioned element producing compression in prestressed concrete.

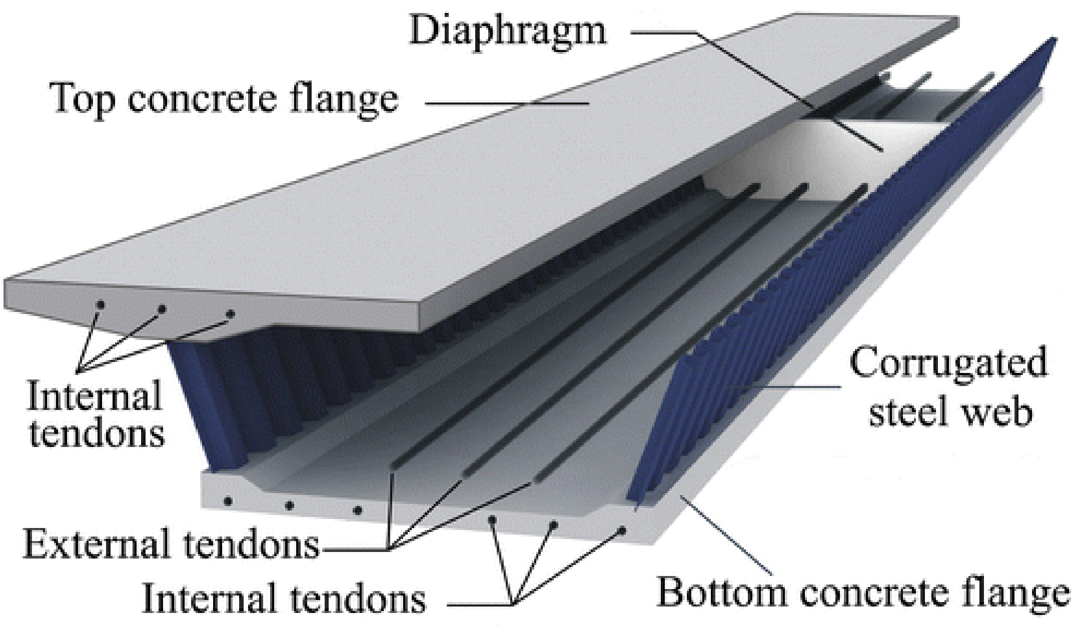

Figure 46 Diagram depicting tendons in concrete

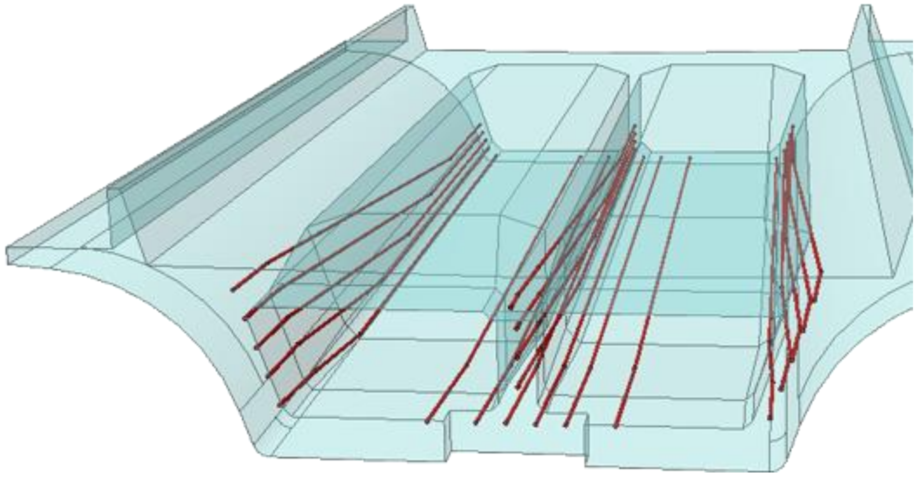

Figure 47 Model depicting tendons in concrete

Field	Definition	R	T
Name	Name of tendon for referencing purposes.		■
Material	Material properties of tendon.		■
Geometry	Tendon shape defined by swept disc solid.		■
Connection Head	Reference to tendon anchor at head.		■
Connection Tail	Reference to tendon anchor at tail.		■

Table 27 Requirements for Element Tendon strands

A deviator refers to a prestressed tendon redirection structure.

