Modélisation des INformations INteropérables pour les INfrastructures Durables

Livrable

IDM
Bridge Design Process and IFC Extensions

Auteurs/Organismes

Pierre BENNING (Bouygues Travaux Publics)
Bertrand CAUVIN (CEREMA)
Grégoire CORRE (Strains)
Vincent COUSIN (Processus & Innovation)
Claude DUMOULIN (CDC)
Arnold LEDAN (EGIS)

IFC Bridge (UC3)

MINnD_UC3_03_IDM_Bridge_design_process_015B_2019
Février 2019

Table of content

I. SUMMARY

Abstract

First phase of the MINnD project

The first phase of the MINnD project took place from March 2014 to March 2016. The Use Case 3 "IFC Bridge" working group studied the state of art of the IFC. The latter is related to the field of the bridge design and construction. It identifies missing concepts and recommends a holistic approach to:

- Derive IFC definitions.
- Complete concepts used by users and stakeholders involved in the bridge's lifecycle.

Second phase of the MINnD project

The second phase of the MINnD project took place from March 2016 to December 2018. The working group goes deeper into the design process. It took the example of a typical bridge:

- Exhibiting a fair amount of all events and problematic that can be encountered during a bridge project.
- Considered from the complete lifecycle perspective.

Aim of the present deliverable

This document details the process of a typical bridge. It underlines how the conclusions and works carried out could be affected by other types of bridges.

During this process the manipulated concepts are identified, and how they could be described within the framework of a theoretical and complete IFC. A final section defines globally the extensions required and places them into the more global contexts of the IFC extensions under discussion in the infraRoom of buildingSMART International.

Finally, the last part details the input data necessary for the design of a bridge whose geometry (architectural model) is strongly related to the computation (analytical model). This chapter specifies the mechanical properties related to the geometrical elements to be integrated in the IFC model.

Résumé

Déroulement de la première tranche du projet MINnD

La première tranche du projet MINnD s'est déroulée de mars 2014 à mars 2016. Le groupe de travail « Cas d'usage 3 – IFC Bridge » a livré un état de l'art des IFC. Ce dernier concerne le domaine de la conception et de la construction des ponts. Il a identifié les concepts manquants et a recommandé une approche holistique pour :

- Approfondir les définitions IFC.
- Compléter les concepts utilisés par les utilisateurs et les parties prenantes participants au cycle de vie complet des ouvrages d'art.

Déroulement de la deuxième tranche du projet MINnD

La deuxième tranche du projet MINnD s'est déroulée de mars 2016 à décembre 2018. Le groupe de travail a approfondi le processus de conception. Pour cela, il a pris l'exemple d'un pont typique :

- Représentant la majeure partie des événements et problématiques rencontrés lors d'un projet d'ouvrage d'art.
- Considéré pendant son cycle de vie complet.

Objet du présent livrable

Ce document détaille le processus complet d'un pont typique. Il souligne comment les conclusions et les travaux réalisés peuvent être enrichis pour les autres types de ponts.

Ce document identifie et décrit les concepts manipulés dans le cadre d'une réflexion IFC théorique et complète. Une partie définit les extensions requises et les place dans les contextes globaux des extensions IFC, en discussion dans l'infraRoom de buildingSMART International.

Une dernière partie détaille les données d'entrée nécessaires à la réalisation d'un ouvrage d'art. La géométrie (modèle architectural) de ce dernier est liée au calcul (modèle analytique). Ce chapitre précise les propriétés mécaniques liées aux éléments géométriques à intégrer dans le modèle IFC.

2. BRIDGE DESIGN PROCESS

2.1. The infrastructure design

Obstacles and constraints

Definition

A bridge[1] is a component or a subsystem in a global network sustaining traffic or fluxes. This component enables the infrastructure to cross or intersect an obstacle:

- A natural obstacle: river, deep valleys, mountains, mountain slopes, etc.
- An anthropogenic structure such as another network.

Both enclosing infrastructure and obstacle:

- Are defined or pre-existing.
- Define constraints to be respected.

Constraints which impact the bridge design

All the constraints which impact the bridge design must be included into the bridge information system. If not in the bridge organic description[2] itself so that one may check that these constraints are met, whatever the lifecycle step.

Features

Traffic type and traffic flow or fluxes supported

When the bridge design process starts, the following features have been already defined.

Type of traffic	Flow or flux
Road	Pedestrians.
	Cycles.
	Vehicles (cars and trucks).
	Number and width of lanes.
Rail	Urban rail tracks.
	High-speed rail tracks.
	Number and width of lanes.
	Ancillaries.
	Long-distance rail tracks.
Canals and waterways	Traffic class.
Energy and telecom networks	Type of fluids.
	Dimensions.
Water networks	Type of water flows.
	Dimensions.
Mixed combination	Combination of the types described above.

Lanes or infrastructure profile

The infrastructure designer:

- Determined the plan profile of the infrastructure within a corridor width.
- Specify to which extent the longitudinal profile varied by the bridge designer. From this starting chainage to this end chainage.

Plan profile means the mathematical definition of the curve on the earth surface:

- It is the succession of straight lines, clothoids (spirals) and circles along the curvilinear ordinate.
- It is not just the x, y, z ordinates of the curve according to a geodetic reference grid.

The longitudinal profile might have been already defined or not. For example, if the earth moving cut and fill optimization has already been carried out.

---

[1] But it would be true of any structure such as a tunnel for instance, or a lock in a water channel, or more generally in a linear infrastructure.

[2] See section hereafter.

2.1 The infrastructure design | Features

Native import

All these features must be imported natively into the bridge modelling. Thus into the IFC entities as they represent an essential part of the geometrical constraints at least[3].

Specific rules and requirements for each type of traffic:

All these profile definitions are linked to rules and requirements. The latter are specific to each type of traffic:

- The maximum slope of a road is not the same as the high-speed train one.
- The minimum curvature radius of a 90 km/h road is smaller as the same for a motorway.
- The transversal slope of a tramway line is nil when a certain value for a high-speed train depending on the actual curvature.
- Etc.

Specific management process for requirements

These rules are specified in the overall 'requirements' or needs but not yet affected to a particular organic component. A specific management process for requirements is separately set in place. The latter derives these needs into requirements at the level of each component as in any engineering process.

2.2. IFC sets extensions

Recent initiatives to complete IFC entities

IFC entities are defined with reference to the design and construction of buildings. Apart from the incomplete IFC bridge initiative a decade ago, the IFC entities remain incomplete. In terms of requirement to support design and construction activities of infrastructure and bridges. This is where the following recent initiatives come into line:

- IFC Alignment integrates the above identified constraints concerning the supported traffics.
- IFC Road (or IFC Rail[4]) integrates the specific traffic constraints, mainly geometrical and structural.
- IFC Bridge strive after being complete in terms of a 'smart' modelling of the bridge. The latter inheriting and enclosing natively the entities deriving from the IF Alignment, road and IFC rail initiatives. i.e., the supporting structure.

Goal

The ultimate goal of this working group is described below.

The IFC should be complete for itself and not separate fields for alignment, road, rail and bridge		
On the contrary the IFC sets ultimately called in by a specific project should be complete in terms of:		
• Alignment.	• Road or Rail or both if the bridge covers both types of traffic.	• Bridge.
The extensions should be complete to satisfy the bridge part of the global infrastructure theoretical functions		
The bridge alignment(s) is (are) related to the infrastructure(s) alignments and is (are) part of it.		
The road (or the rail) features are complementing the infrastructure alignments to satisfy all traffics supported or crossed, and also the bridge model to integrate the mechanical features connecting the lanes and the bridge structures.		
The bridge features integrate the features inherited from the alignment and from the road (rail) domains and develop for its own needs all missing entities from its own perspective.		
Entities' improvement		
During a bridge project, the entities inherited the alignment and road (or rail) domains. They are progressively improved by the project working stakeholders for what they are entitled to. According to the information modelling process defined by the project management.		

---

[3] As a matter of fact, they convey requirements in terms of imposed traffic loads to the structures.

[4] The case of IFC Canal might be too simplistic to deserve an extension set for itself: longitudinal slopes are usually minimal and cross sections simple.

2.3. Operational, functional and organic views in engineering

Engineering framework systems

Aim

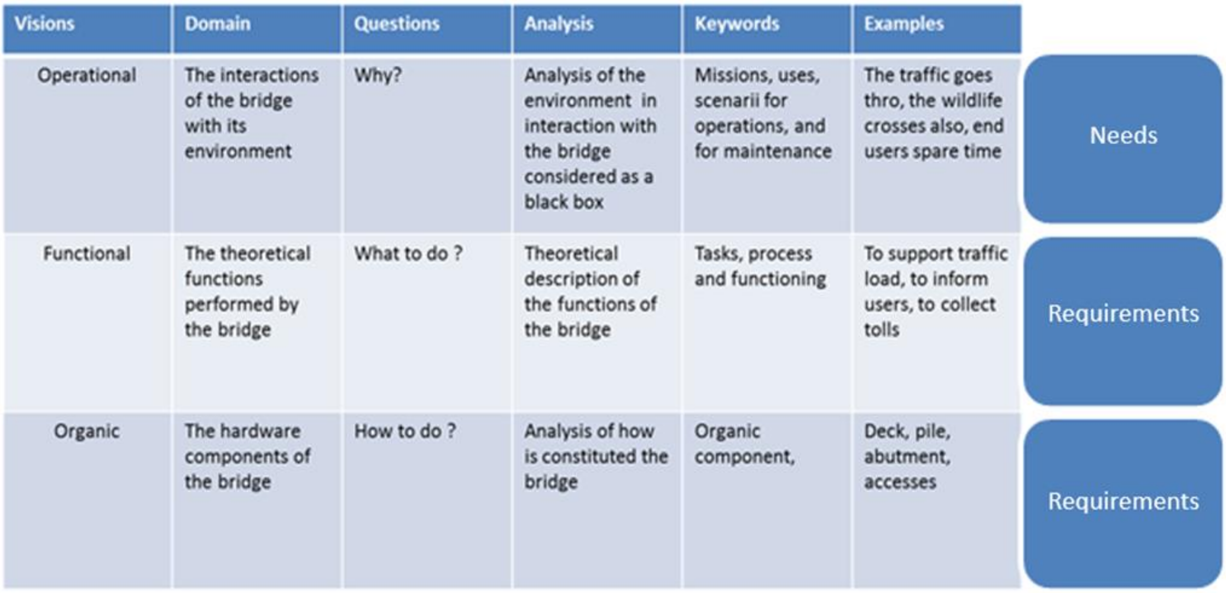
The working group adopt the engineering framework systems as the most global reference framework to:

- Develop engineering activities.
- Be as exhaustive as possible in its work, as detailed further into the deliverables of the MINnD project phase 1.

Viewpoints structure consideration

In such a framework, one must consider the structure to design and construct from the following viewpoints:

Operational view	Stating WHY the structure is needed. It is the description of the structure in what stakeholders expect it to deliver or to impact (or not impact) their own processes.
Functional view	Stating WHAT the structure should deliver. It is the description of what the structure should deliver or perform to satisfy the stakeholders expectations.
Organic view	Stating HOW the structure should be made to deliver or perform the functions described in the functional view.



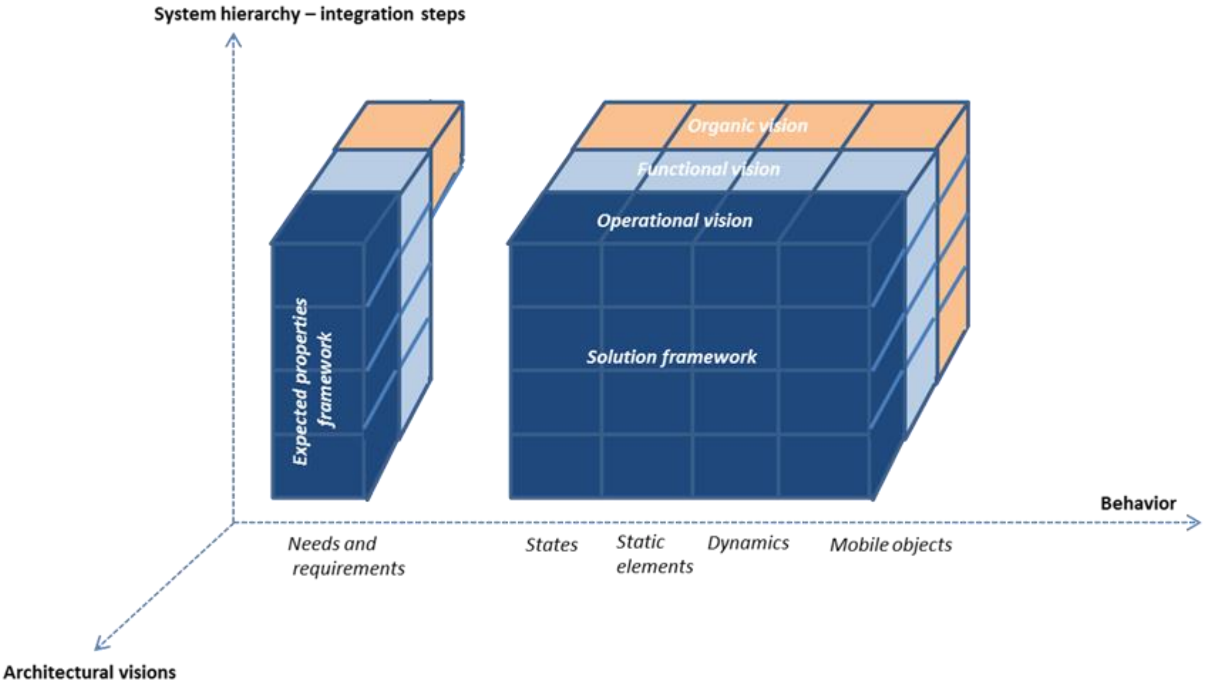
Visions	Domain	Questions	Analysis	Keywords	Examples	
Operational	The interactions of the bridge with its environment	Why?	Analysis of the environment in interaction with the bridge considered as a black box	Missions, uses, scenarii for operations, and for maintenance	The traffic goes thro, the wildlife crosses also, end users spare time	Needs
Functional	The theoretical functions performed by the bridge	What to do ?	Theoretical description of the functions of the bridge	Tasks, process and functioning	To support traffic load, to inform users, to collect tolls	Requirements
Organic	The hardware components of the bridge	How to do ?	Analysis of how is constituted the bridge	Organic component,	Deck, pile, abutment, accesses	Requirements

Operational, functional and organic views in engineering

2.3 Operational, functional and organic views in engineering

Engineering process The following steps complete the engineering:

Step	Action
1.	Go into more details progressively from the higher level of the bridge to its subsystems' girder, supports, foundations, etc.
2.	Consider all lifecycle states and events 'from cradle to grave' with an emphasis to the bridge exploitation and maintenance and to the bridge construction.
3.	Develop the requirements[5] for each view and its subsystems or components.
4.	Check and valid all requirements from the functional and organic views back to the higher levels operational needs after integrating all details into the bridge model.



Representation of operational, functional and organic views

Example Concerning the bridge design process explained above:

Terms	Definition
Alignment domain	Description of the function 'conduct the traffic flow' at the infrastructure hierarchical level. It encloses the bridge as a subsystem.
Road domain	Description of the function 'conduct the traffic flow' at the hierarchical level below the infrastructure level.
	The alignments and cross sections to conduct the individual traffics of: The functions 'provide mechanical continuity between the traffic and the bridge structure' and 'provide impermeability between the environment and the bridge structures.' The organic components how these connections between bridge and circulation lanes are made of.
Bridge domain	This domain inherits and complements these definitions in the functional and organic views. It is required to design and construct the bridge and its pavement lanes or tracks.

---

[5] When considering the operational view, requirements are called needs in this document.

3. DESIGN PROCESS FOR A TYPICAL BRIDGE

3.1. Typical bridge selected

Reinstatement of a secondary road network

The working group has chosen a common bridge to reinstate a secondary road network intersected by a major motorway under design.

3D view of the bridge case

Description

At the crossing point between the motorway and the secondary road, the motorway is in an excavated section below the adjacent level of the ground.

The ground level is the same on both sides of the motorway. But the secondary road intersects the motorway:

- At a certain skew angle.
- Not at square angles.

The motorway is a dual carriage way 2 × 2 lanes with side lanes for emergency stops and shoulders, and a green central part.

The secondary road is a simple dual-lane road allowing:

- Mixed traffic between bicycles, cars and trucks.
- A separate traffic for pedestrians in both directions.

3D View of the bridge case: a secondary road crossing a motorway

3.2. Design process

Overall infrastructure	
Centreline definition	The motorway design is adapted to a long linear infrastructure. The centreline has been decided within a 10 km corridor in a GIS software following LandXML or another international standard. In the tangent developed horizontal plan at the earth surface, this centreline results from the aggregation of mathematically defined curves: • Straight lines. • Circles. • Clothoids.
Cuts and fills	Find below the cases of cuts and fills defined or not.

If	Then
The motorway design has not yet determined cuts and fills	The z ordinate is the ground elevation according to the geoid at the x and y coordinates of the centreline.
Cuts and fills are defined with the true transversal profiles	The z elevation of the motorway is already defined - either in cut or fill - as well as the extent of the cuts and fills either side.

Exchanges and confirmation	The design process supposes that several data exchanges are performed in between the bridge model and the motorway profile design software. Until everything is firmed up.

Perspective view of a railway crossed by a road and wildlife bridges

3.2 Design process | Overall infrastructure

Measurement

In infrastructure design, the position of work item is measured according to the one-dimensional coordinate along the centrelines from a starting point or origin. It defines the chaining of the motorway.

Kilometer as the unit

The unit is the kilometer with significant digits up to the mm.

Bridge local reference location

The bridge local reference is centered at the intersecting point of:

- The bridge centreline.
- The motorway centreline.

X, Y and Z directions

Find below the location of X, Y and Z directions.

Direction	Location
X direction	Along the bridge axis in the direction of increasing chaining of the way to be reinstated.
Y direction	The perpendicular direction anticlockwise
Z direction	The local vertical usually with the value of the elevation according to either a local or national elevation reference or the geoïd.

Structure/bridge introduction

Infrastructure design team role

The infrastructure design team:

- Identified that the motorway centreline intersects a secondary road at chainage on format xxx.xxxxxx.
- Decided that the crossing after reinstatement should be straight for a certain length at a certain skew angle and be supported by a bridge above the motorway.

Angle's measurement

Angles can be measured in various units such as:

- Grades.
- Sexagesimal.
- The centesimal degrees.

Please refer to the figure below for proper definitions of the various angles.

Geographic reference system definition

The geographic reference system and its system of projection must be accurately defined. To coordinate system change that could be defined from time to time by authorities:

- Automatically.
- At any point in time of the bridge lifecycle.

LandXML language

The motorway centreline is defined in LandXML:

- Without mandatory reference to the geographical system used and its projection system.
- Resulting in manual exports procedures.

This is not satisfactory regarding the changes that occur over:

- The bridge lifecycle.
- The design phase.

As an appendix, a LandXML file presents transferring data on the centreline and on the ground contour. The several centrelines may be present for studying alternatives. It is important to foresee indicating in the files which of these alternatives must be used.

Intersection of bridges and motorways in urban areas with their main axis

Relation between infrastructure design team and bridge design team

The infrastructure design team transfers the duty to design the bridge to the bridge design team. The infrastructure design team hand him over the motorway numerical model:

- From Chainage i- to Chainage i+.
- To include the bridge model over a length of xyz m.

Infrastructure design team constraints

The infrastructure design team are:

- Centreline of the motorway remains unchanged. But the typical transversal section can be modified within the impacted area by the bridge for a few details like the interline section and the abutments.
- Centreline of the secondary road must remain the same in its plan view. It can be modified in z to accommodate the sizes of the vehicles using the motorway.

In case of a major obstacle

Needs

In case the motorway crosses major obstacles such as a river, the infrastructure design team would proceed in a rather similar way. However:

- The motorway centreline in top view shall remain the same. The centreline elevation can be modified. Thus, the bridge leaves the necessary clearance above the river. The modified centreline still complies with the requirements of curvatures and transversal slopes according to the speed and type of the traffic.
- There might be other built features not impacted by the motorway bridge.

Materialization

All these needs are materialized by transferring into the future bridge model:

- The centrelines of all motorway supported traffic and fluxes. For instance, there are often telecommunication cables laid along a motorway.
- The centrelines of all secondary road supported traffic and fluxes.
- The ground contours after cuts and fills (digital terrain model).

In case of
a major obstacle

Ground contours

The ground contours can either come from:

- The DTM (Digital Terrain Model).
- Topographic surveys of several points on the surface in geodetic local references out of which can be developed contour lines or altitudes of other points.

An example of ground contours transfer files is given in appendix 7.1.

A list of points with identifiers are given with X, Y, Z as well as the associated triangulation to make meaningful interpolating ground level at any other place.

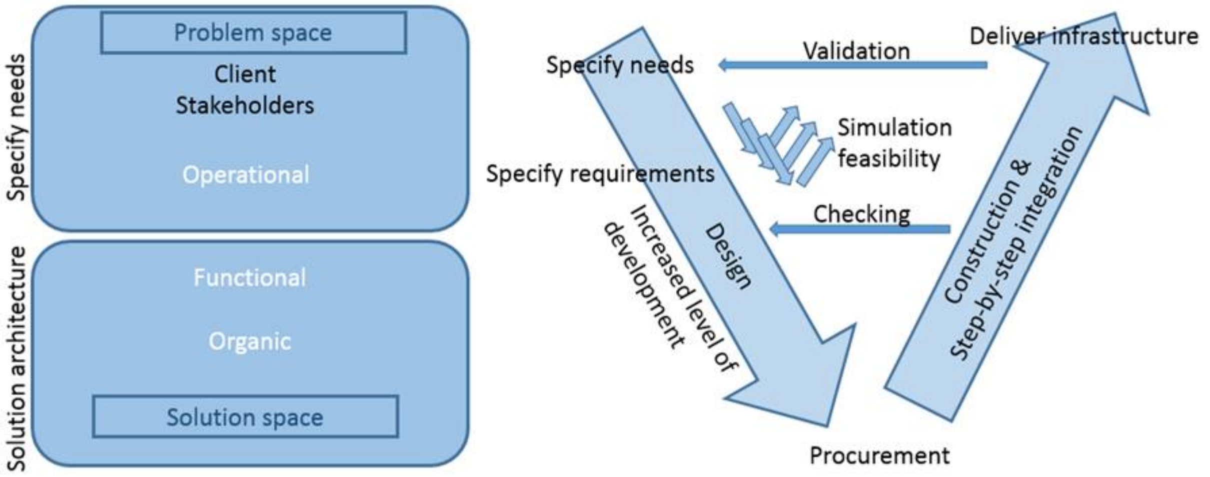
A triangulation gives the triplet of the summits of each triangle identifying them in a unique manner by using the identifiers' triplet.

For a triangulation to be acceptable, each triangle must be, on the ground surface as close as possible (within a given tolerance) to a planar surface.

Bridge design process

The bridge design starts and evolves with back and forth loops:

From the problem space	The operational view expressed by the stakeholders.
To the solution space	Both the functional and organic views enabling the engineers to define the bridge, check and validate that it meets all needs and derived requirements.