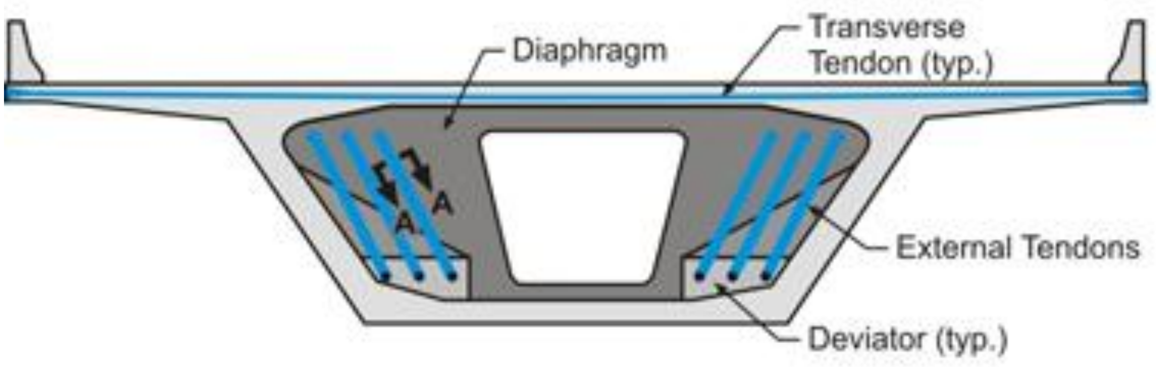

Figure 48 Diagram of a deviator

Figure 49 Example of a deviator

A blister refers to part of concrete where the anchor for prestressing can be embedded.