- Validation: Validation of the whole infrastructure through operational tests → Satisfy needs
- Checking: Verify infrastructure components through functional and organic tests →Satisfy requirements

V Cycle

Operational view and its needs

Below the description of operational view and its needs:

Reminder

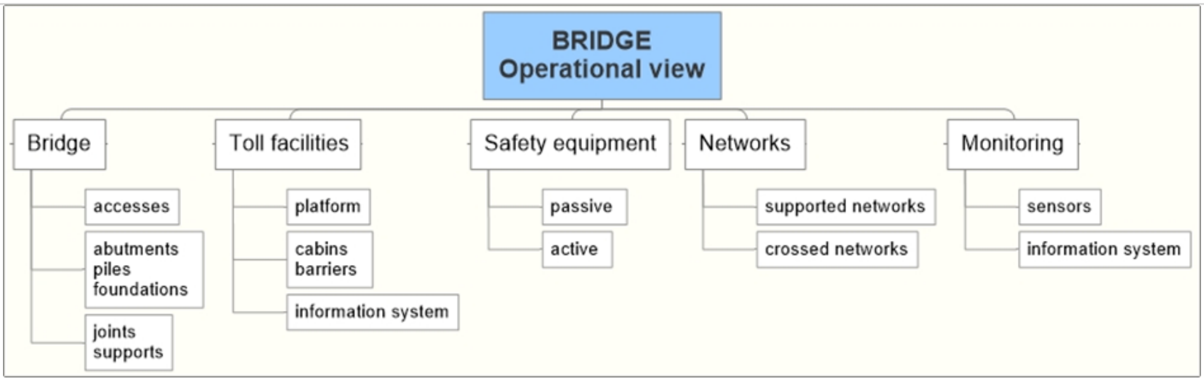
As already explained above, 'any bridge is a component or subsystem in a more global network sustaining a particular traffic or particular fluxes. This component enables the infrastructure to cross or intersect an obstacle which can be a natural obstacle (river, deep valley, mountain, mountain slop, etc.) or an anthropogenic structure such as another network. Both the enclosing infrastructure and the obstacle are either defined or pre-existing to the bridge to be constructed and both define constraints that the bridge have to meet.'

Consequently, the supported infrastructure functional view becomes mandatory inputs for the bridge operational view. Find some examples below.

Operational view of a bridge

The figure 'Operational view of a bridge' is an example of the bridge operational architecture. In the case of this bridge for reinstating a secondary network, the operational view is reduced to:

- The bridge.
- The safety equipment (passive only).
- The supported networks. A telecommunication, power cable or a potable water pipe).



Operational view of a bridge

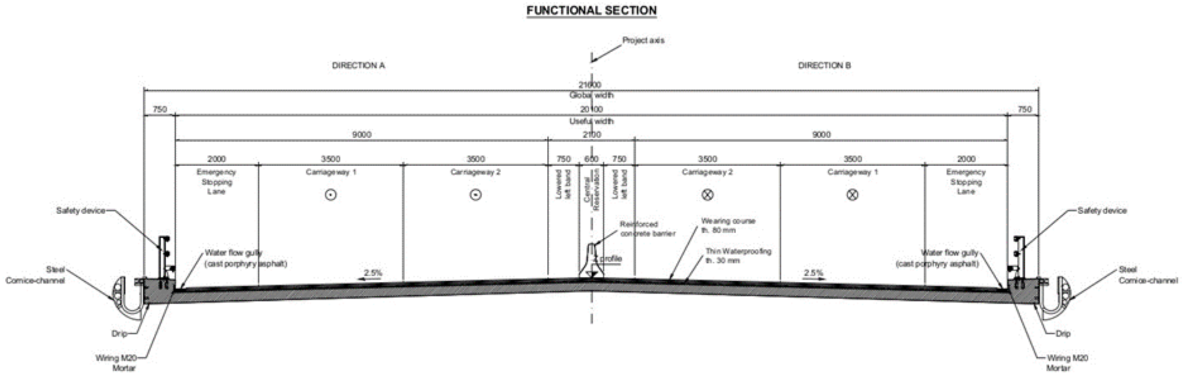
Functional section

Motorway operational view

The motorway operational view:

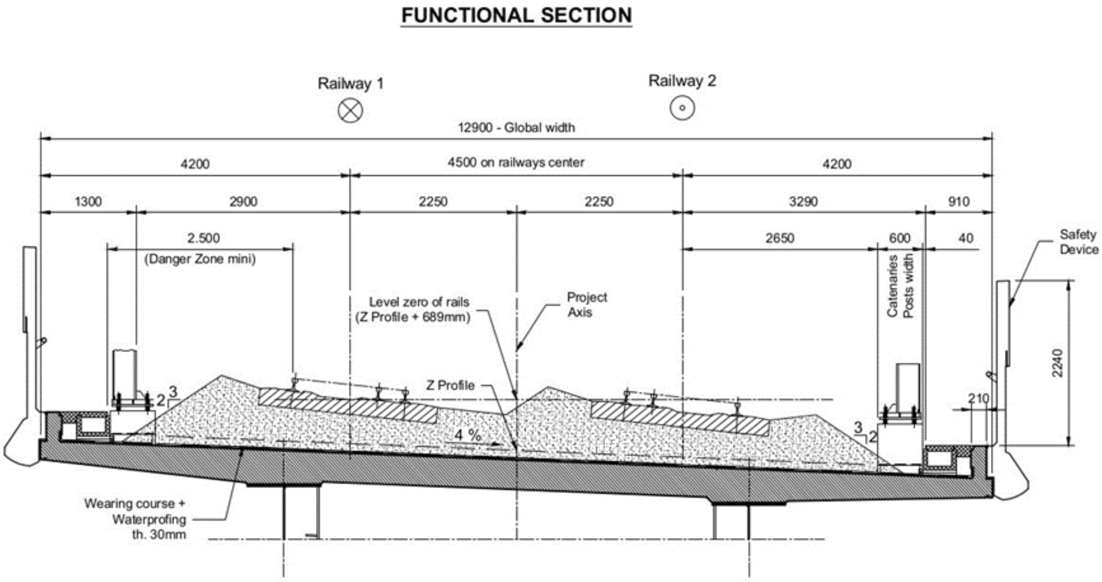
- Exists already.
- Is under the responsibility of the infrastructure design team.

It is not recommended that the crossed networks shown in the figure be used for that purpose. Indeed, it would jeopardise the hierarchy of systems in that case). One should just not forget that the architecture presented here is part of a larger system, the one of the motorways of which it constitutes one of the existing networks and links reinstatement.



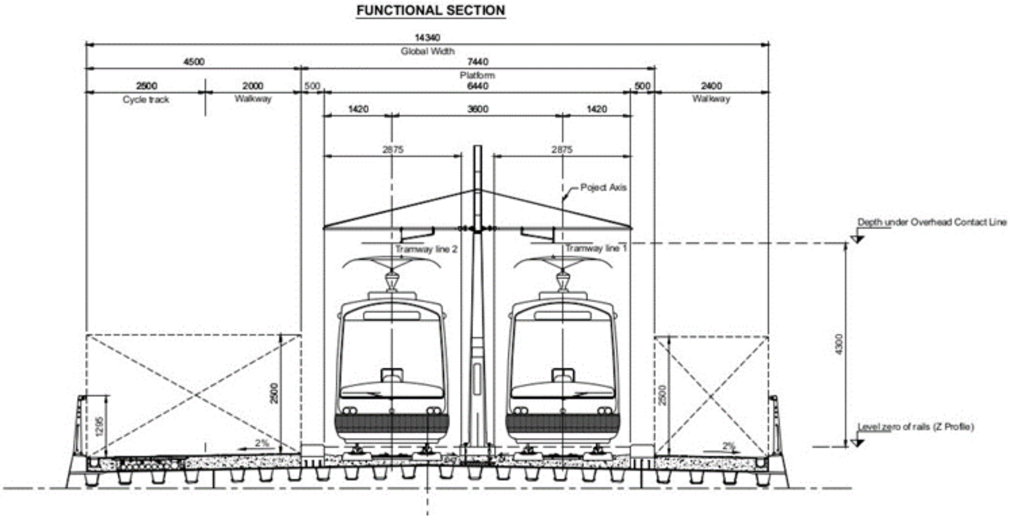
Functional section of a motorway project

Functional section of a railway project



Functional section of a railway project

Functional section of a tram project



Functional section of a tram project

Operational view and its needs

Stakeholders' identification

Around this subsystem, all the stakeholders must have been identified by the infrastructure team. Each stakeholder expresses its needs in terms of this subsystem and all these needs are attached to the 'bridge', 'safety equipment' and 'supported networks'. They also cover the complete lifecycle of the bridge from design to construction, exploitation and maintenance.

Needs check

The bridge design team first check the completeness of the inherited needs with the stakeholders:

- All needs deriving from the integration of the bridge into a particular context, physical and environmental (geosphere, terrain and geology, hydrography and hydrology, climate, built environment, biosphere, etc.).
- All regulations that must be applied.
- Traffic and police authorities.
- Emergency services.
- Networks operators.
- Motorway operators and maintenance services.
- Contractors.

Data development

It is imported into the model to develop as much as possible the following data:

Data	
The geodetic system applicable.	
The existing environment near the bridge. The area delegated to it by the infrastructure team.	The digital terrain model.
	The geology.
	The hydrography.
	The built environment contours.
The motorway.	The centreline.
	The typical transversal section (embankments, longitudinal drains, shoulders, emergency lanes, lanes, safety railings, central separation, etc. and their composition in layers) and its reference point to the centreline.
	The intersect chainage between motorway and secondary roads centreline.
	The vehicle dimensions driven on the motorway (geometrical 3D description and weight).
The secondary road.	The centreline.
	The typical cross-section (shoulders, lanes, etc. and their composition in layers) and its relation to the centreline.
	The dimensions of the vehicles that may run onto the secondary road.
	The skew angle at the intersection point.

Functional view and its requirements

Functional view

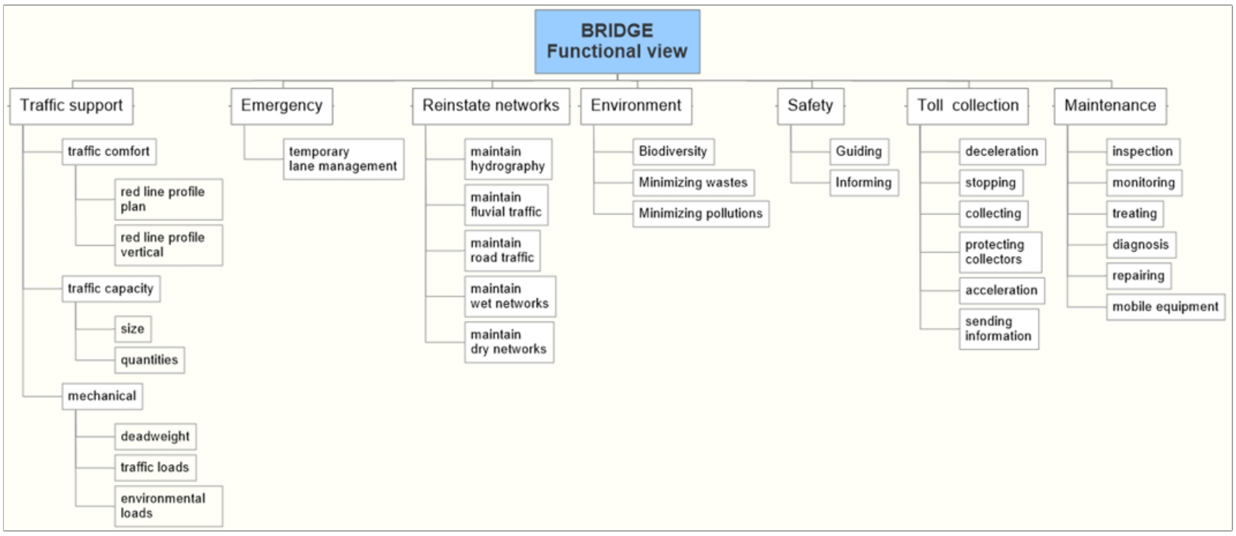
The figure below is an example of the bridge operational architecture. In the case of this bridge for reinstating a secondary network over a motorway, the functional view is reduced to:

- The traffic support function. Considering all networks.
- The safety equipment (passive only).
- The maintenance function.

In this case, the traffic capacity and comfort function is met very simply:

- It complies with the required transverse section.
- It has a bridge straight centreline.

In this case, others supported networks do not require anything special in terms of profile.



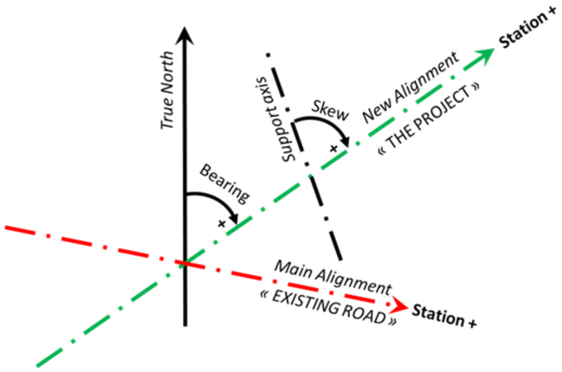
Bridge functional view

Functional view
and its requirements

Requirements

The main issue is to support mechanically all imposed loads from:

- Traffic.
- Environment.
- Supported networks.
- Deadweight.



Definitions of angles between axis of project and existing roads

A mechanical model made of piers, girders, abutments, joints, supports and foundations transfers loads onto the soil.

Traffic capacity and comfort function are more complex to achieve if the studied bridge for the motorway crosses a major obstacle.

Example
For instance, for a road traffic only the basic requirement is to have dual lanes of the required dimensions complying with constraints of vertical slopes, transversal slopes and top view radius.
The obstacle or facility to be crossed has further requirements in terms of the air draft over the water surface, or of vehicles dimensions circulating on the network to be crossed. Further constraints may also come from the ground elevation at the end and starting point of the bridge.
In the most complex of cases, lanes may end up by having their separate centrelines that each have their own definitions in terms of aggregation of mathematical curves.
This may further be complicated in case the bridge is to support mixed rail and road traffics which have both different constraints value and different vehicle sizes.
For other supported networks, it is mostly expected that their centrelines may be defined relatively to organic elements of the bridge itself.

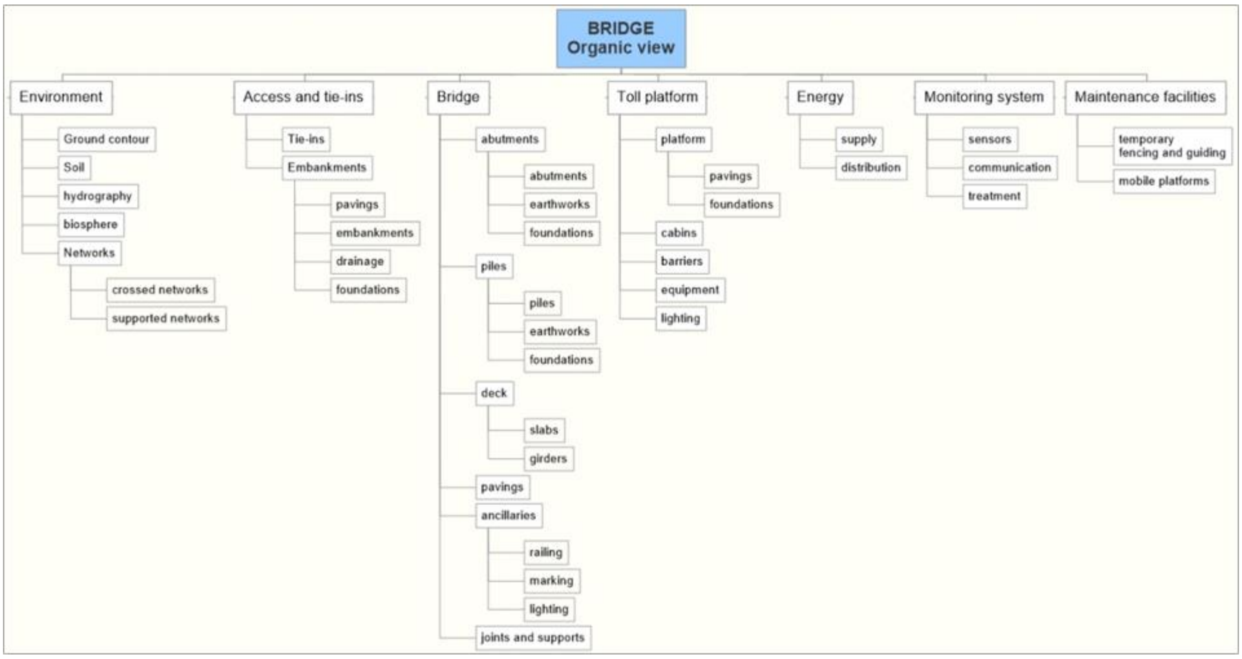
Organic view
and its requirements

Example of an organic architecture

The figure below is an example of the organic architecture of the bridge. For reinstating a secondary network over a motorway, the organic view may be simplified to:

- The bridge itself.
- The access and tie-ins.

The maintenance is limited to operating most probably a working platform that may be suspended to a truck for accessing the girder edges. This is a further type of vehicle using the bridge with a special geometry.



Bridge organic view

When a bridge supports a secondary road

When a bridge supports a secondary road, the type of the bridge is already fixed:

Slab	A slab supported on one central pier and two side abutments with sliding supports: • On top of vertical walls (aligned with the motorway axis) for the abutments. • On circular piles (centered along the motorway axis) for the central support.
Walls and piers	In contact with the ground by means of longitudinal beams aligned with the motorway axis.
	Supported by the ground through deep piles.

Cross section at the intersection of the 2 roads

3.2 Design process | Bridge design process

Organic view
and its requirements

Description of the design process

Below the design process:

Step	Action
1.	Place a slab at ground level above the centreline intersects points. For such a standard bridge, the thickness of the slab may be approximated by a reasonable guesstimate. The slab cross section center point is placed orthogonally to the bridge centreline (itself at a skew angle of the motorway axis) at such a distance under the said centreline that it represents the necessary thickness of the bituminous pavement and of the impervious layer.
	Extrude the section in both directions until it meets the existing adjacent terrain (after cut and fill).
	Measure the resulting air draught between the invert of motorway lanes slabs and surface.
	Lift the slab until the air draught is above the minimum value.
2.	Position the central piers and abutment walls at the motorway centreline for the first and laterally parallel to the motorway axis, at a clearance from the lane edges so that foundations don't interfere with the motorway foundations for the second.
	Adjust them in height and position to allow the positioning of the mechanical supports:
	• Between the slab invert and the piers/walls tops. • For the proper depth for the foundation beams and tops of piles.
3.	Cut the slab parallel to the motorway axis thanks to a Boolean operation so that there is enough space for placing the bridge longitudinal joint.
	Introduce transition slabs on both sides of the abutments to ensure the loads transfer between the abutments and the adjacent earthworks.
4.	The rest of the bridge design is performed including placement of pedestrian ways, supported networks, guard rails etc.

The design proceeds by performing procedural geometry tasks along components axis, themselves defined in relation to either:

- The motorway axis.
- The bridge axis
- The secondary road axis.

It is essential to the good performance of the design that all these axis and definitions procedures are kept within the model to support all future tasks and simulations. In this simple case, the road centreline also remains the reference for the centreline of the bridge girder (there is a simple vertical translation).

Bridge team responsibility

The bridge team oversees:

- The bridge.
- Its supports, abutments and foundations and its transition slabs, up to–for the ground level and foundations–a line parallel to the motorway axis at a 2:3 ratio from the edge of the transition slab away from the motorway.

Complex cases

In more complex cases, such as the motorway bridge crossing a major obstacle, **the road axis (or the motorway axis) might become distinct from the bridge girder centreline**.

Indeed, when the road axis is made of three sections (straight, clothoid and circle), over a certain length, it might be advantageous from a bridge construction point of view, to:

- Adopt a constant curvature in the lane plane.
- Have a wider track width to remain compatible with the lane width attached to the road centreline.

In this case, the road axis is distinct from the bridge axis. Both have their own geometrical definitions using mathematical curves and has at least one common intersect. The acceptability of such a design is verified by checking that the theoretical road remains within the bridge pavement.

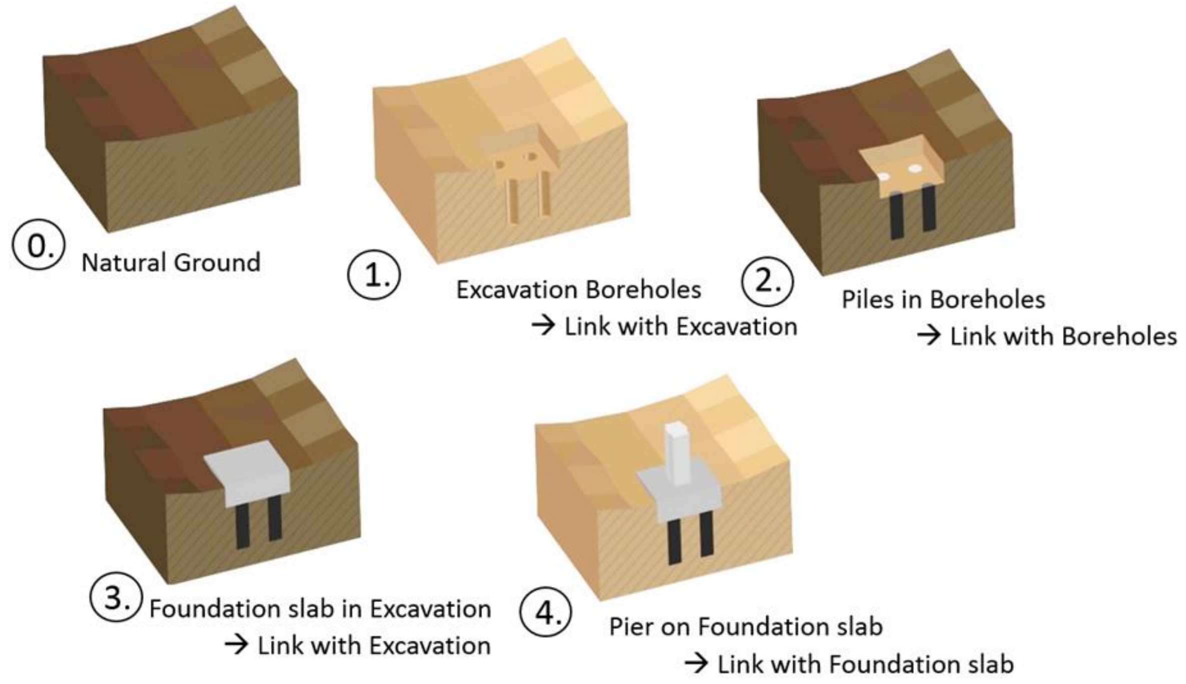
3.2 Design process | Bridge design process

Organic view and its requirements

We have seen in Section 2.3 that we have to consider the system to be designed under the requirements of the whole lifecycle: 'Consider all lifecycle states and events 'from cradle to grave' with an emphasis to the bridge exploitation and maintenance and to the bridge construction.'

Specificities of the construction phase

We need to model the earth works. Which means to have an entity associated to the ground that remains in place and other ones associated to the earth excavation and boreholes that voiding the ground (stages 0 and 1 of the figure below). Then piles entities fill the boreholes and are connected to the surrounding ground entity (stage 2). Then the foundation slab fills partly the associated excavation and is connected to the piles and the surrounding ground entity (Stage 3). And finally, the pier entity is connected to the foundation slab (Stage 4). Such a modelling allows associating quantities to the different steps. Association of these entities to a work plan and tasks allows 4D analysis and visualisation.



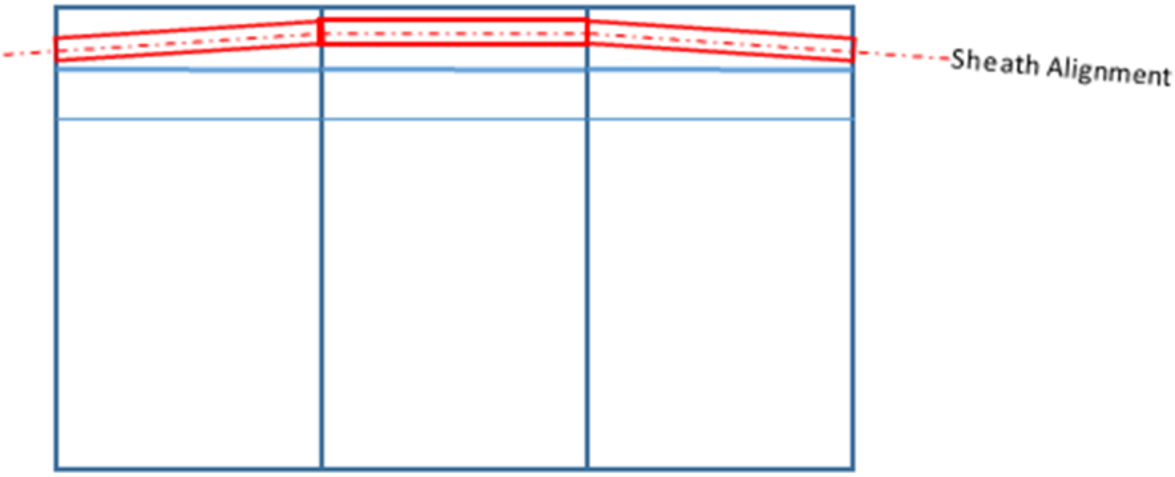
Construction phases for a bridge pier

For instance, the process of constructing a bridge pier starts by excavating, including lateral slopes as needed for ground stability, a shaft to the size of the future pile cap or cap structure and its shuttering tool, then by drilling boreholes and by pouring concrete in the case of cast in situ concrete piles. Then it continues by constructing the pile cap and later the pier itself. This requires the possibility of creating voids by extrusion processes connected to stability calculations.

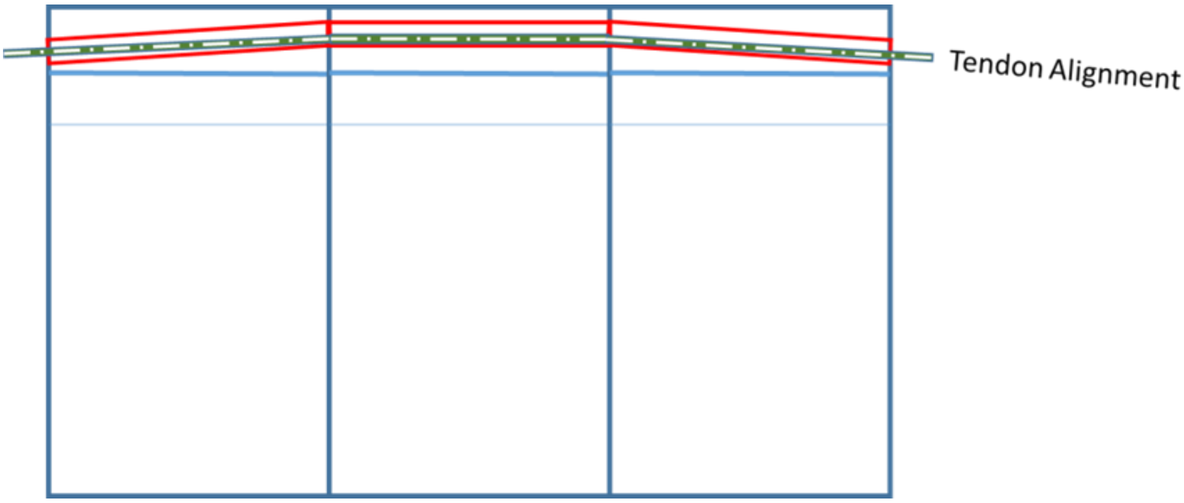
In bridge design, the reinforcement design (and the post-tensioning system design also) can be a very time-consuming process. For the simplest structures, when the constructive constraints are not very demanding, a simple design process starting in 2D can be selected for reinforcement. Whenever the concrete structure is rather complex in its shape and the reinforcement density high with large diameter rods, it is necessary to design in 3D directly (available space and possibility to pour concrete and possibly vibrate it) and to then to simulate step by step the site assembly process (bars already bent and crossed, etc.) with all the possible manipulations (threading in, rotating, tilting, etc.).

In the case of pre-stressed concrete, design (and construction) starts by placing sheath defined as successive curved lines between supporting points. The post-tensioning strand is then threaded in the sheath from one anchoring point to the next one, the sheath supporting points acting as deviators so that the final curved line of the tendon is aligned with the theoretical line of post-tensioning system if the system is internal to the slab or web or to the structure. In case the post-tensioning system is external, then the deviators or supporting points act as the points of applying the post-tensioning system forces.

Specificities of the construction phase

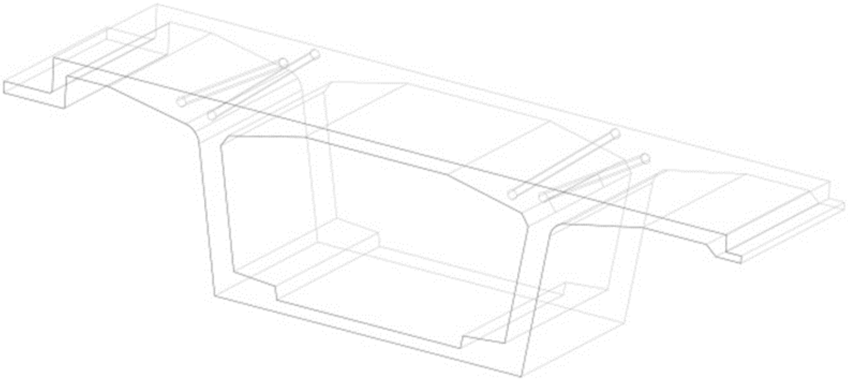


Post-tensioning system sheath inside a concrete slab as successive straight lines



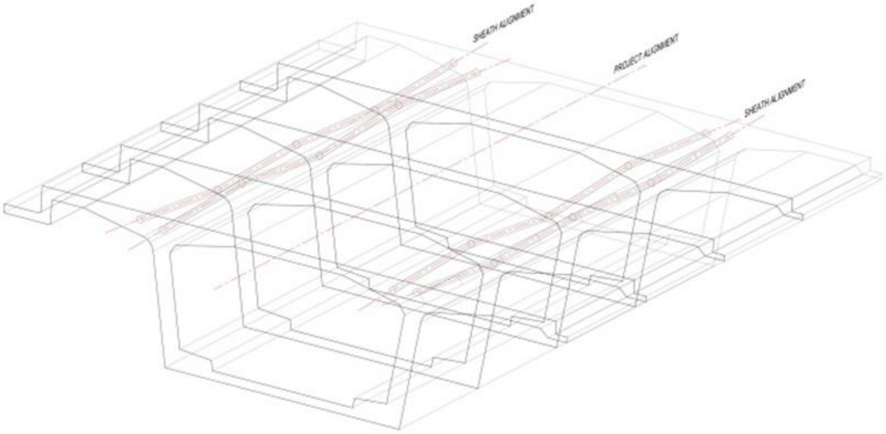
Post-tensioning system tendon inside the post-tensioning system sheath

In case the girder is erected by segments, either cast in place or prefabricated, the segments are constructed with sheath (i.e., conduits leading to voids inside the segments) aligned from one segment to the next one. Whenever one segment is placed, it is fixed into position by threading-in the tendons whose anchor is placed in the segments and by tensioning the said tendon between the segment on the pier and the segment under construction. All these tendons constitute the construction post-tensioning system. Other tendons constitute the continuity post-tensioning system and are threaded in only after completion of a complete span. Other tendons are also threaded in at this late stage to counteract the effects of creep phenomena.

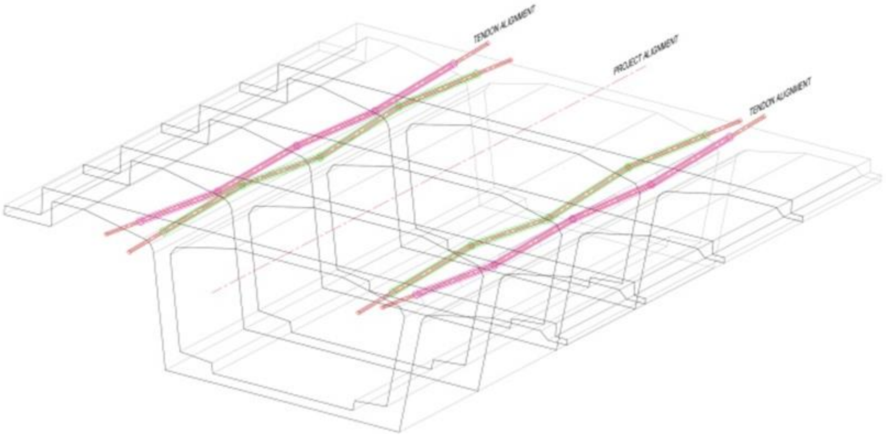


A bridge segment

Specificities of the construction phase



Bridge segments assembly with sheath alignments



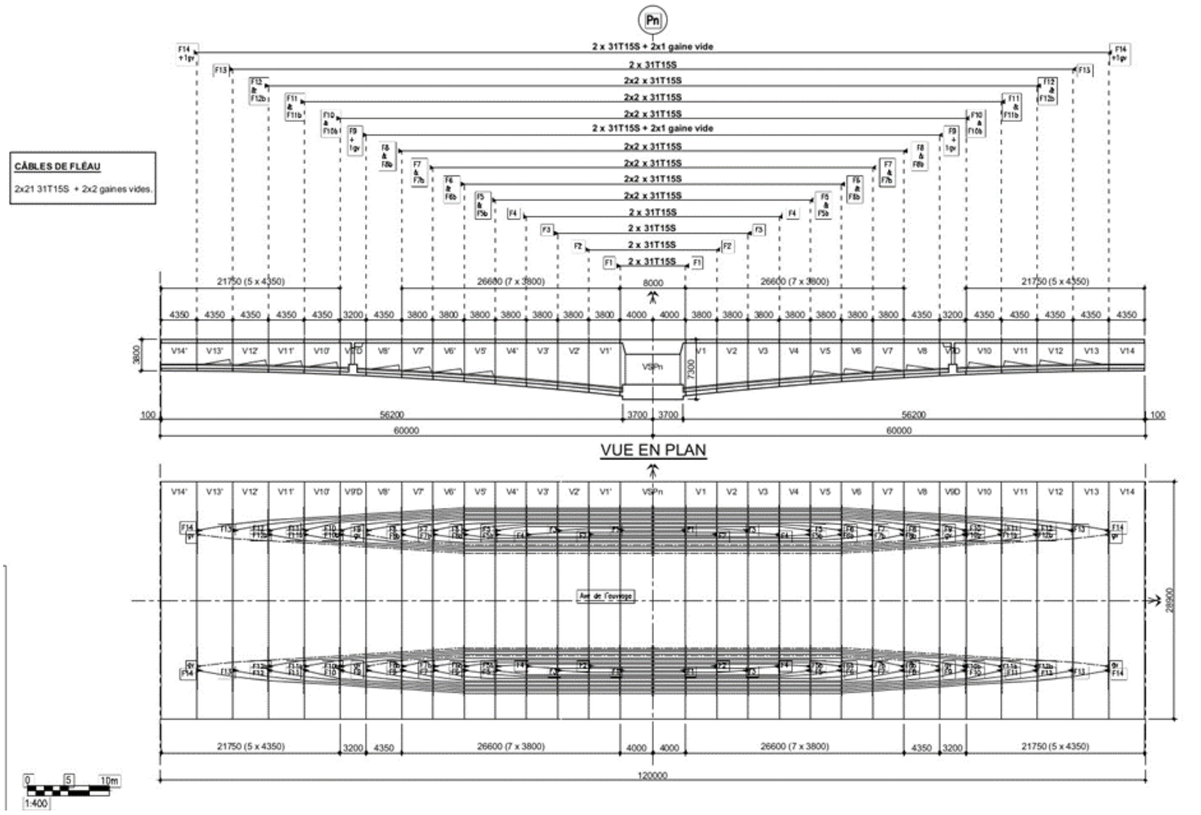
Bridge segments assembly with a sheath and post-tensioning tendons

The construction phase of the lifecycle is the phase during which the bridge is in successive states, from both the organic and the functional point of view, which are extremely different from the case in service. For instance, even in the case the concrete structure is poured on temporary shutters and scaffolds in its entirety as it would be mostly the case with the case selected, the mechanical model is different for dead loads and for circulation loads in view of the creeping phenomena under constant loads. In many cases, the bridge exhibits smaller safety margins under construction loads and modified mechanical models than under the case under operation and its own mechanical model. This is particularly the case with constructive methods like pushing girders or when temporary piling is necessary as for oblique portal frame bridges. The complexity of the construction phase must be approached previously from both the operational and functional viewpoints.

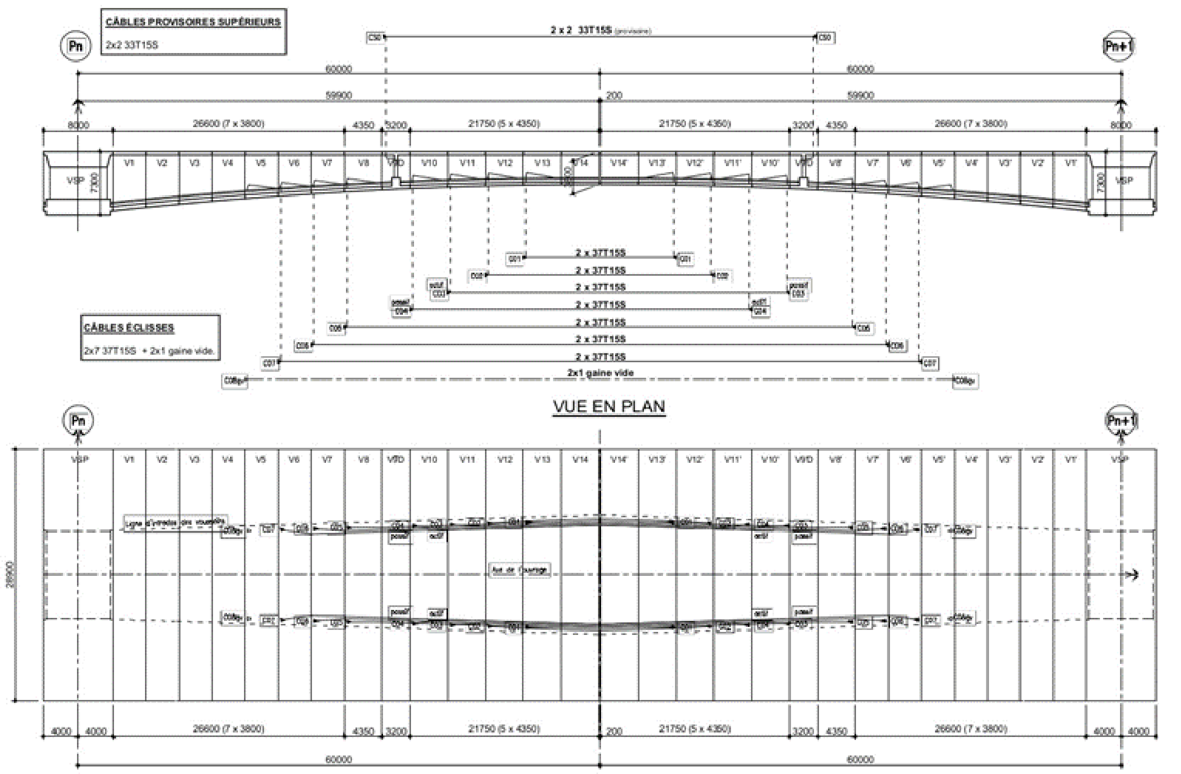
Hereafter is presented three post-tensioning systems designed for:

- Dead loads during segmental erection.
- Partial transfer of dead loads due to creeping.
- Traffic loads during operations. They are all installed at different phases of the construction.

Specificities of the construction phase

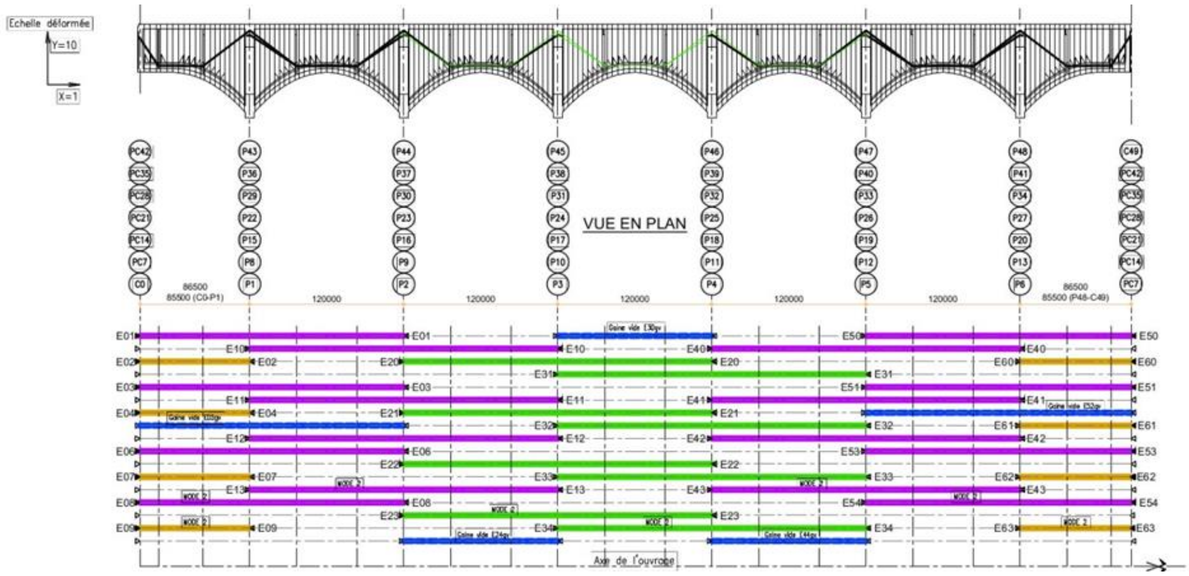


Plan and longitudinal view of post-tensioning cables for each segment erection



Plan and longitudinal view of post-tensioning cables for long-term creeping

Specificities of the construction phase



External post-tensioning cables for continuity in multiple spans bridges

In all these cases, the mechanical model should be evolving in parallel to the construction process and steps.

Specificities for bridges under renovation

These cases are not different. The process differs in that it should start, at the operational view step, by the needs to adjust to, or to start from the existing structures. The existing structures must be digitalised as it is the case of any physical environment. It has, of course, consequences in the operational, functional and organic viewpoints.

Specificities for maintenance and operation phase, or dismantling phase

Most of the time, these phases of the lifecycle introduce new needs and requirements at all three viewpoints and also introduce mobile structures and plants (special crane, or gantries, or nacelle supporting devices) enabling the maintenance organisation to inspect, audit and maintain the bridge.

3.3. Required entities

Introduction

The entities required for the project description according to the different views and domains are discussed in the sections below. For more details, they are indicated into the Excel sheet appendix.

Terrain level

Development

The digital terrain model is expected to be available with IFC 4. Further developments are required to cope with geology, built environment and all other features describing the physical context.

Elements included in the bridge project

Nevertheless, it is important to identify what is impacted by the bridge project and what is not. Therefore, elements below must be included in the bridge project (IFC-Bridge):

- Earthworks required for the bridge foundations.
- Earthworks acting directly on the bridge abutments.
- Mandatory works for the bridge erection.

Earthworks description and foundation are discussed in the section below on IFC-Bridge.

IFC Alignment level

Geodetic reference and infrastructure axis

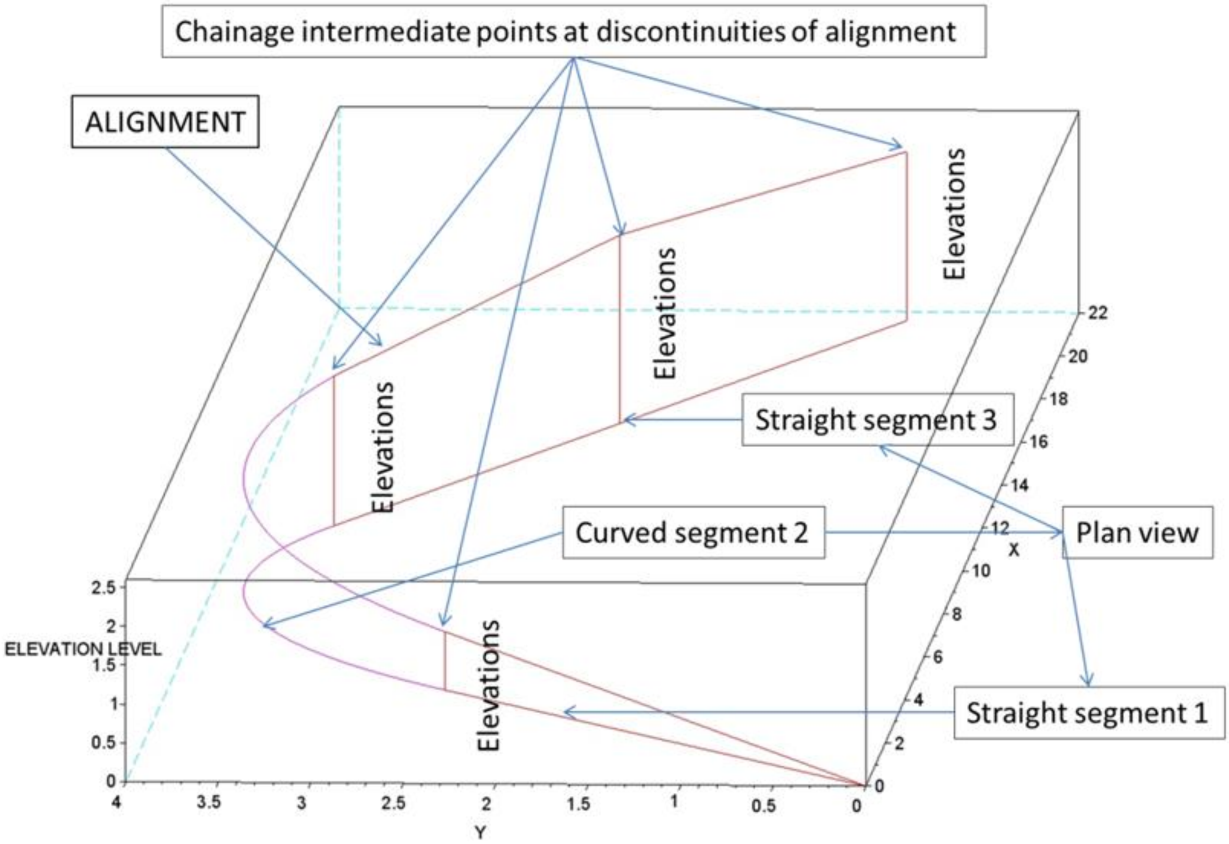
Geodetic reference and infrastructure axis are defined within this context:

Geodetic references	Geodetic references allow for different systems to be in use at different scales and positions. Particularly when long infrastructures linking different countries with distinct geodetic reference grids.
Infrastructure axes	Several infrastructure axes cover the axis of supported infrastructure (roads, rails, and other networks) and the one of all intersected networks (roads, rails, networks, rivers and waterways). They all support mathematical definitions or point by point. But mathematical definitions should never be degraded into point by point definitions.