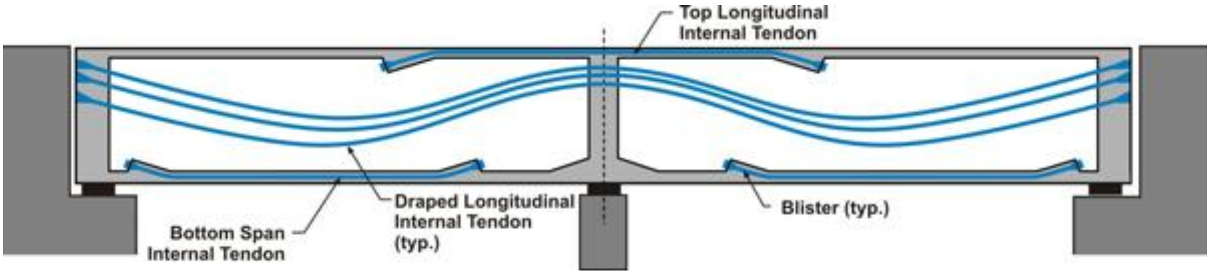

Figure 50 Diagram depicting the element blister

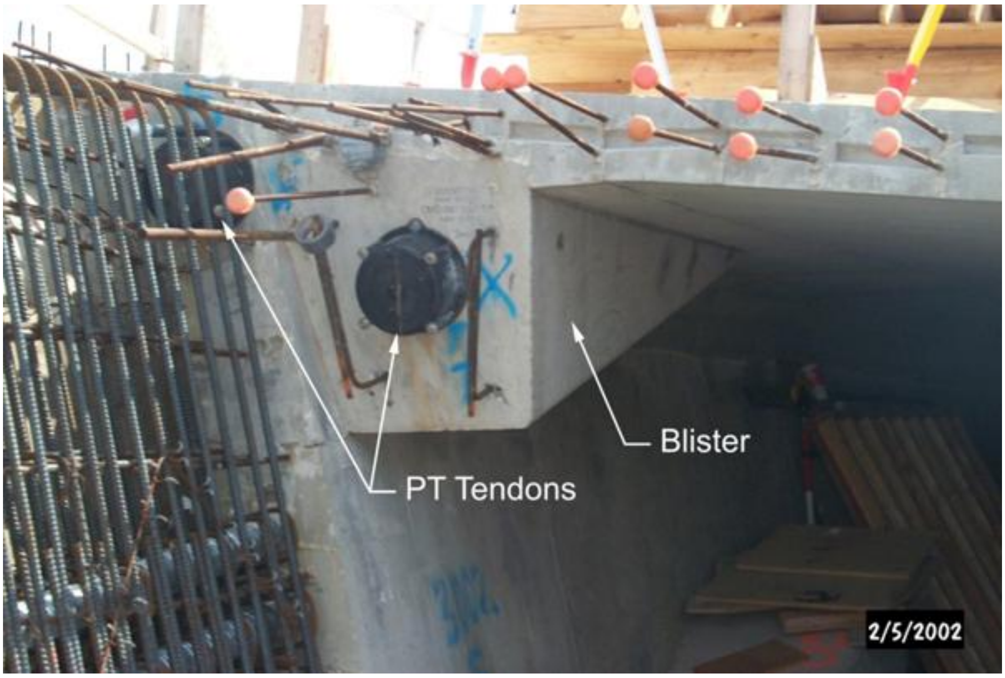

Figure 51 Example of a blister

Field	Definition	R	T
Name	Name for referencing purposes.		■
Material	Material properties of concrete.		■
Geometry	Shape typically defined by sectioned solid with variable cross section.		■
Containing Element	Reference to girder segment or diaphgram hosting the deviator/blister, where the connection indicates a continuous concrete pour.		■
Tendon Ducts	Reference to tendon ducts embedded within deviator/blister.		■

Table 28 Requirements for Elements Deviator and Blisters

Conduit refers to a channel for housing prestressing tendons.

Figure 52 Example of a conduit

Field	Definition	R	T
Name	Name of tendon duct for referencing purposes.		■
Material	Material properties of duct.		■
Axis	Axis curve of tendon duct, which may leverage parabolic shapes using vertical alignment curves.		■
Geometry	Duct shape defined by swept disk solid following axis.		■
Connection Head	Reference to deviator anchoring tendon head.		■
Connection Tail	Reference to deviator anchoring tendon tail.		■
Connection Axis	Reference to deviator(s) anchoring tendon duct along span.		■
Tendons	Reference to tendons within duct.		■

Table 29 Requirements for Element Tendon ducts

2.2.5 Vents

Vents allow air to move between compartments within box girders (to avoid pressure difference with differing temperatures), while potentially protecting infestation from birds and other wildlife.

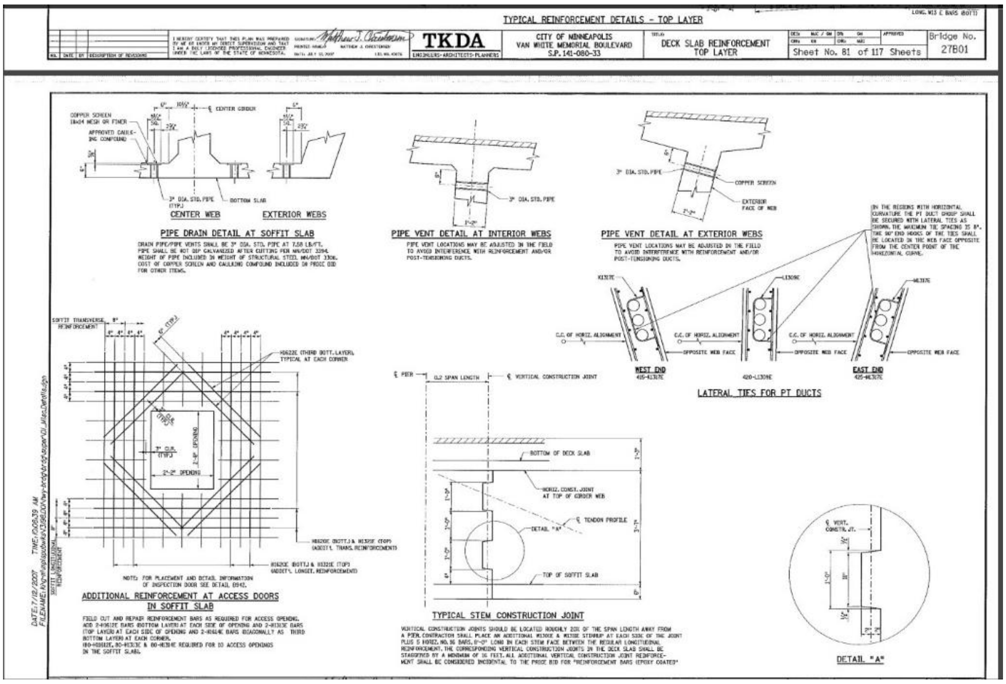

Figure 53 Example of vents on plans (source: TKDA)

Field	Definition	R	T
Name	Name for referencing purposes.		■
Containing Element	Girder segment containing vent.		■
Geometry	Shape of void		■
Screens	Screens attached to inhibit habitation by animals		

Table 30 Requirements for Element Vent

2.2.6 Access Panels

For box girder bridges with enclosed compartments, access panels allow for inspection and maintenance of components, while restricting access from unauthorized persons or wildlife.