Alignments

From a practical and site procedural point of view, alignments are defined in two features:

A plan view	Vertical projection on a 2D map with connecting points from one curve segment (straight line, clothoid, circles, etc.) to the next.
A longitudinal profile	Vertical view along the plan view alignment indicating elevations at the same connecting points or additional intermediate points with successive curved or linear segments.



Alignment from both plan view and elevation

IFC roads/rail/canal level **Entities**	On top of axis and reference grids inherited from IFC alignment there are: • Entities of traffic support lanes may be composed into transverse sections. • Entities defining the connections between circulating lanes and the bridge. Attached to these the concept of gauges to represent the supported traffic attached to each network is needed, be it supported traffic or intersected. All these elements are specific to a type of traffic. Therefore, entities must be defined in those domains.

3.3 Required entities

IFC bridge level	The IFC domain complements the supporting structures and its other ancillaries, all extension sets: - Alignment. - Roads. - Rail. - Other networks.
Entities in the organic architectural view	Below the entities used at the organic architectural view. Entities that should be developed are written in bold and underlined.

Entities	Description
IfcProject	IfcProject defines the representation context and the units in context.
IfcSite	IfcSite defines the position of the project. It also contains the project context, such as the Digital Terrain Model (remaining untouched by the project) and both the ways crossed and supported by the project.
IfcBridge	IfcBridge defines the structure position locally in relation to IfcSite. It contains the alignments linked to the bridge project (might be different from the supported way alignment).
IfcBridge Part	IfcBridgePart is either:
	- The deck. - The supports (piers and abutments). - The equipment (non-structural elements).
	They are associated to an alignment. They are constituted of more elementary parts. They contain all physical elements of works.
IfcGround	Foundations is the contacts between the ground and the bridge. IfcGround represents the fill and cut earthworks (resp. excavation and backfill). It is different from the Digital Terrain Model DTM.
	IfcGround represents the earthworks around abutments or the access roads.
IfcOpening	An excavation is like an IfcOpening in an IfcWall.
IfcWall	
IfcRelVoidsElement	An opening is inside an IfcGround. The relation is an IfcRelVoidsElement.
IfcRelFillsElement	When backfill is put back in place either in a previous excavation or on top of existing ground, the relationship is then IfcRelFillsElement.
	This procedure enables the piling works description, where piles: - Are poured in concrete in a previously excavated borehole. - Cap or a foundation slab or beam is constructed on top of a lean concrete, poured at the bottom of a larger excavation or trench.
	Concerning geometry, it is important to record the Boolean operations in the IFC entity:
	- Concatenation. - Segmentation. - Intersection.
	It is the same for other procedural geometry procedures.
IfcSystem	Post-tensioning strand systems are far more complex than the elements developed in IFC4. They constitute subsystems of the bridge system. Its complexity justifies introducing an IfcSystem to cover post-tensioning and other systems essential to the bridge operation. Those systems may concern:
	- The monitoring system. - The lighting system. - Etc.
	Post-tensioning systems call for items and elements are often used in:
	- Plumbing - Piping. - Electrical networks and ducts. - Tray and cable installation.
	Special entities cover:
	- Deviators. - Saddles. - Anchoring points.
	Internal and external cables. For bridges constructed in segments, it is usual to plan internal and external cables (continuity). Internal cables are segment and creeping cables.
IfcDuct	In the case of ducts, IfcDuct is threaded in by an IfcTendon and its remaining void later filled-in by an IfcGrout. The void is the internal volume of duct less the external volume of cable.

3.3 Required entities | IFC bridge level

Gauge element	A gauge element: • Simulates that a structure frees enough space for: – Placing something. – Letting vehicles pass under the bridge. – Etc. • Makes sure that there is enough volume at each anchoring point to carry out the tensioning operations.
Systems and equipment	Systems and equipment consist of linear elements. They are always defined by reference to an alignment.
Reinforcement description	The reinforcement description is in the same state of an insufficient coverage by IFC4, even for ordinary bridges. Indeed, IFC4 does not explicit if the rebars take the place of concrete. It isn't sure that the *IfcRelAggregates* is sufficient from that regards. From a construction procedure point of view, reinforcement might be prefabricated. It is important to study the feasibility of such prefabrication and handling. When it is not prefabricated, the erection of the rebars might be problematic and the placement bar by bar must be simulated. The possibility of letting fresh concrete to flow and be vibrated is important. One must also be able to plan for covering bars.

3.4. Prestressing system

Prestressed, pre-tensioned and post-tensioned concrete

Note

This section is based on contributions of engineers of contractors' staff and design offices involved daily in bridge:

- Design.
- Construction method.
- Site production.

The focus is put on their needs and expectations based on BIM capabilities and manufacturing industries use of digital mock-ups.

Definition	
Prestressed concrete	Is concrete that has had internal stresses introduced to counteract, to the degree desired, the tensile stresses that is imposed in service. The stress is usually imposed by tendons of individual hard-drawn wires, cables of hard-drawn wires, or bars of high strength alloy steel.
	Prestressing may be achieved either by pre-tensioning or by post-tensioning.
Pre-tensioning	To pretension concrete, the steel is first tensioned in a frame or between anchorages external to the member. The concrete is then cast around it. After the concrete has developed sufficient strength, the tension is slowly released from the frame or anchorage to transfer the stress to the concrete to which the tendons have by that time become bonded. The force is transmitted to the concrete over a certain distance from each end of a member known as the transfer length.
Post-tensioning	Post-tensioned concrete is made by casting concrete that contains ducts through which tendons can be threaded. An alternative is to cast the concrete around tendons that are greased or encased in a plastic sleeve. When the concrete has sufficient strength, the tendons are tensioned by means of portable jacks. The load is transmitted to the concrete through permanent anchorages embedded in the concrete at the ends of the tendons. Ducts are usually grouted later or filled with grease to protect the tendons against corrosion. In some applications the post-tensioning tendons are run alongside the concrete member. One advantage of post-tensioning is that it permits using tendons that are curved or draped (this can be achieved in pre-tensioning but not so easily). Post-tensioning can be done on the jobsite without any need of heavy temporary anchorages. Anchorages are needed for each tendon, however, which is a significant cost item.
Internal prestressing	Internal prestressing is characterized by the fact that the prestressing tendons are entirely placed inside the concrete structure.
External prestressing	External prestressing is characterized by the following features: • The prestressing tendons are placed on the outside of the physical cross section (mostly in concrete) of the structure. • The forces exerted by the prestressing tendons are only transferred to the structure at the anchorages and at the deviators. • No bond is present between the tendon and the structure, except at anchorage and deflector locations.

Advantages

Compared to internal bonded post-tensioning, the external prestressing has the following advantages:

- The external prestressing application can be combined with a broad range of construction materials: steel, timber, concrete, composite structures and plastic materials. This can considerably widen the scope of the post-tensioning applications.
- Due to the tendons' location and accessibility, monitoring and maintenance can be readily carried out compared to internal, bonded prestressing.
- Due to the absence of bond, it is possible to restress, destress and exchange any external prestressing cable. Provided that the structural detailing allows for these actions.
- Improves the concrete placing due to the absence of tendons in the webs.
- Improvement of conditions for tendon installation which can take place independently from the concrete works.
- Reduction of friction losses. Because the unintentional angular changes, known as wobble, are practically eliminated. Furthermore, with the use of a polyethylene sheathing the friction coefficient is drastically reduced compared to internal bonded prestressing using corrugated metal ducts.

- External prestressing tendons can easily and without major cost implication be designed to be replaceable, re-stressable and de-stressable.
- Generally, the webs can be thinner, resulting in an overall lighter structure.
- Strengthening capabilities.

As an overall result, better concrete quality can be obtained leading to a more durable structure.

Examples

Precast cantilever segments typical features

The figure below presents a perspective of a typical balanced cantilever segment. It shows various features of the concrete shapes, post-tensioning tendon locations and post-tensioning anchorage locations.

The principal types of post-tensioning tendons in these bridges are:

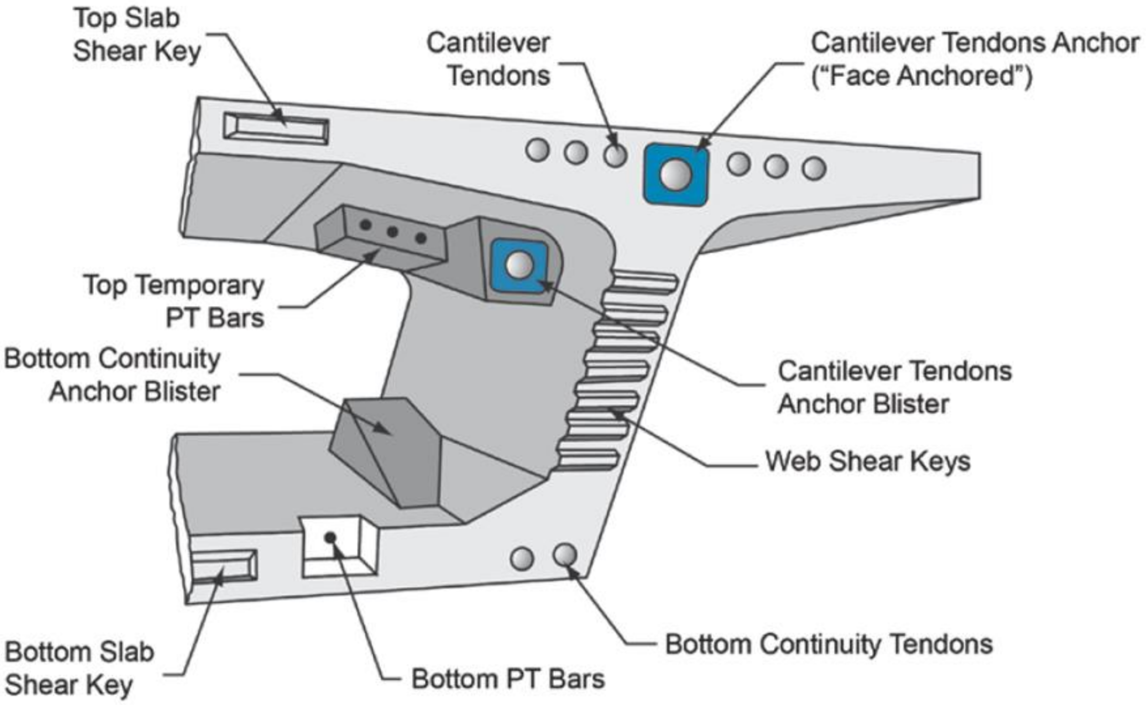
- Cantilever.
- Continuity tendons.

The cantilever tendons are stressed to resist:

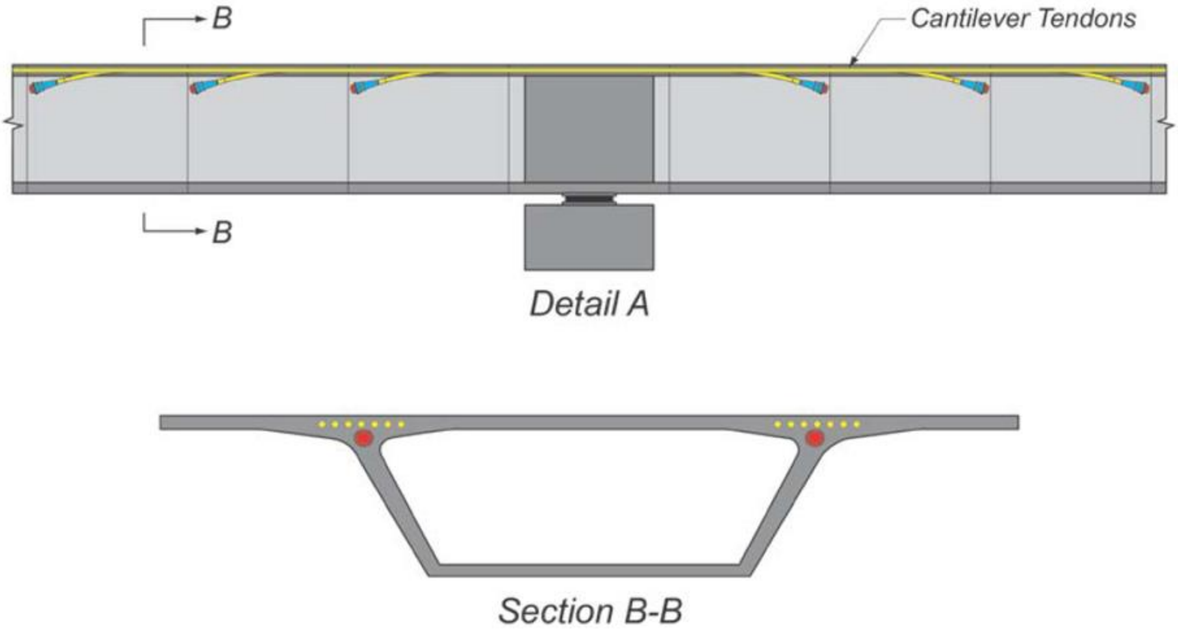
- The cantilever dead load moments during construction.
- The effects of superimposed dead loads and live loads on the continuous bridge.

Continuity tendons are stressed to join adjacent cantilevers and resist positive moments from:

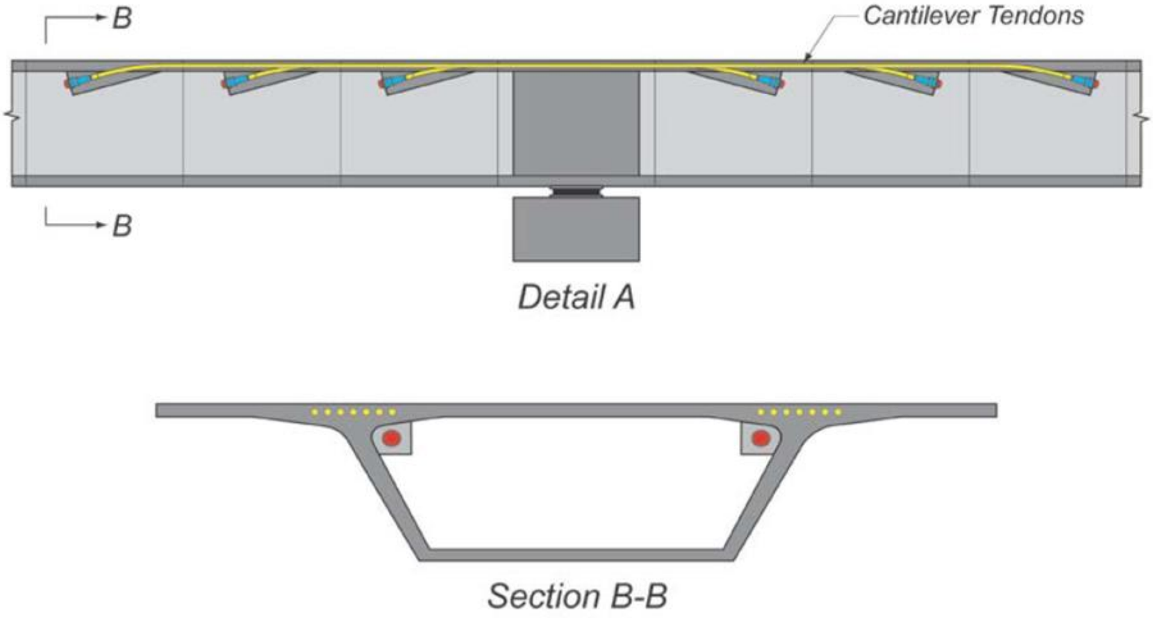
- Superimposed dead loads.
- Creep redistribution.
- Live loads.



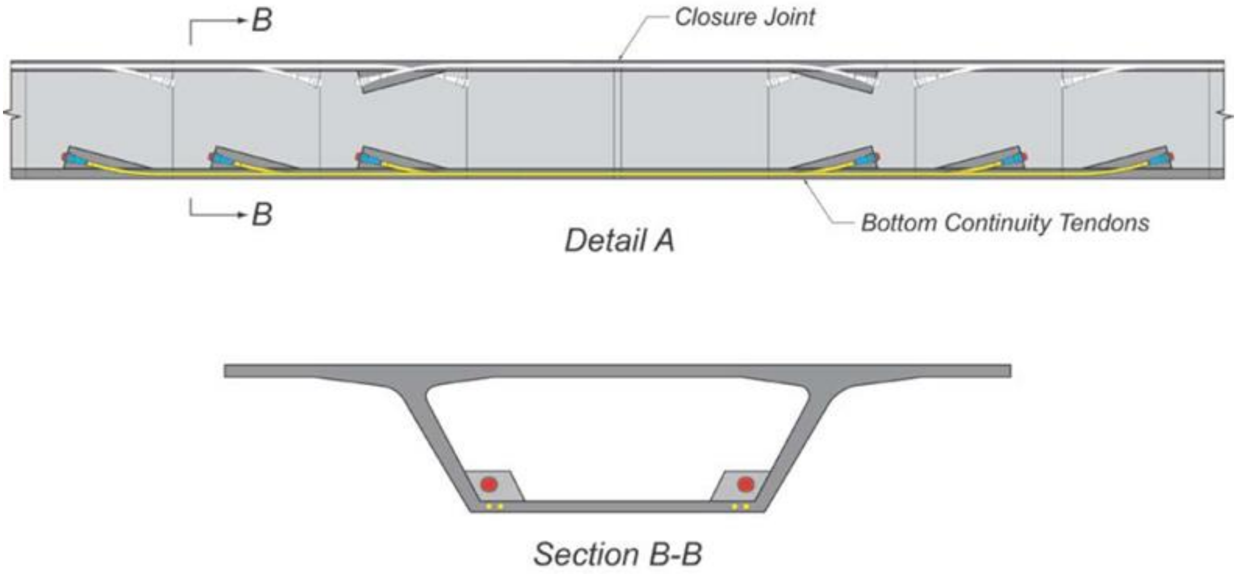
Typical balanced cantilever segment. Source FHWA-hif12026.pdf



Cantilever post-tensioning tendons anchored on end faces. Source FHWA-hif12026.pdf



Cantilever post-tensioning tendons anchored on blisters. Source FHWA-hif12026.pdf



Bottom continuity tendons for balanced cantilever construction. Source FHWA-hif12026.pdf

3.4 Prestressing system

Prestressed concrete design process

Viewpoints

The MINnD project adopt the engineering systems framework as the global reference framework for developing engineering activities.

In such a framework, the designed and built structure is considered according to the following viewpoints:

Operational view	Stating WHY the structure is needed. It is the description of the structure in what stakeholders expect it to deliver or to impact (or not impact) their own processes.
Functional view	Stating WHAT the structure should deliver. It is the description of what the structure should deliver or perform to satisfy the stakeholders expectations.
Organic view	Stating HOW the structure should be made to deliver or perform the functions described in the functional view.

Below the prestressed concrete design process summary:

View	Domain	Questions	Analysis	Keywords	Examples	Expected performances
Operational	Interactions with the concrete structure.	Why?	Analysis of the concrete structure in interaction with the prestressing system considered as a black box.	Uses, scenarios for operations and maintenance.	To counteract tensile stresses imposed to the concrete structure supporting the service loads.	Needs.
Functional	Theoretical functions performed by the prestressing system.	What to do?	Functions theoretical description.	Functions.	To develop compressive forces, to protect against corrosion.	Requirements.
Organic	Hardware components.	How to do?	Analysis the prestressing system constitution.	Organic component.	Tendon, anchorage, deviator, sheath, jack, wedges.	

Prestressed concrete decks and precast segments

The bridge deck is often concerned by prestressed concrete:

- It supports directly the traffic.
- It has to endure high value bending moments and then tensile stresses.

In addition, prestressed concrete decks are more and more erected by using precast segments. Prestressing connects the segments together during construction. It is applied to other bridge parts, such as high piers.

Detailing the design process for a typical deck

Operational view and its needs

The tensile strength of concrete is only about 10% of its compressive strength. As a result, plain concrete members are likely to crack when subject to bending moment. Reinforcing steel is embedded in the concrete members to counteract tensile forces which plain concrete cannot resist. Reinforcing is dimensioned assuming that:

- The concrete tensile zone carries no load.
- Tensile stresses resist only by the reinforcing bars. The resulting reinforced concrete members may crack, but it can effectively carry the tensile loads.

Although cracks occur in reinforced concrete. The cracks are normally very small and well distributed. Cracks in reinforced concrete can reduce long-term durability. Introducing a means of pre-compressing the tensile zones of concrete members to:

- Offsets anticipated tensile stresses.
- Produces more durable concrete bridges.

- Reduces or eliminates cracking.

The functional view and its requirements

The prestressing function places the concrete structure under compression in the regions where load causes tensile stress. Tension caused by applied loads first have to cancel the compression induced by the prestressing before it can crack the concrete.

By placing the prestressing low in the simple-span beam and high in the cantilever beam, compression is induced in the tension zones. It creates upward camber.

Prestressing by post-tensioning involves installing and stressing prestressing strand or bar tendons after the concrete has cured and reached a minimum compressive strength for that transfer.

Regarding new bridges crossing over large body of water or transport routes, one solution to reduce the construction impact is to:

- Erect them by an overhead launching gantry.
- Use a precast-segmental balanced cantilever method of construction.

This induces that the deck is made of precast segments assembled by prestressing systems.

Stressing calculations

To ensure that the correct force is applied to each tendon, calculations:

- Account for losses (friction, wobble, anchor set and anchor friction) along the length of a tendon.
- Estimate the elongation as a check against the gauge pressure on the jack.

Key information is developed for subsequent tendon stressing. Example: jacking force or gauge pressure and anticipated elongation.

Friction losses along the length of the tendon, between anchorages, are attributed to two sources:

The first of these frictional losses is the result of the expected friction between tendon and duct as the profile of the tendon changes. These losses are related to angular changes in the tendon profile. The friction coefficient (μ) is defined to predict losses of this type. The value of the friction coefficient is a function of the duct material.

Predicting frictional losses along the length of a tendon using the friction coefficient alone does not typically correlate well with field results. Wobble (k) is another coefficient of frictional loss. It accounts for additional friction between strand and duct as a result of unintended duct misalignments.

The equation relating tendon force at a point along the length of a tendon, as a function of friction and wobble determined from the formula:

P(x) = Pjack exp (-(· · +kx))

Where:

x	Distance along length of tendon where tendon force is being evaluated.
P(x)	Force in tendon at a distance x along tendon length.
Pjack	Stressing force at anchorage.
μ	Friction coefficient.
K	Wobble coefficient.
θ	Sum of all angular changes (absolute values) from stressing end to point x.

Various parameters for calculation of tendon forces and elongations are defined as follows:

- Length of tendon.
- Assumed area of tendon.
- Modulus of Elasticity assumed.
- Coefficient of friction between tendon and duct (μ).
- Wobble coefficient (k).
- Distance from jacking end to location of interest (x).
- Accumulated angle of curvature to point (μ (x)).
- Length of portion of tendon between two points 'I' and 'j', xij.
- Anchor seating loss.
- Friction losses in anchor (%).
- Friction losses in jack (%).
- Pjack = force at the jack.

3.4 Prestressing system | Detailing the design process for a typical deck

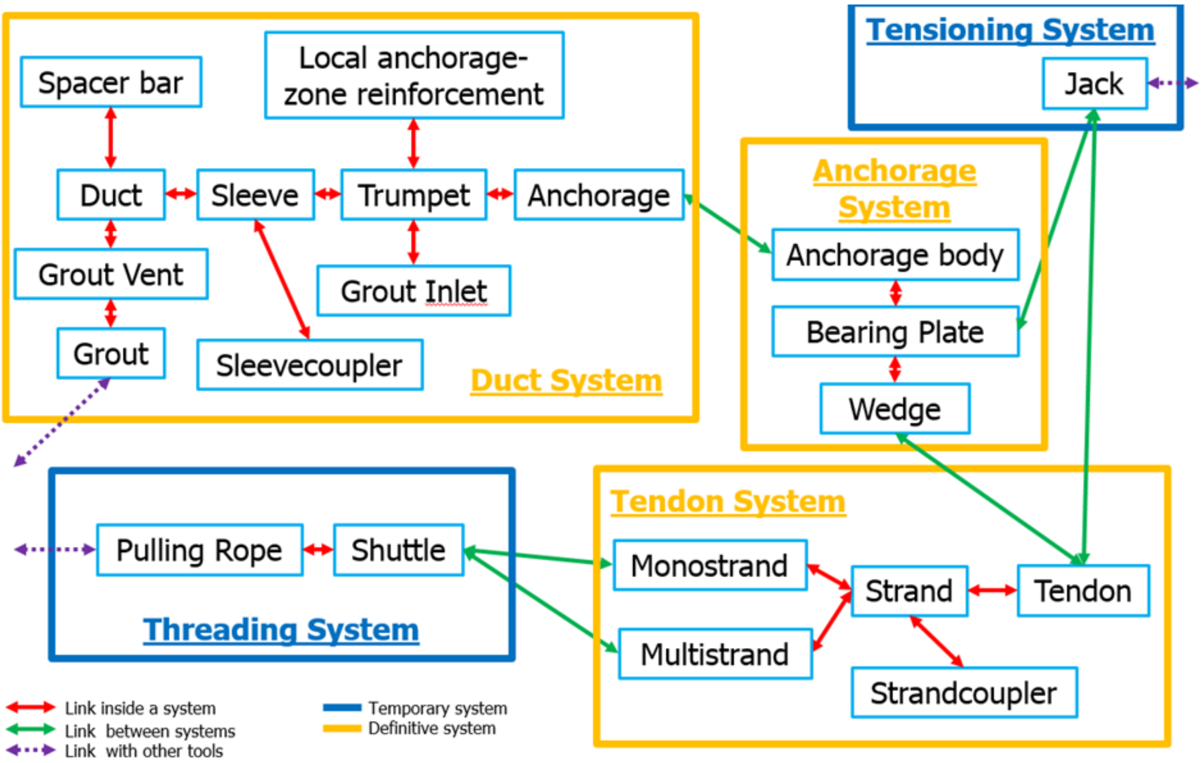
System approach

Definition

The system approach is a decomposition:

- Using both spatial (organic) and functional approaches.
- Considering lifecycle constraints.

Main prestressing system	
Anchorage	For specific volumes to carry out the tensioning.
Duct	For IFC-alignment.
Tendon	For IFC-alignment.
	Axis offset tolerance 11 % with duct axis.
Installation system	
Threading system.	
Tensioning system.	
External components	
Deviator.	
Reinforcement.	



Prestressing systems–Manufactured components

Legend

Yellow subsystem	Definitive sub-system of the prestressing system.
Blue subsystem	Temporary sub-system used for the prestressing setting.
Red arrow	Link between objects constituting a subsystem.
Green arrow	Link between objects of different sub-system.
Violet arrow	Link between an object and an external object (i.e. crane, handling device, etc.).

3.4 Prestressing system | Detailing the design process for a typical deck

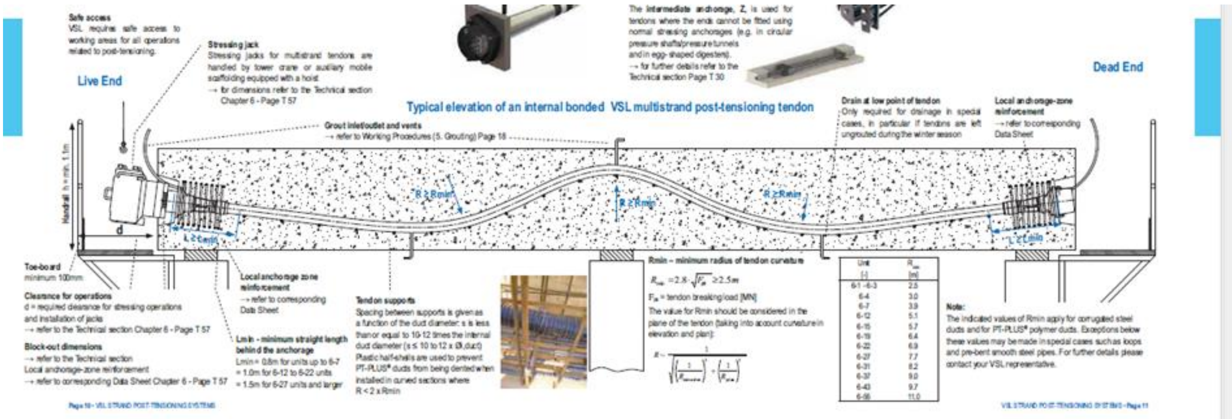
Organic view and its requirements

The components of post-tensioning systems are manufactured products. For instance:

- Tendons.
- Strands.
- Anchorages (active, dead, coupling).
- Ducts.
- Vents.
- Deviators.

Concrete segments are cast industrially on site. Components included in the concrete are specific ones related to the bridge project. For instance:

- Concrete segments.
- Tendon spacers.
- Blisters.
- Additional reinforcements.



Safe access
VSL requires safe access to working areas for all operations related to post-tensioning.

Stressing jack
Stressing jacks for multistrand tendons are handled by tower crane or auxiliary mobile scaffolding equipped with a hoist.
→ for dimensions refer to the Technical section Chapter 6 - Page T 57

The **intermediate anchorage, Z,** is used for tendons where the ends cannot be fitted using normal stressing anchorages (e.g. in circular pressure shafts/pressure tunnels and in egg-shaped digesters).
→ for further details refer to the Technical section Page T 30

Typical elevation of an internal bonded VSL multistrand post-tensioning tendon

Grout inlet/outlet and vents
→ refer to Working Procedures (5. Grouting) Page 18

Drain at low point of tendon
Only required for drainage in special cases, in particular if tendons are left ungrouted during the winter season

Local anchorage-zone reinforcement
→ refer to corresponding Data Sheet

Toe-board
minimum 100mm

Clearance for operations
d = required clearance for stressing operations and installation of jacks
→ refer to the Technical section Chapter 6 - Page T 57

Block-out dimensions
→ refer to the Technical section
Local anchorage-zone reinforcement
→ refer to corresponding Data Sheet Chapter 6 - Page T 57

Local anchorage zone reinforcement
→ refer to corresponding Data Sheet

Lmin - minimum straight length behind the anchorage
Lmin = 0.8m for units up to 6-7
= 1.0m for 6-12 to 6-22 units
= 1.5m for 6-27 units and larger

Tendon supports
Spacing between supports is given as a function of the duct diameter: s is less than or equal to 10-12 times the internal duct diameter ($s \leq 10$ to $12 \times Ø_i$,duct)
Plastic half-shells are used to prevent PT-PLUS® ducts from being dented when installed in curved sections where R < 2 x Rmin

Rmin – minimum radius of tendon curvature

$$R_{min} = 2.8 \cdot \sqrt{F_{pk}} \geq 2.5\,m$$

F_{pk} = tendon breaking load [MN]
The value for Rmin should be considered in the plane of the tendon (taking into account curvature in elevation and plan):

$$R \sim \frac{1}{\sqrt{\left(\frac{1}{R_{elevation}}\right)^2 + \left(\frac{1}{R_{plan}}\right)^2}}$$

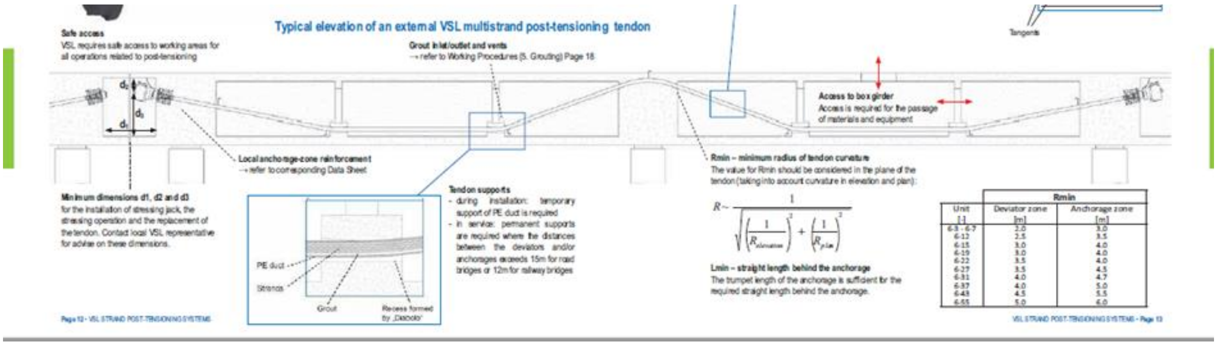
Unit [-]	R_{min} [m]
6-1 - 6-3	2.5
6-4	3.0
6-7	3.9
6-12	5.1
6-15	5.7
6-19	6.4
6-22	6.9
6-27	7.7
6-31	8.2
6-37	9.0
6-43	9.7
6-55	11.0

Note:
The indicated values of Rmin apply for corrugated steel ducts and for PT-PLUS® polymer ducts. Exceptions below these values may be made in special cases such as loops and pre-bent smooth steel pipes. For further details please contact your VSL representative.

Page 10 - VSL STRAND POST-TENSIONING SYSTEMS

VSL STRAND POST-TENSIONING SYSTEMS - Page 11

VSL post-tensioning solutions



Typical elevation of an external VSL multistrand post-tensioning tendon

Safe access
VSL requires safe access to working areas for all operations related to post-tensioning

Grout inlet/outlet and vents
→ refer to Working Procedures (5. Grouting) Page 18

Access to box girder
Access is required for the passage of materials and equipment

Local anchorage-zone reinforcement
→ refer to corresponding Data Sheet

Minimum dimensions d1, d2 and d3
for the installation of stressing jack, the stressing operation and the replacement of the tendon. Contact local VSL representative for advise on these dimensions.

Tendon supports
- during installation: temporary support of PE duct is required
- in service: permanent supports are required where the distances between the deviators and/or anchorages exceeds 15m for road bridges or 12m for railway bridges

Rmin – minimum radius of tendon curvature
The value for Rmin should be considered in the plane of the tendon (taking into account curvature in elevation and plan):

$$R \sim \frac{1}{\sqrt{\left(\frac{1}{R_{elevation}}\right)^2 + \left(\frac{1}{R_{plan}}\right)^2}}$$

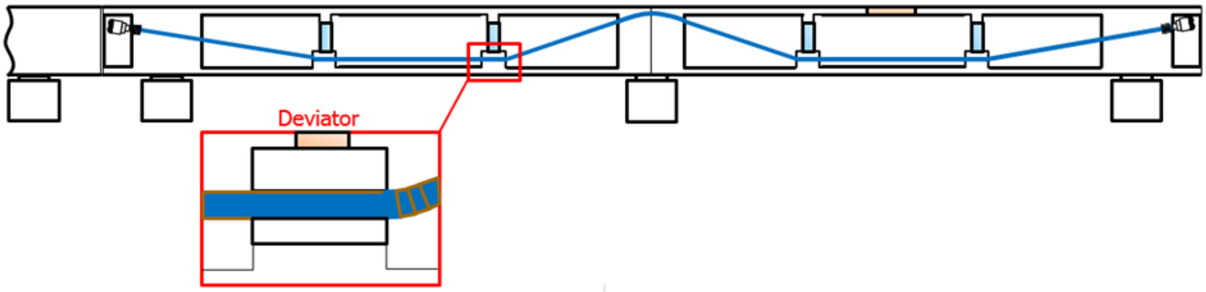
Lmin – straight length behind the anchorage
The trumpet length of the anchorage is sufficient for the required straight length behind the anchorage.

Unit [-]	Rmin Deviator zone [m]	Rmin Anchorage zone [m]
6-3 - 6-7	2.0	3.0
6-12	2.5	3.5
6-15	3.0	4.0
6-19	3.0	4.0
6-22	3.5	4.0
6-27	3.5	4.5
6-31	4.0	4.7
6-37	4.0	5.0
6-43	4.5	5.5
6-55	5.0	6.0

Page 12 - VSL STRAND POST-TENSIONING SYSTEMS

VSL STRAND POST-TENSIONING SYSTEMS - Page 13

Detailing for post-tensioned



Prestressing systems–None manufactured components

Examples of Object properties

Each object must be defined by a set of specific properties.

Duct	Brand
	Model
	Material
	Diameter
	Thickness
	Max Lenght
	Min Radius
	Weight / m

Tendon	
	Brand
	Model
	Material
	Diameter
	Max Lenght
	Min Radius
	Weight / m

Strand	
	Monostrand / Multistrand
	Toron number
	Int / Ext
	Coating
	Diameter
	Max Lenght
	Min Radius
	Weight / m
	Applied strenght

Examples of object properties

Breakdown structures

Spatial breakdown structure: the organic view

Spatial structure is composed of:

Bridge	IfcBridge
Deck	IfcBridgePart

Each deck segment is a building element aggregating the tendon conduits, the reinforcements, etc. that it hosted.

System breakdown structure: the functional view

Components associated to a given tendon are related to a specific prestressing system that means:

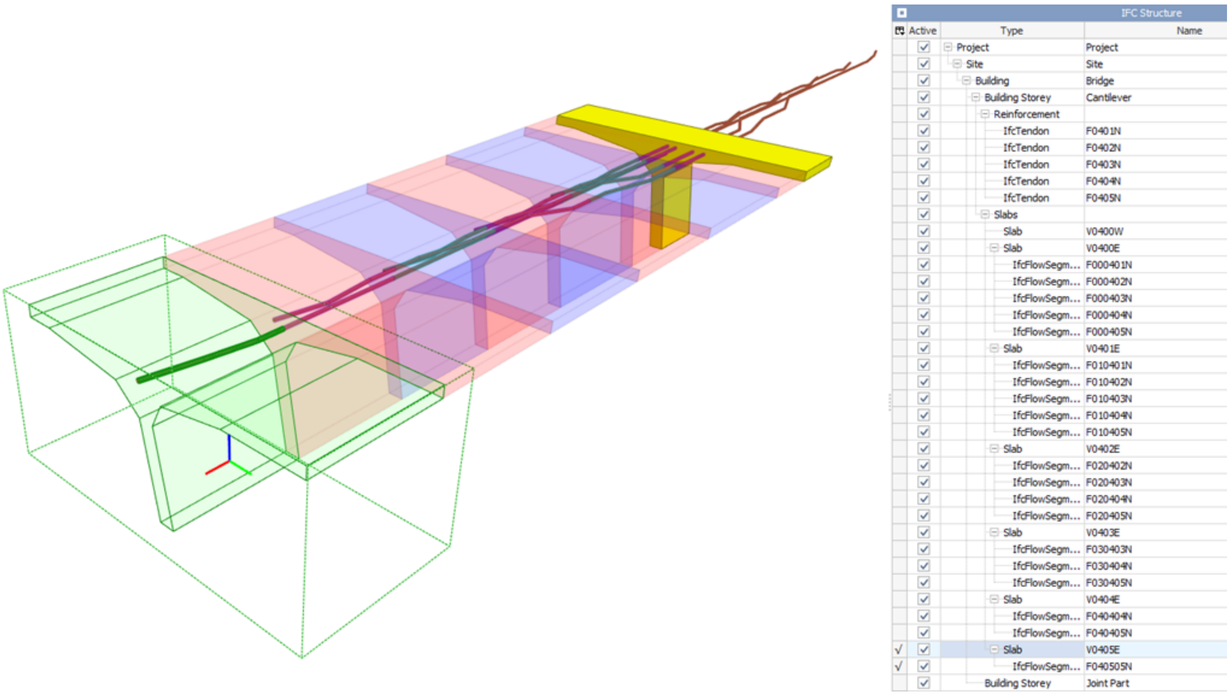
- Tendon.
- Tendon conduit.
- Tendon anchorage.
- Etc.

Below the description of IfcDistributionSystem and IfcPrestressingSystem networks.

Network	**Description**
IfcDistributionSystem	Network designed to receive, store, maintain, distribute, or control the flow of a distribution media.
	Example: a heating hot water system that con-sists of a pump, a tank, and an interconnected piping system for distributing hot water to terminals [www.buildingsmart-tech.org/ifc/IFC4.]
IfcPrestressingSystem	Network designed to receive, store, maintain, distribute, or control the prestressing of a tendon.
	The tendon conduits installed in the concrete segments control the position of the tendon in order to distribute appropriately the provided prestressing.
	The tendon tensioning is provided by the anchorages.
	The tendon conduits right positioning is driven by the tendon spacers.
	The prestressing system includes the tendon and all the components defining its interface with the pre-stressed concrete structure.

In addition, all these components are contained in IfcBridgeParts aggregated in the IfcBridgePart deck.

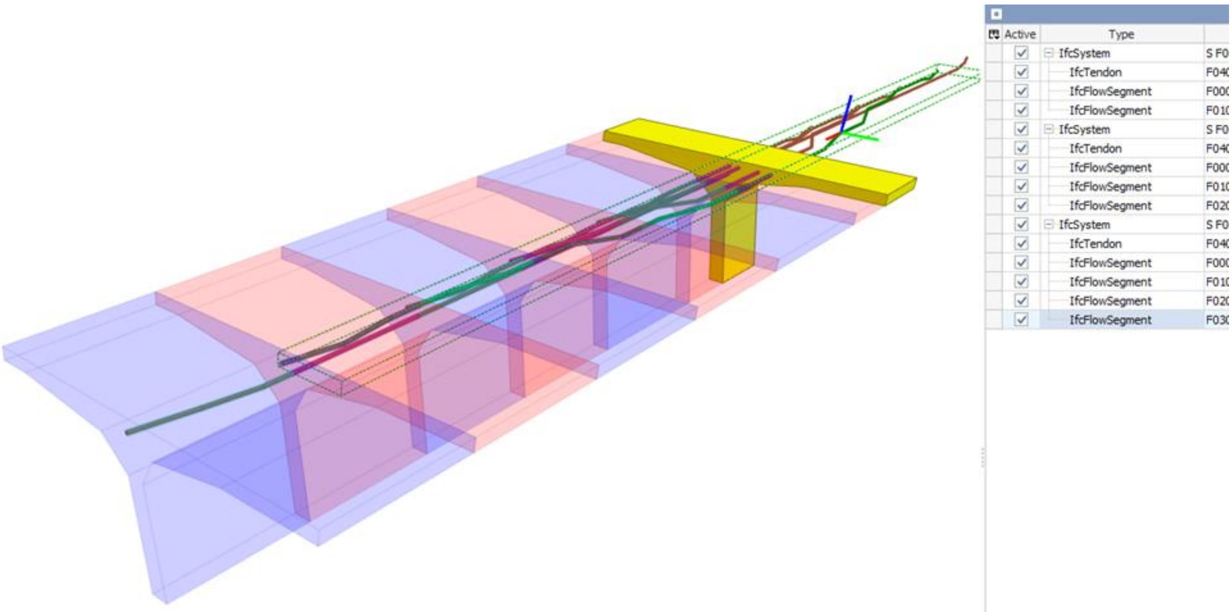
See the pictures below.



IFC Structure

	Active	Type	Name
	☑	Project	Project
	☑	Site	Site
	☑	Building	Bridge
	☑	Building Storey	Cantilever
	☑	Reinforcement	
	☑	IfcTendon	F0401N
	☑	IfcTendon	F0402N
	☑	IfcTendon	F0403N
	☑	IfcTendon	F0404N
	☑	IfcTendon	F0405N
	☑	Slabs	
	☑	Slab	V0400W
	☑	Slab	V0400E
	☑	IfcFlowSegm...	F000401N
	☑	IfcFlowSegm...	F000402N
	☑	IfcFlowSegm...	F000403N
	☑	IfcFlowSegm...	F000404N
	☑	IfcFlowSegm...	F000405N
	☑	Slab	V0401E
	☑	IfcFlowSegm...	F010401N
	☑	IfcFlowSegm...	F010402N
	☑	IfcFlowSegm...	F010403N
	☑	IfcFlowSegm...	F010404N
	☑	IfcFlowSegm...	F010405N
	☑	Slab	V0402E
	☑	IfcFlowSegm...	F020402N
	☑	IfcFlowSegm...	F020403N
	☑	IfcFlowSegm...	F020404N
	☑	IfcFlowSegm...	F020405N
	☑	Slab	V0403E
	☑	IfcFlowSegm...	F030403N
	☑	IfcFlowSegm...	F030404N
	☑	IfcFlowSegm...	F030405N
	☑	Slab	V0404E
	☑	IfcFlowSegm...	F040404N
	☑	IfcFlowSegm...	F040405N
√	☑	Slab	V0405E
√	☑	IfcFlowSegm...	F040505N
	☑	Building Storey	Joint Part

The structure point of view



	Active	Type	
	☑	IfcSystem	S F0
	☑	IfcTendon	F04
	☑	IfcFlowSegment	F00
	☑	IfcFlowSegment	F01
	☑	IfcSystem	S F0
	☑	IfcTendon	F04
	☑	IfcFlowSegment	F00
	☑	IfcFlowSegment	F01
	☑	IfcFlowSegment	F02
	☑	IfcSystem	S F0
	☑	IfcTendon	F04
	☑	IfcFlowSegment	F00
	☑	IfcFlowSegment	F01
	☑	IfcFlowSegment	F02
	☑	IfcFlowSegment	F03

The system point of view

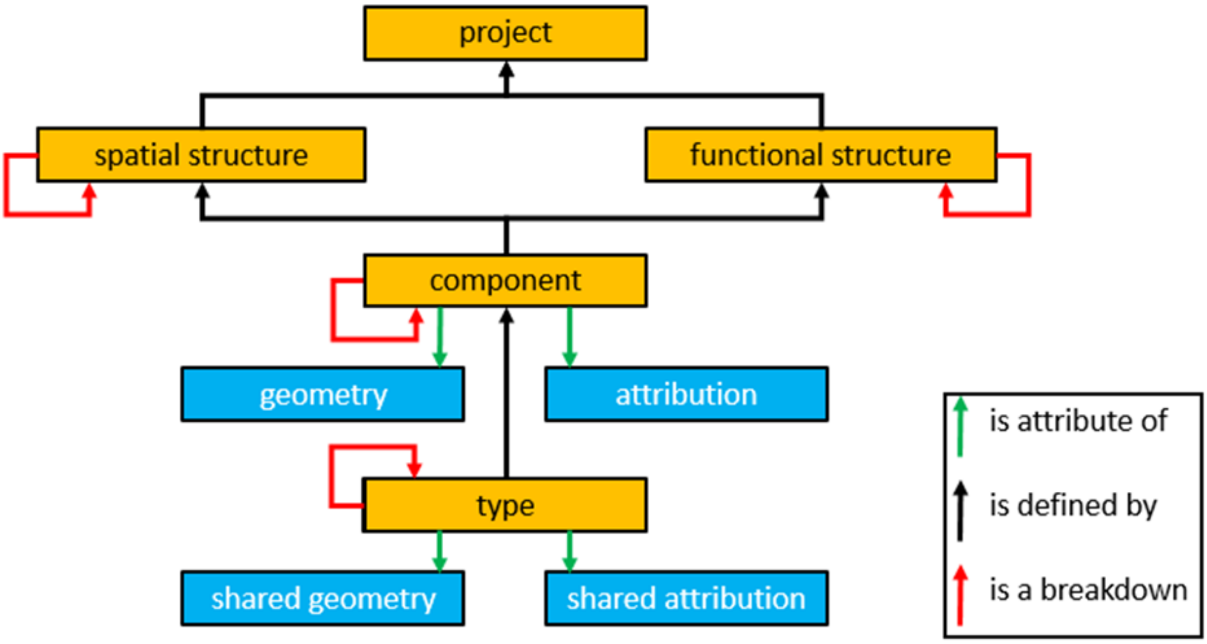
4. PROSPECTIVE ADAPTATION FOR IFC CONCEPTUAL MODEL

Three types of breakdown structure are being considered

A bridge, like any infrastructure project can be broken down into different ways. Following the general IFC modelling principles, three main types of breakdown structure are being considered:

- Spatial breakdown structure.
- Functional breakdown structure.
- Product breakdown structure.