Field	Definition	R	T
Name	Name for referencing purposes.		■
Containing Element	Girder segment containing access panel.		■
Geometry	Shape of access panel		■

Table 31 Requirements for Element Access Panel

2.3 Drainage

Drainage elements include all elements used for carrying stormwater away from the bridge structure.

2.3.1 Waste Terminals

Figure 54 Example of a waste terminal

Field	Definition	R	T
Name	Name for referencing purposes.		■
Containing Element	Reference to deck segment containing drain.		■
Connection Tail	Reference to pipe segment connected to drain.		■
Geometry	Shape of waste terminal		■

Table 32 Requirements for Element waste terminal

2.3.2 Pipes

Figure 55 Example of pipes on a bridge

Field	Definition	R	T
Name	Name for referencing purposes.		■
Containing Element	Reference to element containing or anchoring pipe segment.		■
Connection Head	Reference to distribution element at head of pipe segment.		■
Connection Tail	Reference to distribution element at tail of pipe segment.		■
Geometry	Shape of pipe segment in the form of a swept disk solid.		■

Table 33 Requirements for Element Pipe

2.4 Electrical

Electrical elements are comprised of fixtures, wiring, conduit, and junctions that carry electrical power, communications, or other electric signals.

While electrical requirements are often captured separately from bridge structures, embedded elements (e.g. conduit) must be captured for concrete construction.

2.4.1 Junction Box

Field	Definition	R	T
Name	Name of the junction box for referencing purposes as would be found on construction plans.	■	■
Embedding Element	If embedded in concrete, indicates the element containing the junction box.	■	■
Anchoring Element	If attached to a surface, indicates the element anchoring the junction box.	■	■
Body Geometry	Geometry of junction box.	■	■
Conduit	Conduit connected to junction box.		■

Table 34 Requirements for Element Junction Box

2.4.2 Conduit

Conduit is defined as a segment connecting one electrical device (or junction box) to another, following a linear path, and potentially embedded within another element (e.g. parapet wall).

Field	Definition	R	T
Name	Name of the conduit for referencing purposes as would be found on construction plans.	■	■
Embedding Element	If embedded in concrete, indicates the element containing the conduit.	■	■
Anchoring Element	If attached to a surface, indicates the element anchoring the conduit.	■	■
Body Geometry	Geometry of conduit, in the form of a swept disk solid.	■	■
Connection Head	Connection to junction box at head.	■	■
Connection Tail	Connection to junction box at tail.	■	■

Table 35 Requirements for Element Conduit

2.4.3 Lighting

Lighting is defined as placeholder objects without further elaboration.

Figure 56 Example of lighting on a bridge

Field	Definition	R	T
Name	Name of the light fixture for referencing purposes as would be found on construction plans.	■	■
Placement	Placement of light fixture.		
Anchoring Element	Reference to physical element anchoring light fixture, such as a mounting plate.		
Conduit	Reference to conduit for which wiring is connected.		

Table 36 Requirements for Element Lighting

2.5 Traffic Control

2.5.1 Lanes

For bridge design, spaces may be used to designate travel lanes for vehicles, bicycles, pedestrians, or other usage. Such usage may not always be necessary for construction requirements, however may be used for reference purposes to relate actual conditions as observed by humans (e.g. pothole in middle lane) to the physical structure.

Field	Definition	R	T
Name	Name of lane.	■	■
Category	Usage of lane such as "Vehicle", "Bicycle", "Pedestrian", "HOV", according to DOT classification. Specific identifiers are not established in this specification.	■	■
Geometry	Geometry of lane defined as sectioned solid relative to alignment curve, where height indicates required clearance.	■	■
Lane In	Connection to lane(s) converging into this lane.		■
Lane Out	Connection to lane(s) diverging from this lane.		■
Lane Left	Connection to laterally adjacent lane to the left.		■
Lane Right	Connection to laterally adjacent lane to the right.		■

Table 37 Requirements for Element Lane

2.5.2 Signs

Traffic signs include static signage, signals, and displays (using LEDs or video displays). It is anticipated that sign definitions (and “road furniture” in general) provide for placement and dimensions, along with specification of colors, reflective materials, graphics and lettering. Such definition is outside the scope of this project; it is anticipated that the IFC-Road extension will capture such detail.