Those breakdown structures are presented below.



Breakdown structures in IFC

Spatial and product structure refer to the organic view detailed under § 2.3 above.

IFC modelling principles

The IFC modelling principles are indicated below.

Hierarchical spatial breakdown structure

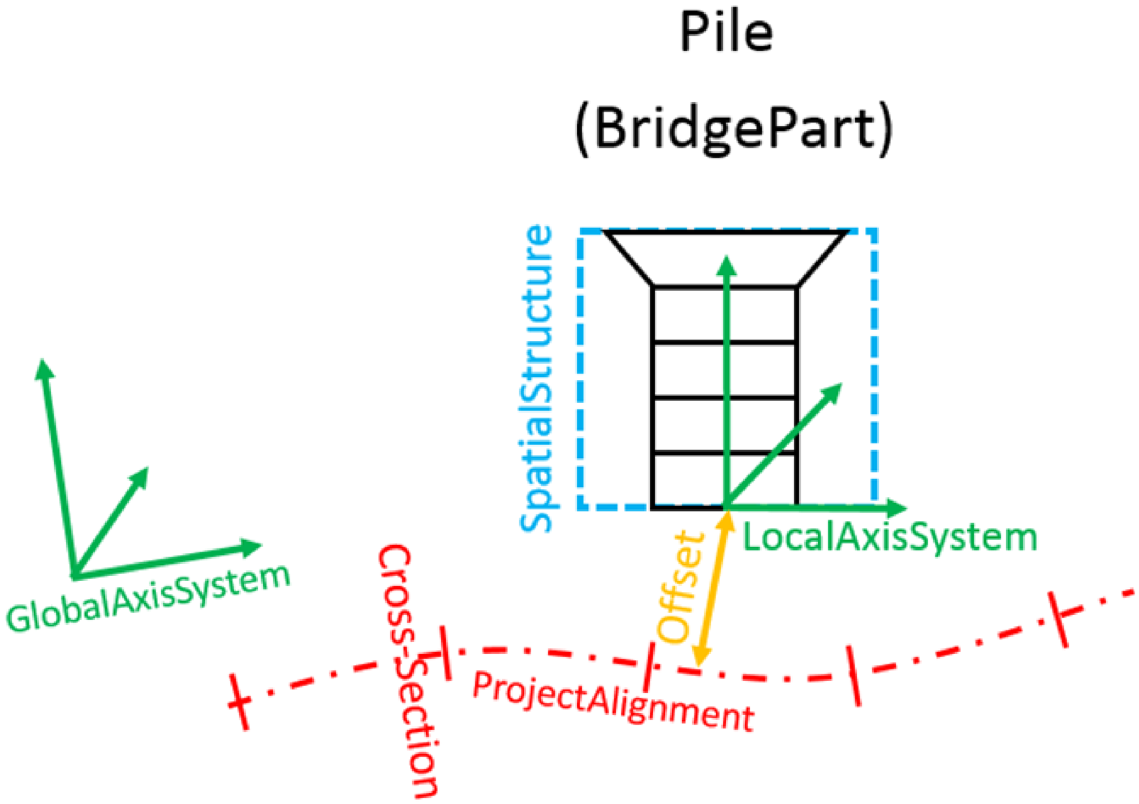
Each infrastructure project shall have a hierarchical spatial breakdown structure (Project/Site/Bridge/Bridge Part) with at least one level of hierarchy.

All components are assigned to the spatial project structure

- All physical components (Slab/Beam/Column) shall be assigned to a certain level of the spatial project structure. Any element can be assigned:
  - Once and directly to a certain level of the spatial structure.
  - Indirectly through an aggregation relationship.

Breaking down of the spatial hierarchical structure

The spatial hierarchical structure (also referred as the organic view) breaks down the infrastructure (in this example, a bridge) in physical elements or components. Those elements/components are fully described from an organic point of view. Each component possesses a local geometry positioned in the local axis system of the spatial structure as seen below. Additional properties can be associated to each component.



Local axis system of a spatial structure

Grouping relationships

Product/Physical elements also belong to the functional structure (Structural/Drainage/Signage/Prestressing) via grouping relationships (nonhierarchical).

The functional structure organizes this grouping so the components can fully describe the infrastructure from its functional viewpoint, thus making it a performing system.

Derivation of components

Components may have their geometry and properties derived **from types**.

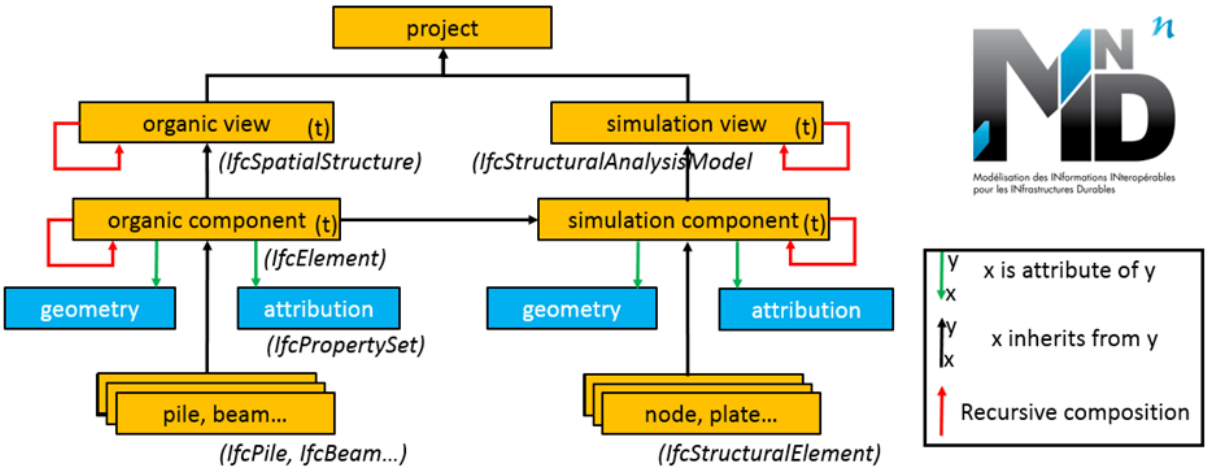
Example
'Drain' is defined as a type but is installed in different locations of the model as a component.

All these may have dynamic association of properties (RelDefinesByProperties) to complement the statically defined object attributes.

Association of concepts

Concepts can be associated in different ways:

When a component is attached to one unique function…	… the previous breakdown structure in IFC figure represents the simplest way to associate these concepts.
When a single component is associated to more than one function…	… it may be more advantageous to adopt the figure below because it is more general. In this instance, we have substituted 'simulation' to 'function' as the functional studies cannot in this case be carried out without going into simulation with data about simulation components to be transferred to simulation software.
When many physical components support one function…	



Conceptual model with 'Works to do and Works to be delivered' - Theoretical Proposal

Association of the simulation model to the organic view

In case there are changes, the simulation model must be associated to the organic view **to maintain consistency between the organic view and the IFC representation**.

Simulation software packages

Simulation software packages can be based:

On bar models	The geometry of bar models is driven by the position of physical nodes connecting components. These nodes, bars, shells should be represented in IFC.
On finite element method (FEM)	The geometry of FEM models is driven by these nodes, but also by the decomposition of the component into several calculation elements according to considerations of numerical constraints. This decomposition has no separate physical existence in the real world. It is not represented in the organic view and IFC representation.

Difficulty

The main difficulty of this association is the complexity introduced by the relationship between organic components and simulation model components that must be incorporated.

Advantages

However, associating a simulation model to the organic view has several advantages:

Advantages
The functional structure is very clear because it is supported by its own components or elements.
The functional structure may be developed ahead of the organic structure. This is in line with the design process: • From the theoretical function first (what to do or the question to solve). • To the identification of its practical or concrete way of implementing (how to do or the selected solution).
The field of the functional structure is mainly supported by scientific knowledge, rather universal whereas the field of the organic structure is mainly supported by technical knowledge (technologies, materials, industrial background, etc.). In this way: • The description of the organic structure is rather industrial and depends on the context. • The description of the functional structure is mostly universal and depends on science.
Several organic solutions may exist to fulfil the functions and it is easier to keep intact the functional structure and to change only the organic structure whenever another solution or a modification is necessary.
The simulations are mostly based on theoretical models. Those models are similar to the functional structure. In this way, the transfer to a simulation software is easier by making this structure more visible, clear and completely described with its own set of elements.
For structures or elements whose geometry is very different loaded as opposed to unloaded (and this the case for flexible structures or for cables), the real geometry in place is so different from the theoretical geometry when installing the components and transferring progressively the loads that the geometry of the organic model should be strongly linked to the functional model possibly including its behavioural laws.

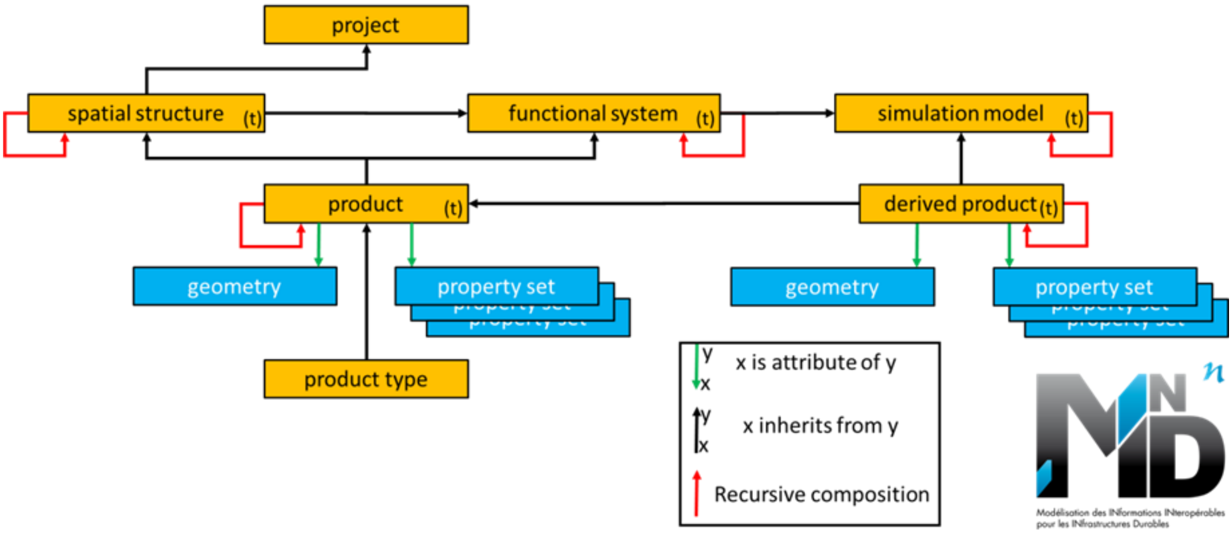
Association of the simulation model to the organic view

A new representation

This way of doing the association is presently very different from the way it is currently done. Indeed, in the breakdown structures in IFC, the component carries:

- The organic description.
- The functional view.

It is therefore proposed to use another schema where an additional simulation model is introduced as a 'plug-in' as shown below.



Conceptual model with 'Works to do and Works to be delivered'–Practical Proposal

Current situation

For now, the existing IFC entities are kept as they are.

Supplements are being developed in order to make the existing IFC structure compatible with the simulation model used by simulation software packages.

Practical cases

Existing IFC set using

Below are practical cases where the existing IFC model is used:

Cases where the existing IFC set is used
When an H beam is simply supported on a column, one creates from a mechanical point of view a support element (IfcRelConnects) that figures the fact that the beam transfers its own weight on the column, does not allow the movement of the contact point downwards but allows the movements either upwards or in a horizontal plane at the point of contact. The organic element may possibly be a sliding support with Teflon or nothing at all.
A bridge deck may be theoretically defined first by a simple IfcBeam (one axis from a to b with an elasticity modulus and a modulus of inertia) and later in the engineering process as a slab and several I beams taken out from a steel manufacturer.

Incomplete IFC model

Beyond prestressing tendons already considered before, below are cases where IFC model is incomplete:

Cases when the IFC model is incomplete
Drainage
Drainage happens when the gutter on both sides of the roadway collects rainwater and discharges it through drains in sewer pipes. Drains and pipes are physical components, but the gutter is most of the time made of the corner between the footpath and the pavement with a minimum longitudinal slope. The theoretical component or model for water carriers (a line, a slope, a section depending of the flow) may eventually become a gutter, a drain or a sewer.
This theoretical component may be of a different type when one considers a free surface flow or a pressurised flow.

Cases when the IFC model is incomplete
Organic components may serve several purposes. In general, safety barriers like steel railings are only considered as such. However, unless specially designed therefore, concrete separators may also act as water barriers, wanted or not. These water barriers should be figured as a functional element.
Stay Cables and Suspension Cables
Their geometry is highly driven by their tension and the local applied loads. This requires specific structural analysis software. Regarding the IFC model, what is expected is the geometry of the bridge delivered at the end of the construction, the key parameters of the cables including their length at free stress, and the envelope of the displacements of the cables in order to design appropriately the components connected to the cables.
The cables geometry is necessary for the design studies result.

Suspension bridges and cable-stayed bridges

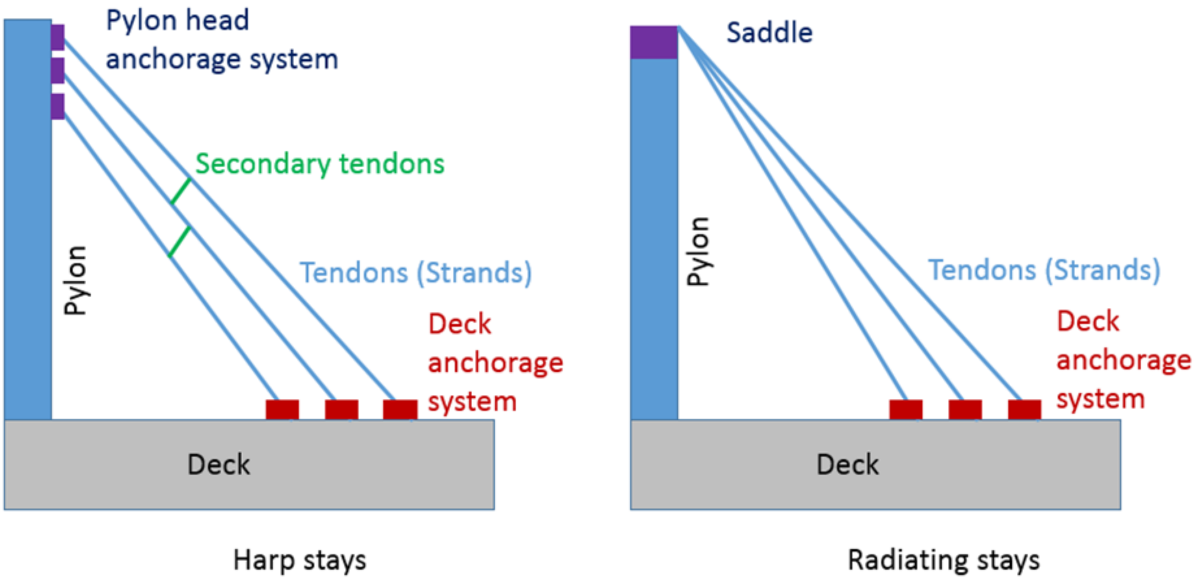
For the present work dedicated to bridges, we examine with more details the cables for suspension bridges or cable-stayed bridges. These types of bridges are:

- Flexible to a large extent.
- Sufficiently large for having real geometries during construction phases. Those geometries are very different from the nominal geometry which is obtained at the completion stage. It is necessary to separate the functional structure and the organic structure (the geometries of the components differ or vary over time and construction phases) with strong links expressing the deformation under evolving loads. It is thus necessary to include at least as a "plug-in" the simulation model as proposed.

Generally, the geometry control of a bridge structure during its construction is driven by a specific modelling software package including:

- Creep and shrinkage of the concrete.
- Relaxation of the cables.
- Appropriate modelling of stay cables and suspension cables.
- Components installation according to the construction calendar.

Due to the large deflection of this kind of structure, this is mandatory, because the owner expects a given geometry.



Different types of Cable stay bridge

5. IFC BRIDGE INPUTS FOR NUMERICAL ANALYSIS

5.1. Introduction

Relation between the IFC file and the structural analysis software

The design of a bridge is strongly related with the numerical analysis of its structure. This critical link must be translated in the IFC format by defining a clear relation between the IFC file and the structural analysis software.

This relation must :

- Be easily manageable by the user.
- Allow frequent mutual data exchanges, both from the IFC to the software and from the software to the IFC.

Data needed for the numerical computation

The structural software must find in the IFC file all data needed for the numerical computation.

Element of the bridge

An element of the bridge is defined by an entity IfcStructuralItem. This element is spatially described by an entity IfcBuildingElement which is contained in another entity called IfcSpatialStructureElement.

Twin entity

A twin entity:

- Is associated to this element.
- Contains all mechanical and geometrical data necessary to process a mechanical computation.

Data aggregation

All the data is grouped into the IfcStructuralAnalysisModel (IFC4, 7.7.3.6 IfcStructural AnalysisModel).

Requirements

◥ **Data must be exhaustive…**

Data must be exhaustive enough to enable the user to process computations on the structural element with different kinds of numerical models, from beam solutions to full 3D solutions.

◥ **… and use more recent and complex finite element models**

Moreover, it is important not to consider only classic reduced model theories, but to allow the use of more recent and complex finite element models.

In this document

In this document, data that must be filled in the IFC file and required by structural software are identified.

Based on the study of structural elements, the geometrical and mechanical data needed by the most relevant numerical model associated to the element's geometry are established.

We ensure that these data are comprehensive enough to enable the use of other finite element models.

5.2. Required data

Categories of data

We consider a structure (or a single component) submitted to a given loading. Data required by the user to process a mechanical computation with any given model can be classified into 3 categories:

- Geometry.
- Mechanical properties.
- Loads.

Geometry…

In geometry description, it is important to know the difference between a BIM model and a structural analysis model.

The BIM model describes the structure as it is delivered to the owner at the end of the construction whereas the structural analysis must:

- Analyze the behavior of the structure in operation and construction.
- Define the geometry of the component when it must be built and installed.

… in a BIM model

In a BIM model, the geometry of a component is defined by:

- The local geometry which is linked to a local axis system.
- The positioning of the local axis system regarding in the global axis system of the project. In a structural analysis model, the frame members or the finite elements are connected to joints or nodes, whose coordinates are directly given in the global axis system of the project.

…. in a structural analysis model

We describe hereafter the structural analysis model:

Structural analysis model
An IfcStructuralConnection is associated to a node described in a structural analysis model.
An IfcBoundaryCondition is associated to the node boundary conditions.
An IfcStructuralMember is associated to a frame member or a finite element. The connection with an IfcStructuralConnection is managed with IfcRelConnectsStructuralMember. The association with the corresponding IfcBuildingElement is managed with the relationship IfcRelAssignsToProduct.
Regarding IFC4, only curve members and surface members are available. Nevertheless, we must consider the large number of structural analysis software packages and their various capabilities, the key point is to describe the geometry envelope of the component we want to analyze and let the user choose the appropriate finite elements mesh, based on the key node definitions to describe appropriately the structure. You must be able to manage the geometry changes in the two views.

Current concerns

To conclude, what is today available concerns frame members described by a curve. Plate elements are also available. To these elements, a material could be associated with its properties (see IfcMaterial). To these elements, a profile could be associated with properties such as mass per length, cross section area, moments of inertia y, moments of inertia z. (SeeIfcProfileProperties).

The pending problem concerns prestressed concrete structures (see section 5.5 – Bridge prestressed beams).

Regarding finite element analysis software package, we should not exchange more and let the meshing procedure to the software.

Mechanical properties

The mechanical properties of all the sub-elements must then be given. Below is a non-exhaustive list of the properties that may be needed by the mechanical computation:

Sub elements	Mechanical properties
Elasticity	Young modulus
	Poisson's ratio
	Constitutive law
Plasticity	Hardening modulus
	Yield stress
	Traction limit, compression limit (e.g. for concrete)
	Any other property related to the plastic criteria
Creep	Properties depending on the law considered
Thermo-mechanics	Conductivity
	Temperatures
	Thermal expansion coefficient
Phasing	Date of casting (concrete)
	7-days/28-days strength
Dynamic	Mass
	Absorption

Load and boundary conditions

Load description

Description

The load description includes the following elements:

- Category: linear load surface load or volume load.
- Geometric description of the loaded area (according to the category).
- 3D direction of loading.
- Amplitude of loading.

In case of dynamic computation

In case of dynamic computation, the loaded area, direction and amplitude may vary with time.

Every time a mechanical computation is processed on an element/sub-element

Every time a mechanical computation is processed on an element/sub-element of the structure, the loads applied on this element/sub-element must be identified and described with the 4 items listed above.

Boundary conditions

Definition

The structure considered does not necessarily include the supports and even if it does, the boundary conditions can be represented in different ways. Therefore, the considered boundary conditions must be given as an input data. We suggest defining a boundary condition as follows:

- Surface defining the boundary.
- Degrees of freedom of the surface blocked by the boundary conditions.
- If needed: friction coefficient.

Boundary conditions

Translation for a numerical computation

Any numerical model should be able to accept and translate this general definition of a boundary condition for a numerical computation.

Current concerns

Today the IFC data exchange is limited to static and elastic loadings. But additions of new capabilities are not a key problem. The difficulty is more to be open to all the various Finite Element Analysis (FEA) software packages. Their assumptions and required data are different.

5.3. Metallic box Girder Bridge

Case study

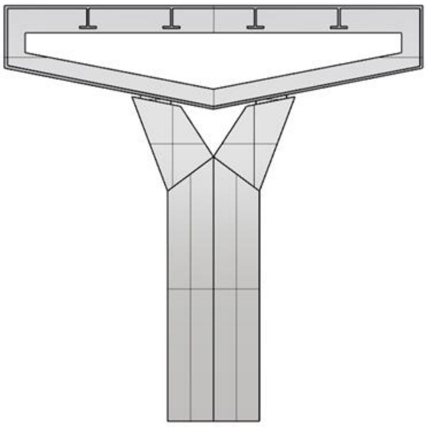
We consider the bridge presented in the figures below as a first example.