Figure 57 Example of signs on a bridge

2.6 Temporary Elements

This section refers to elements specifically intended for constructing a bridge. While any physical element may be temporary, including even temporary bridges, elements described herein have specific purpose.

Figure 58 Example of a Launching nose

2.6.1 Launching Gantry

Figure 59 Example of a launching gantry

2.6.2 Staying Mast

Figure 60 Example of a staying mast

2.6.3 Casting Bed

Figure 61 Example of a casting bed

2.6.4 Pulling (Pushing) Jack

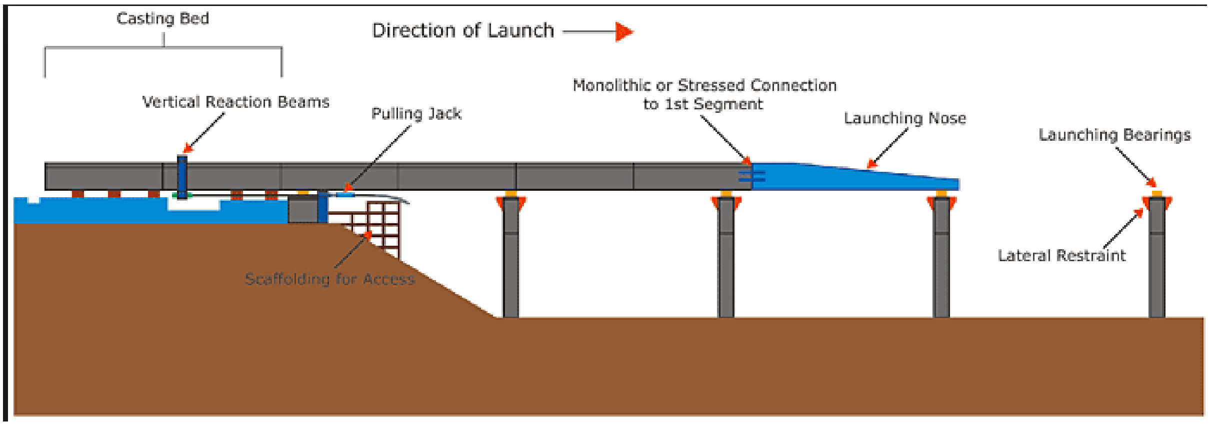

Figure 62 Cross section including a pulling (pushing) jack

2.6.5 Launching Bearings

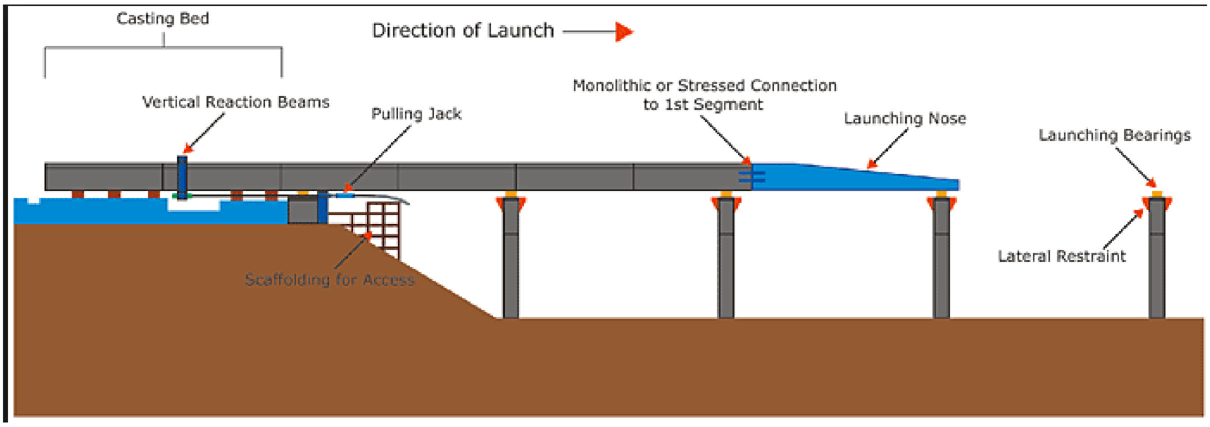

Figure 63 Cross section including launching bearings

Annex 2: List of Figures

Annex 3: List of Tables