Description

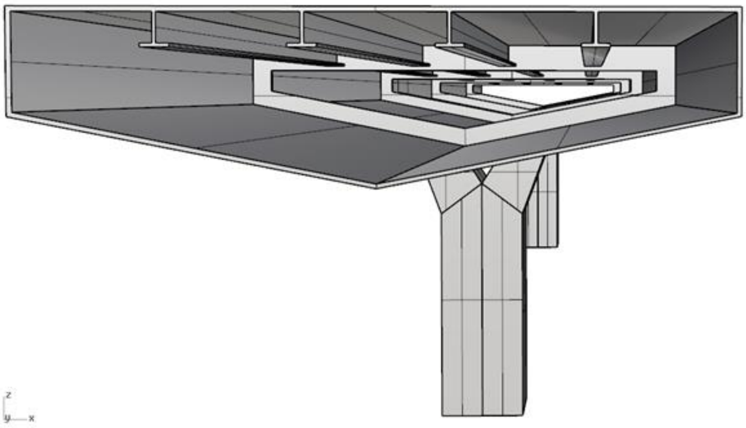
The bridge is defined by a metallic box stiffened:

- Transversally by 4 transversal stiffeners.
- Longitudinally by 4 longitudinal stiffeners.

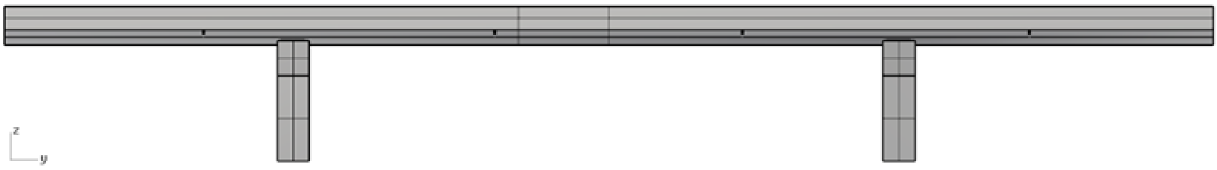
This deck rests on two piers. Bearings are placed between the metallic box and the piers.



Cross-sectional view of the bridge



3D view of the metallic box girder bridge



Longitudinal view of the bridge

Modelling

According to the slender geometry of the structure, a numerical computation using beam finite elements or shell elements seems to be relevant to model the bridge deck. Piers could be modelled by using either beam elements or full 3D elements for discontinuity regions.

We will therefore:

- Identify the geometric mechanical and load data required by mechanical computations.
- Enable the use of the most relevant numerical models for each component.

Components

The following components can therefore be distinguished in the description of this bridge:

Components	
Deck	**Piers**
Panels	Columns
Webs	Bearings
Flanges	
Longitudinal stiffeners	
Transversal stiffeners	

This kind of component geometry is already supported by:

- IfcStructuralSurfaceMember.
- IfcStructuralCurveMember.

Geometric data

The deck is basically composed of a shell and stiffeners. According to the Eurocode 3 (dedicated to metallic structures), buckling must be checked on each panel of the deck box. The box considered here is composed of 5 panels.

Component	Expected geometric data
Panel	Linear section definition
	Thickness
	Longitudinal length
	Web/Flange status according to EC3
Longitudinal stiffeners	Definition line
	Thickness
	Longitudinal length
	Distance between each stiffener
	Reference to the stiffened panel
Transversal stiffeners	Section geometry
	Thickness
	Distance between each stiffener
Columns	3D geometry
Bearings	Section geometry
	Thickness

Mechanical data

Mechanical properties of each component must be given according to the computations considered (elastic, elastoplastic, dynamic, phasing, etc.).

The list given for each element below tries to be exhaustive. The user then may choose to use only part of these properties according to the modelling and constitutive law considered for each material.

Example
Concrete can be modelled by: • Considering a simple isotropic elastic perfectly plastic constitutive behavior. • Using more complex anisotropic laws with damage parameters.

In most cases, an isotropic Von-Mises elastoplastic criterion is considered for steel.

	Expected mechanical data		
	Steel components	**Concrete components (piles)**	**Bearings**
Elastic	- Young modulus. - Poisson's ratio.	- Young modulus. - Poisson's ratio. - Creep/Shrinkage parameters.	- Global stiffness (6 components). - Sliding directions if any. - Hinge axes if any.
Elastoplastic	Either: - Yield stress. - Hardening modulus. Or: - Steel grade with reference to a standard.	Either: - Traction limit. - Compression limit. - Damage parameters. Or: - Concrete grade with reference to a standard.	- Friction coefficients for sliding bearings.

Load and boundary conditions data

General load and boundary condition description as defined in section 5.3 "Load and boundary conditions".

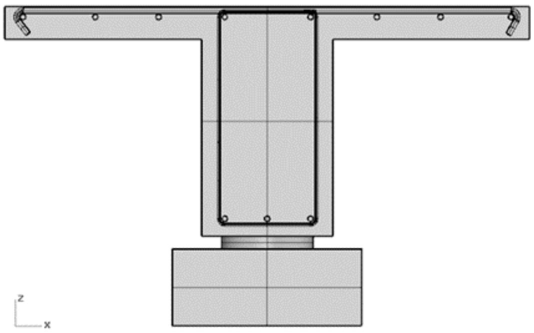
5.4. Reinforced Concrete Beam

Case study

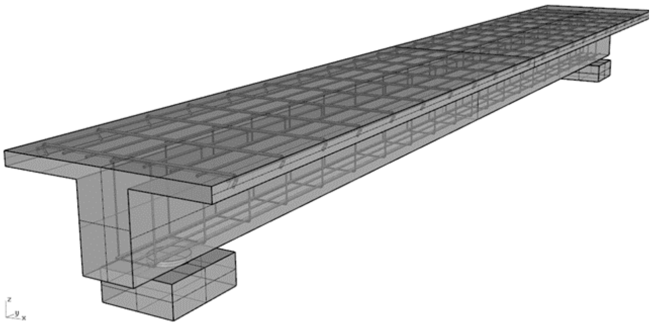
Description

We consider the Reinforced Concrete (RC) T-beam described in the figures below.

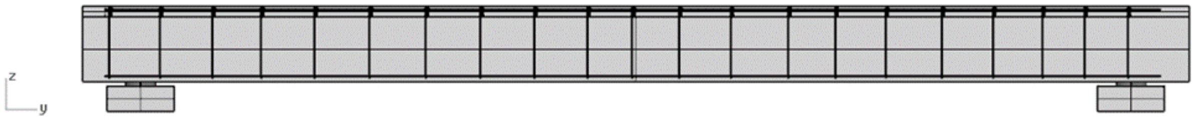
The beam rests at each end on an abutment. The T-beam is reinforced by steel rebars. Longitudinal rebars and transversal frame rebars are placed as described.



Transversal view of the RC beam



3D view of the RC beam



Longitudinal view of the RC beam

Modelling

The geometry of the structure suggests the use of a beam model to compute the mechanical response of the beam. However, rebars represent a numerical complexity that cannot be considered by every beam model. The data mentioned in the IFC-bridge file should therefore allow the user to use different numerical solutions. The four following solutions are identified:

- 1D beam finite element for a homogenized material 'concrete + steel rebars'.
- 1D beam finite element for concrete + 1D bar finite elements for steel rebars.
- 3D finite elements for a homogenized material 'concrete + steel rebars'.
- 3D finite elements for the concrete body and 2D homogenized membranes for steel reinforcement.

Components

The following components are taken into consideration.

Components	
Beam	**Piers**
Concrete body	Columns
Transversal frame rebars	Bearings
Longitudinal rebars	

Geometric data

The geometric description should encompass the descriptions of both concrete and steel rebars. In our case, the description of concrete is quite simple since it consists of an extruded section and two cubic abutments. The geometric description of bearings connecting abutments to the concrete beam must also be given.

The geometric description of rebars depends on the numerical solution considered. Given that some solutions may model steel rebars without using homogenized solutions, it is recommended to describe the real 3D geometric distribution of rebars in the concrete body. These data should enable the user willing to homogenize rebars to compute a posteriori the properties of its homogenized material.

Component	Expected geometric data
Concrete body	Section geometry
	Longitudinal length
Transversal frame rebars	Definition line
	Diameter
Longitudinal frame rebars	Definition line
	Diameter
Columns	3D geometry
Bearings	Section geometry
	Thickness

Developments about this requirement have been developed in IFC4. However, they need to be tested (see IfcSurfaceReinforcementArea).

Mechanical data

Many constitutive laws can be considered for concrete. Therefore, mechanical data for concrete is given according to the considered law. Without going further in detail, we here just mentioned the classic Young modulus, Poisson's ratio and traction and compression limits. An alternate simple though efficient way is to refer to a specific grade in a given standard.

	Expected mechanical data		
	Concrete body	**Steel rebars**	**Abutment**
Elastic	• Young modulus. • Poisson's ration.	• Young modulus.	• Young modulus. • Poisson's ratio.
Elastoplastic	• Traction limit. • Compression limit.	• Yield stress. • Hardening modulus.	--
Phasing	• Date of casting. • 7 days/28 days properties.	--	• Date of casting. • 7 days/28 days properties.

The data given in the table above are not exhaustive and are depending on the mechanical computations considered.

Phasing is typically a specific request for bridge analysis. It is not yet supported by IFC, but it could be easily supported, even by associating a work plan to the load cases (see IfcWorkPlan).

Load and boundary conditions data

General load and boundary condition description are defined in section 5.2 "Load and boundary conditions".

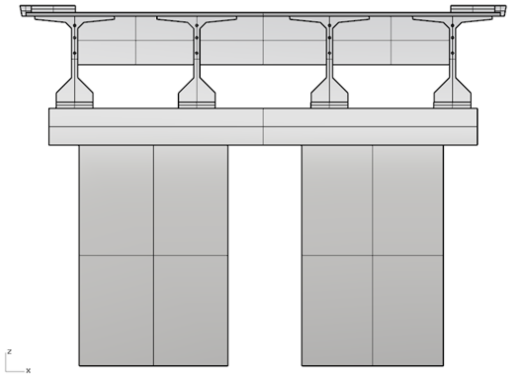
5.5. Bridge prestressed beams

Case study

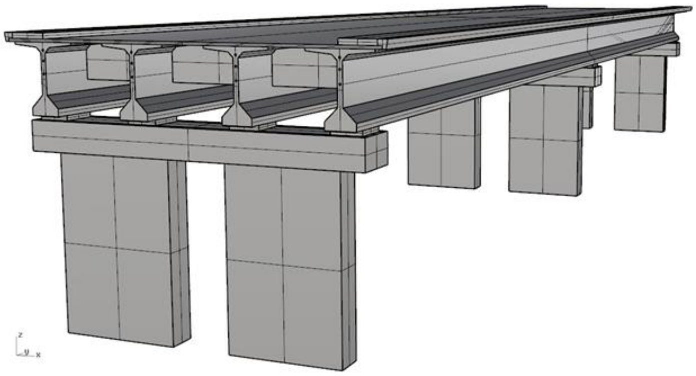
Description

We consider the prestressed-beam bridge described on figures below. The deck is composed of a concrete table supported by 4 concrete beams.

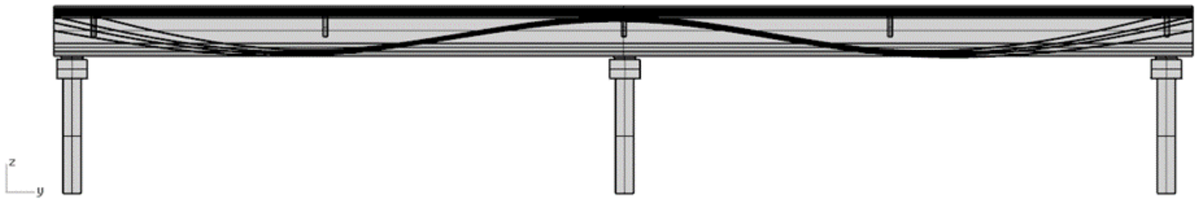
Each beam is prestressed by 4 tendons. The deck is supported by 3 piers and stiffened by 5 transversal beams placed above each pier and at the middle of each span.



Transversal view of the prestressed-beam bridge



3D view of the prestressed-beam bridge



Longitudinal view of the prestressed-beam bridge

5.5 Bridge prestressed beams | Case study

Description

Tendons are related to prestressing systems. Cables are related to stay cables or suspension cables and hangers.

Tendon geometry is a polyline. Its definition is related to the structural elements (beam, slab, etc.) hosting it. But it is not a structural element by itself. It modifies the mechanical properties of the structural element hosting it. In fact, the structural element is the addition of the structural beam and the tendons included into. On the contrary, a stay cable or a suspension cable is a structural element. The value of the tension along the tendon is depending on:

- The tension value at the active anchorage.
- The losses due to the friction with the hosting duct along the tendon.
- The losses due to the setback of wedges.
- The losses due to creep and shrinkage of hosting concrete.
- The relaxation of the tendon steel.

In consequence the tension is varying in space and time along the tendon. The action of the tendon is converted into loads applied to the hosting structure. This transformation of tensions in the tendon into loads applied to structural elements is carried out by the analysis software being depending on the finite element analysis used.

To follow the needs of the site when casting the bridge segments, it is recommended to describe the tendon conduits in the local axis system of the hosting building element, while to describe the tendon in the global axis system of the structural analysis model.

Modelling

In this example, the numerical complexity arises in the description of the prestressed tendons and their interaction with the concrete beams. This structure is modelled as follows:

- 1D beam finite elements for prestressed beams.
- 2D shell finite element for the concrete table.
- 3D finite elements for the piers and bearings.

It is worth mentioning that higher-order beam models enable the modelling of the system ‘4 beams + table’ with one single beam element. The spacers are then directly integrated into the stiffness matrix of the beam element by adding orthotropic components.

Components

The following components are taken into consideration.

Components	
Deck	**Piers**
Beams	Columns
Table	Stringers
Spacers	Bearings
Tendons	
Stay cables	

5.5 Bridge prestressed beams

Geometric data

For each component, here are the expected geometric data:

Component	Expected geometric data
Beam	Section geometry
	Length
Table	Thickness
	Length
Spaces	Section geometry
	Thickness
Prestressed Tendons	Definition line (center of the sheath)
	Radius
Columns	3D geometry
Stringers	3D geometry
Bearings	Section geometry
	Thickness

Mechanical data

Below are the expected mechanical data for each component:

	Expected mechanical data		
	Elastic	**Elastoplastic**	**Phasing**
Beams	Young modulus. Poisson ratio.	Traction limit. Compression limit.	Casting or installation date. 7/28 days properties.
Table	Young modulus. Poisson ratio.	Traction limit. Compression limit.	Casting date. 7/28 days properties.
Piers	Young modulus. Poisson ratio.	Traction limit. Compression limit.	Casting date. 7/28 days properties.
Prestressed tendons	Young modulus. Friction coefficient. Relaxation. Anchoring setbacks.	Yield stress. Hardening modulus.	Tensioning date.

Load and boundary conditions data

General load and boundary condition description as defined in section 5.2 “Load and boundary conditions”.

The active anchorage force must be given as an input load. The tension along the definition line of each tendon is changing over time. However, this must be computed by the finite element analysis software based on:

- The tendon properties.
- The initial tensioning force at the active anchorage.

5.6. Comments

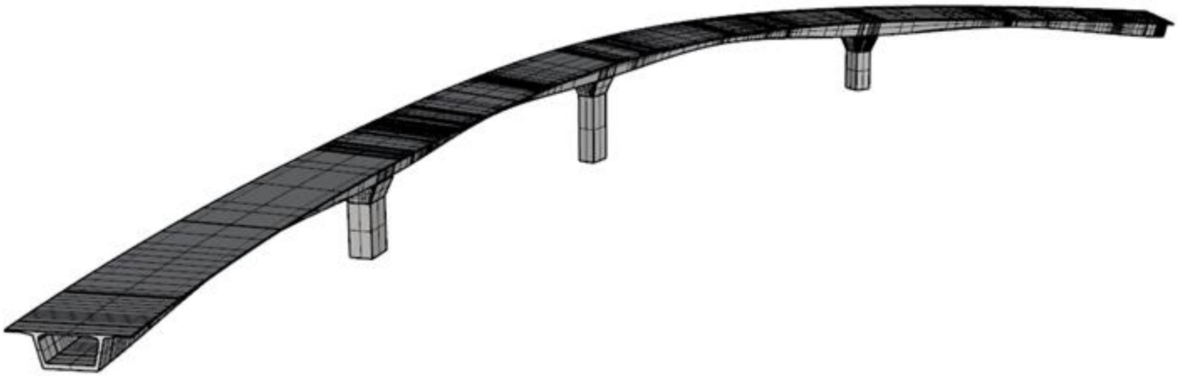
General description of a 3D slender structure

We suggest a relevant and simple way to describe a slender structure, in this case bridge decks. A slender structure that can be defined from:

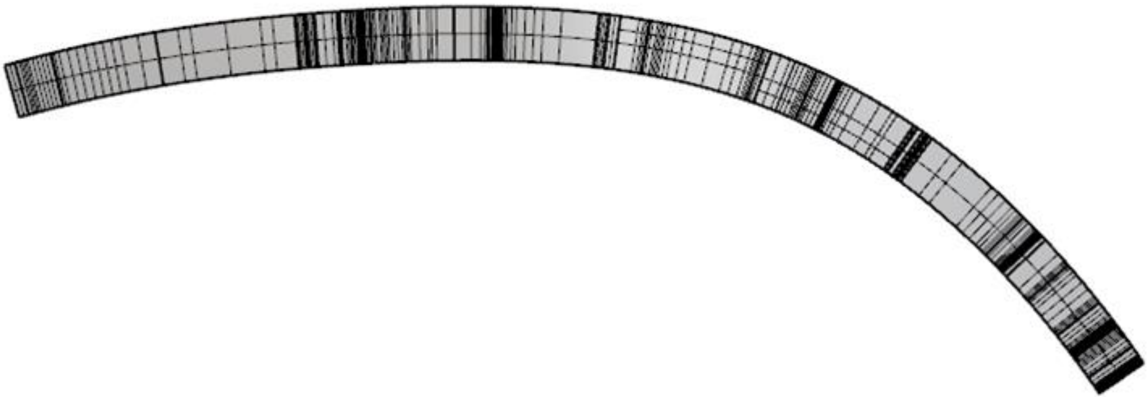
- A 2D section.
- Its extrusion and its variations along the curvilinear abscissa of the bridge (defined as the neutral axis of the bridge).

Illustrations

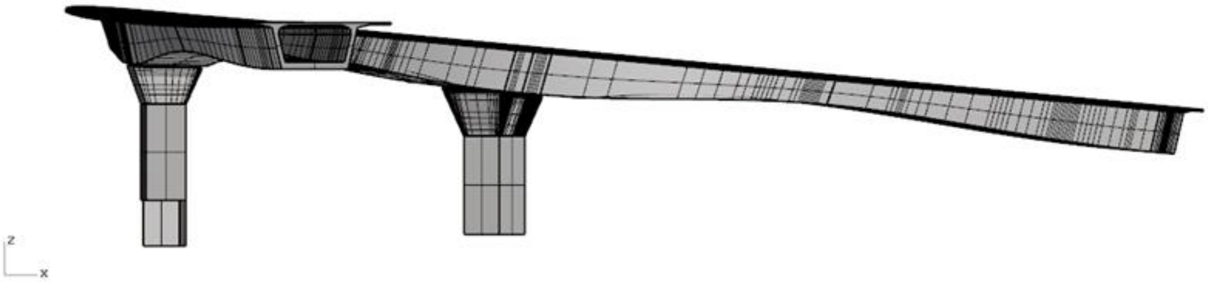
Below are illustrations of the bridge.



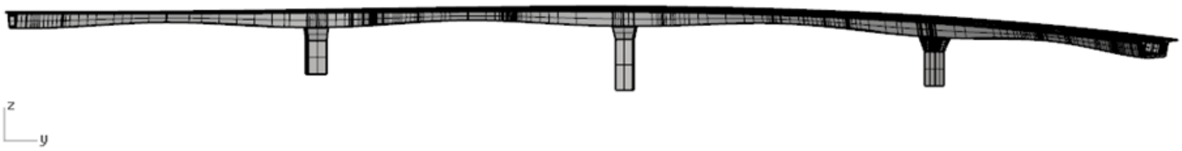
3D view of the bridge



Top view of the bridge



Side view of the bridge (1/2)

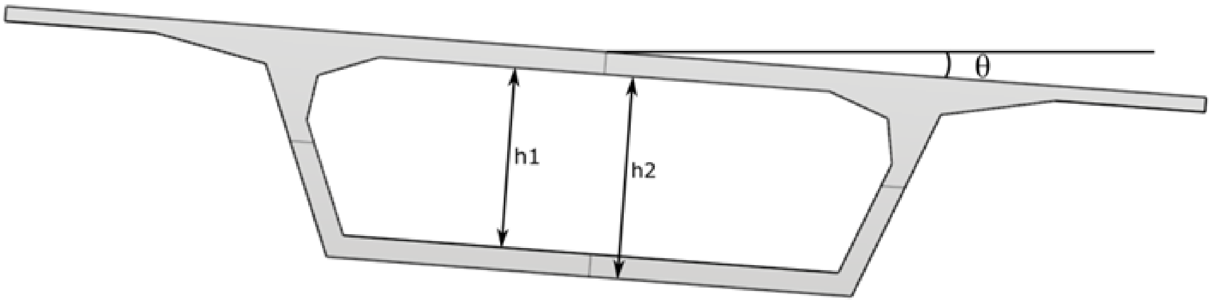


Side view of the bridge (2/2)

5.6 Comments | General description of a 3D slender structure

2D Reference Section

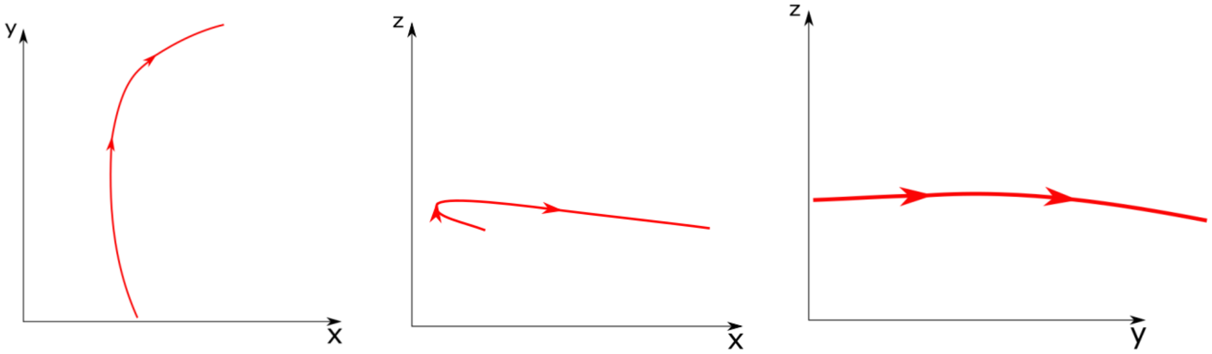
This bridge deck cannot be defined as a prismatic beam, resulting from a straight extrusion of a 2D section. It is defined by a reference 2D section and its variations along the curvilinear axis of the bridge. The 2D reference section is presented below.



Reference section

Curvilinear abscissa

The neutral axis of the bridge defines the curvilinear abscissa used for the extrusion of the reference section. This curvilinear abscissa s(x) is defined in the 3D as a function of x=(x,y,z):



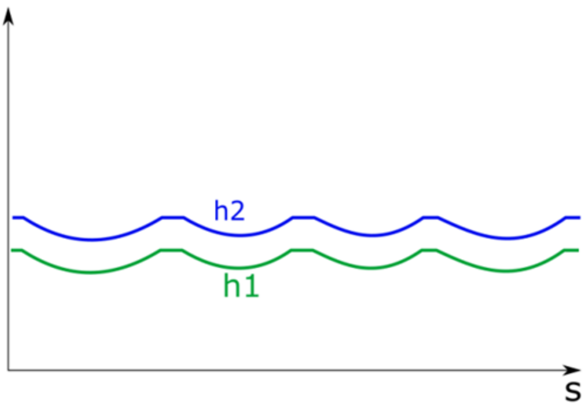
Definition of the curvilinear abscissa s(x)

Variations of the section's parameters

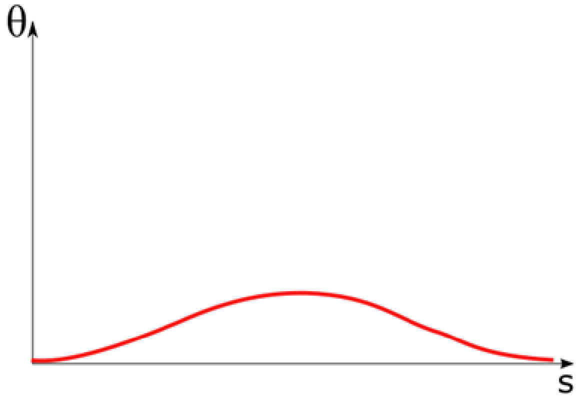
Then, any section of the bridge at a given abscissa s is a variation of the reference section defined above. In this case, possible variations of the reference section concern the parameters:

- h1,
- h2,
- θ.

The extrusion of the reference section along the curvilinear abscissa thus proceeds according to the functions h1(s), h2(s) and to θ(s):



Definition of h1 and h2 as functions of s



Definition of theta as a function of s

5.6 Comments | General description of a 3D slender structure

In a nutshell…

The deck of the bridge is fully defined by:

- The union of the 2D reference section.
- The curvilinear abscissa.
- The functions describing the variations of the section’s parameters.

This definition:

- Is currently available with IFC41.
- Was demonstrated by Tim Chipman (Constructivity[6]).

Phasing

The different construction phases of a structure must be mechanically checked by numerical computations. The IFC-Bridge model must store all these different phases. Each phase is associated to specific load cases which must be accurately defined in the IFC-Bridge file. The following elements must notably be indicated:

Concrete elements
Date of casting
Date of formwork removal
7/28 days properties
Prestressed elements
Date of tensioning
Installation of jacks
For any structure
Date of installation of elements
Installation/withdrawal of supports
Installation/withdrawal of connections
Additional loads during construction (engines, cranes, etc.)

The phasing description is mandatory. The bridge geometry defined in the model is the structure as-built delivered to the owner. Due to the loads acting on the structural elements when the bridge is delivered and the resulting deflection, the structural elements must be defined with a counter-deflection.

The construction task sequencing must be described. This could be done by using an *IfcWorkPlan* whose *IfcTasks* are connected to the bridge components.

---

[6] www.constructivity.com

5.7. Conclusion (IFC Bridge Inputs for numerical analysis)

Input data needed by the IFC Bridge model	This document yields an overview of the data the IFC-Bridge model should contains, **to allow data exchange related to structural analysis**. Three different types of input data have been identified: • Geometrical data for the structural analysis. • Mechanical data for the structural analysis. • Load and Boundary Conditions data, including the erection phasing.
Non-inclusion of the output data management	The output data management has not been addressed because it closely related to the needs of a given numerical analysis. Therefore, bridge behavior simulations based on numerical analysis are not in the current scope of IFC-Bridge because it is difficult clearly defining the exchange needs.
Limits of the IFC	IFC is an exchange format and a model for managing shared information. However, its scope is not to manage in detail the large amount of data associated to a numerical analysis, largely depending on the method assumptions implemented into the software package.
Building designing tasks	
Space organization	When designing a building, one of the first tasks is to organize the space (rooms, hallways, etc.) **to meet the given use of the projected building**. Regarding a bridge, its use is driven by the supported road. Therefore, the key challenge is to define an appropriate structure able to cope with: • The road definition. • The surrounding existing environment.
Preliminary numerical analyses	Preliminary numerical analyses validate different options: • Location of the piers. • Type of foundations. • Span lengths. • Deck structure. • Erection method. • Etc.
Architectural model	The so-called architectural model comes later when the key structural decisions have been validated.
Global geometry	The global geometry is derived from the numerical analysis model.
Spatial organisation	The spatial organization of the components starts at this stage in accordance with the detailed numerical analyses and the bridge erection simulation.
Changes management	To manage the changes, the IFC conceptual model must: • Host only the information related to structural analysis that are exchanged between the different actors including input and output data. • Establish appropriate links with the other views (architectural, 4D, 5D, etc.).

6. GENERAL CONCLUSION

Methods and technologies must be proven

Each construction asset is unique in its location and environment.

However, each building or bridge is based on the implementation of proven methods and technologies.

Structural choices must be based on numerical simulations

Regarding bridges, the structural behavior is critical.

The validation of the chosen structural choices must be based on numerical simulations, including the bridge erection.

Uncertainties regarding geotechnics are one of the main risks

Regarding risks associated to bridge construction and operation, uncertainties regarding geotechnics is one of them.

It includes knowledge of the existing soil and the behavior of associated earthworks. This could be linked to risk analysis associated to tunneling works. Soil behavior is estimated from specific numerical simulations using survey data. The results are used to size the foundations. This data exchange should also be possible with the IFC conceptual model.

Knowledge of the existing environment is also important

The knowledge of the existing environment around the bridge is also important regarding their mutual impact, during the construction phase and during operation.

Consequently, it is important to:

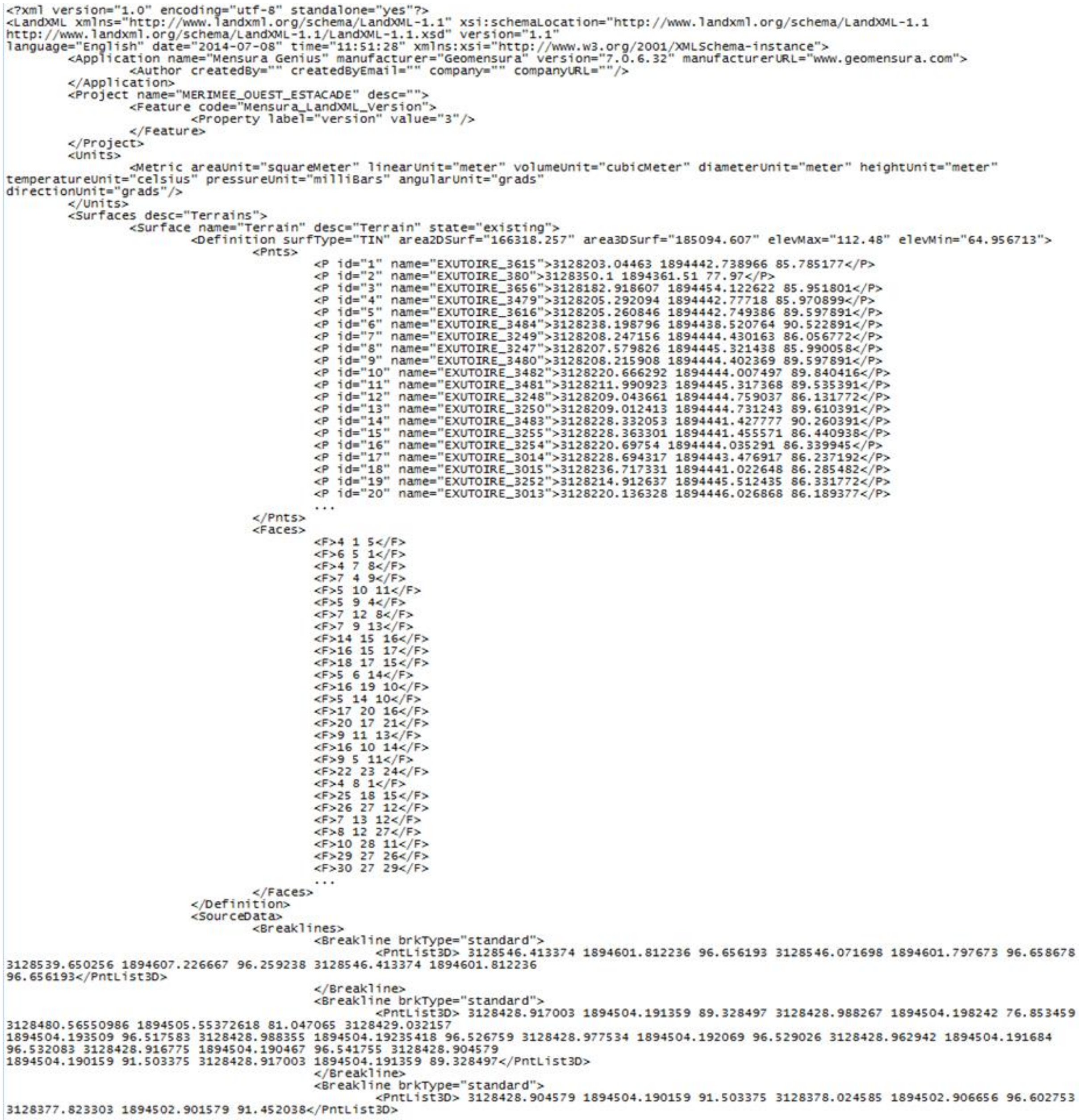
- Import GIS data related to the geographical environment of the bridge location to manage the clashes with existing elements, with anthropogenic ones.
- Export the result of the project in order to be able to update GIS systems if necessary.

The IFC has several uses

The IFC conceptual model is a tool for exchanging information, but also a data provider for making decisions and justifying choices.

7. APPENDIX

1.1 Example of a LandXML exported file



```
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<LandXML xmlns="http://www.landxml.org/schema/LandXML-1.1" xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.1
http://www.landxml.org/schema/LandXML-1.1/LandXML-1.1.xsd" version="1.1"
language="English" date="2014-07-08" time="11:51:28" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
        <Application name="Mensura Genius" manufacturer="Geomensura" version="7.0.6.32" manufacturerURL="www.geomensura.com">
                <Author createdBy="" createdByEmail="" company="" companyURL=""/>
        </Application>
        <Project name="MERIMEE_OUEST_ESTACADE" desc="">
                <Feature code="Mensura_LandXML_Version">
                        <Property label="version" value="3"/>
                </Feature>
        </Project>
        <Units>
                <Metric areaUnit="squareMeter" linearUnit="meter" volumeUnit="cubicMeter" diameterUnit="meter" heightUnit="meter"
temperatureUnit="celsius" pressureUnit="milliBars" angularUnit="grads"
directionUnit="grads"/>
        </Units>
        <Surfaces desc="Terrains">
                <Surface name="Terrain" desc="Terrain" state="existing">
                        <Definition surfType="TIN" area2DSurf="166318.257" area3DSurf="185094.607" elevMax="112.48" elevMin="64.956713">
                                <Pnts>
                                        <P id="1" name="EXUTOIRE_3615">3128203.04463 1894442.738966 85.785177</P>
                                        <P id="2" name="EXUTOIRE_380">3128350.1 1894361.51 77.97</P>
                                        <P id="3" name="EXUTOIRE_3656">3128182.918607 1894454.122622 85.951801</P>
                                        <P id="4" name="EXUTOIRE_3479">3128205.292094 1894442.77718 85.970899</P>
                                        <P id="5" name="EXUTOIRE_3616">3128205.260846 1894442.749386 89.597891</P>
                                        <P id="6" name="EXUTOIRE_3484">3128238.198796 1894438.520764 90.522891</P>
                                        <P id="7" name="EXUTOIRE_3249">3128208.247156 1894444.430163 86.056772</P>
                                        <P id="8" name="EXUTOIRE_3247">3128207.579826 1894445.321438 85.990058</P>
                                        <P id="9" name="EXUTOIRE_3480">3128208.215908 1894444.402369 89.597891</P>
                                        <P id="10" name="EXUTOIRE_3482">3128220.666292 1894444.007497 89.840416</P>
                                        <P id="11" name="EXUTOIRE_3481">3128211.990923 1894445.317368 89.535391</P>
                                        <P id="12" name="EXUTOIRE_3248">3128209.043661 1894444.759037 86.131772</P>
                                        <P id="13" name="EXUTOIRE_3250">3128209.012413 1894444.731243 89.610391</P>
                                        <P id="14" name="EXUTOIRE_3483">3128228.332053 1894441.427777 90.260391</P>
                                        <P id="15" name="EXUTOIRE_3255">3128228.363301 1894441.455571 86.440938</P>
                                        <P id="16" name="EXUTOIRE_3254">3128220.69754 1894444.035291 86.339945</P>
                                        <P id="17" name="EXUTOIRE_3014">3128228.694317 1894443.476917 86.237192</P>
                                        <P id="18" name="EXUTOIRE_3015">3128236.717331 1894441.022648 86.285482</P>
                                        <P id="19" name="EXUTOIRE_3252">3128214.912637 1894445.512435 86.331772</P>
                                        <P id="20" name="EXUTOIRE_3013">3128220.136328 1894446.026868 86.189377</P>
                                        ...
                                </Pnts>
                                <Faces>
                                        <F>4 1 5</F>
                                        <F>6 5 1</F>
                                        <F>4 7 8</F>
                                        <F>7 4 9</F>
                                        <F>5 10 11</F>
                                        <F>5 9 4</F>
                                        <F>7 12 8</F>
                                        <F>7 9 13</F>
                                        <F>14 15 16</F>
                                        <F>16 15 17</F>
                                        <F>18 17 15</F>
                                        <F>5 6 14</F>
                                        <F>16 19 10</F>
                                        <F>5 14 10</F>
                                        <F>17 20 16</F>
                                        <F>20 17 21</F>
                                        <F>9 11 13</F>
                                        <F>16 10 14</F>
                                        <F>9 5 11</F>
                                        <F>22 23 24</F>
                                        <F>4 8 1</F>
                                        <F>25 18 15</F>
                                        <F>26 27 12</F>
                                        <F>7 13 12</F>
                                        <F>8 12 27</F>
                                        <F>10 28 11</F>
                                        <F>29 27 26</F>
                                        <F>30 27 29</F>
                                        ...
                                </Faces>
                        </Definition>
                        <SourceData>
                                <Breaklines>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128546.413374 1894601.812236 96.656193 3128546.071698 1894601.797673 96.658678
3128539.650256 1894607.226667 96.259238 3128546.413374 1894601.812236
96.656193</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128428.917003 1894504.191359 89.328497 3128428.988267 1894504.198242 76.853459
3128480.56550986 1894505.55372618 81.047065 3128429.032157
1894504.193509 96.517583 3128428.988355 1894504.19235418 96.526759 3128428.977534 1894504.192069 96.529026 3128428.962942 1894504.191684
96.532083 3128428.916775 1894504.190467 96.541755 3128428.904579
1894504.190159 91.503375 3128428.917003 1894504.191359 89.328497</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128428.904579 1894504.190159 91.503375 3128378.024585 1894502.906656 96.602753
3128377.823303 1894502.901579 91.452038</PntList3D>
```

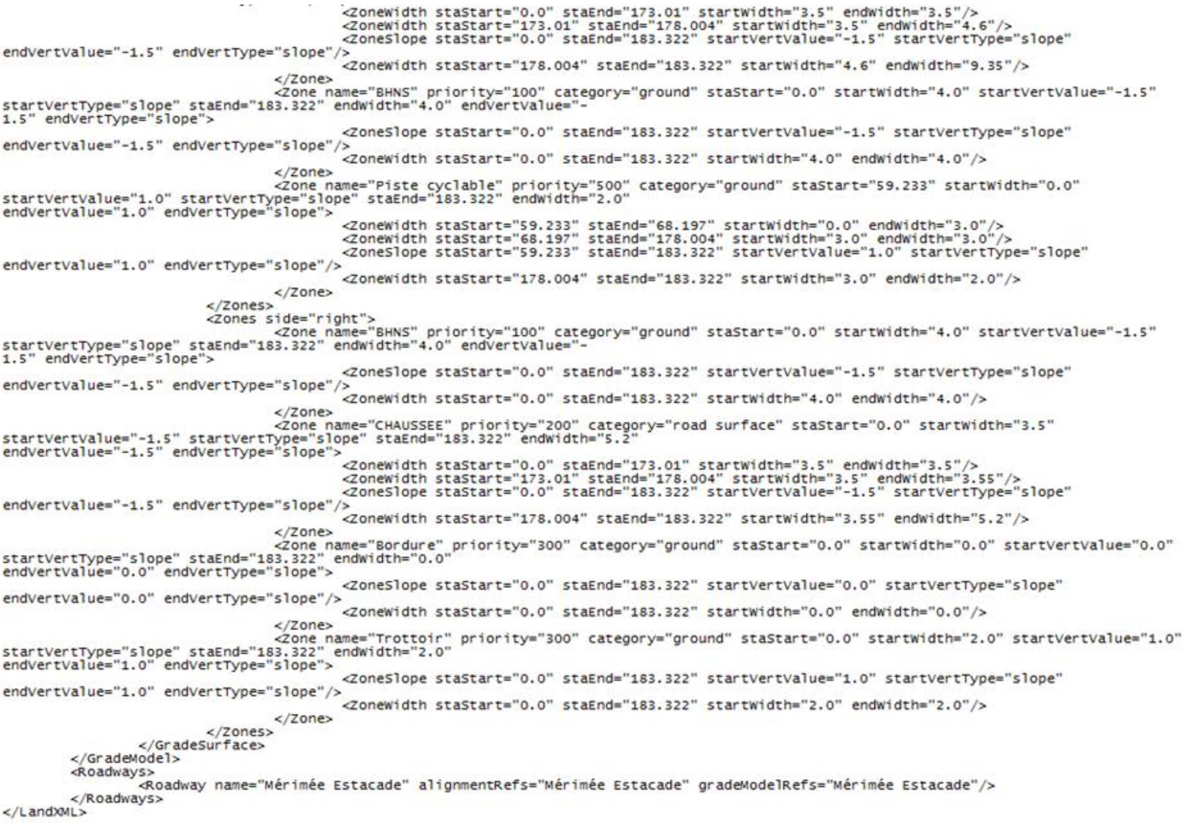
LandXML exported file example

```
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128376.802159 1894494.794453 79.419006 3128380.497841 1894500.459825 79.962533
3128377.722527 1894502.799365 78.346194 3128376.802159 1894494.794453
79.419006</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128420.626 1894499.968 80.301 3128420.323 1894503.189 80.229 3128417.048
1894500.023 80.335 3128420.626 1894499.968 80.301</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128376.84 1894381.897 78.228 3128373.448 1894382.177 78.193 3128378.12
1894396.872 79.226 3128376.84 1894381.897 78.228 3128375.539 1894366.951
77.228 3128375.99353 1894366.937788 77.258458 3128376.84 1894381.897 78.228 3128377.257144 1894381.887466 78.255791 3128375.99353
1894366.937788 77.258458 3128376.052284 1894366.932734 77.379868 3128377.484213
1894366.793992 76.911392 3128377.529708 1894366.790041 70.033927 3128383.99 1894366.22 70.149 3128387.375 1894365.945 70.209 3128390.733
1894365.614 70.272 3128394.187 1894365.422 70.297 3128397.573
1894365.174 70.239 3128400.903 1894364.871 70.154 3128404.382 1894364.545 70.035 3128407.784 1894364.241 69.943 3128409.910095 1894364.077245
69.833085 3128411.523063 1894379.006171 70.628226 3128413.210266
1894376.143193 70.922197 3128414.872418 1894391.419442 71.69549 3128411.523063 1894379.006171 70.628226 3128412.771762 1894391.650577
71.306839 3128414.872418 1894391.419442 71.69549</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128355.41 1894367.62 78.0 3128358.882588 1894364.504144 77.850775 3128359.123755
1894367.567762 77.944861 3128355.41 1894367.62 78.0</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128353.56 1894370.34 78.04 3128354.77 1894368.45 77.75 3128354.72 1894367.32
78.04 3128355.41 1894367.62 78.0 3128354.77 1894368.45 77.75
3128359.123755 1894367.567762 77.944861 3128353.56 1894370.34 78.04</PntList3D>
                                        </Breakline>
                                        <Breakline brkType="standard">
                                                <PntList3D> 3128358.882588 1894364.504144 77.850775 3128355.55 1894364.29 77.92 3128355.41
1894367.62 78.0 3128354.61 1894366.23 77.8 3128354.72 1894367.32 78.04
3128352.87 1894368.92 78.04 3128354.77 1894368.45 77.75</PntList3D>
                                        ...|
                                </Breaklines>
                                <Boundaries>
                                        <Boundary edgeTrim="false" bndType="outer">
                                                <PntList3D> 3128350.1 1894361.51 77.97 3128425.623904 1894361.164659 65.163984 3128518.791674
1894458.244239 76.014078 3128583.633429 1894526.348731 81.451528
3128585.368242 1894528.395676 81.545531 3128586.830269 1894530.585019 81.793141 3128587.998703 1894533.411832 82.021456 3128591.687224
1894545.987032 83.470379 3128606.538274 1894601.142417 88.247223
3128606.903794 1894603.17883 88.427727 3128607.022937 1894605.016536 88.519004 3128606.934759 1894607.069315 88.66656 3128606.587116
1894609.532287 88.800547 3128606.182216 1894611.441766 88.915332
3128605.386519 1894613.59502 89.075126 3128604.492557 1894615.554065 89.152649 3128448.496544 1894954.405878 104.012462 3128437.740097
1894965.177479 103.975366 3128407.702 1894994.17 102.655 3128373.1
1895004.07 103.4 3128368.38 1895003.95 104.14 3128355.1 1895003.45 104.13 3128349.07 1895002.04 104.22 3128345.97 1894998.68 104.61
3128189.893365 1894489.13067 88.036666 3128183.910825 1894468.360103
86.747103 3128183.478333 1894466.019442 86.595446 3128183.282849 1894462.897466 86.468233 3128182.918607 1894454.122622 85.951801
3128203.04463 1894442.738966 85.785177 3128350.1 1894361.51 77.97</PntList3D>
                                        </Boundary>
                                </Boundaries>
                        </SourceData>
                </Surface>
        </Surfaces>
        <Alignments>
                <Alignment name="Mérimée Estacade" length="183.322" staStart="0.0">
                        <CoordGeom>
                                <Line length="59.233" dir="330.756" staStart="0.0">
                                        <Start>3128324.12701 1894734.767555</Start>
                                        <End>3128351.643163 1894787.221902</End>
                                        <Feature code="MensuraElementConnection">
                                                <Property label="Connection" value="1 1/1 0"/>
                                        </Feature>
                                </Line>
                                <Curve crvType="arc" staStart="59.233" rot="cw" length="29.228" radius="57.5" delta="-32.36"
dirStart="330.756" dirEnd="298.396">
                                        <Start>3128351.643163 1894787.221902</Start>
                                        <Center>3128300.723846 1894813.932819</Center>
                                        <End>3128358.205597 1894815.381352</End>
                                        <PI>3128358.581884 1894800.449262</PI>
                                        <Feature code="MensuraElementConnection">
                                                <Property label="Connection" value="6 1/1 3"/>
                                        </Feature>
                                </Curve>
                                <Line length="94.861" dir="298.396" staStart="88.461">
                                        <Start>3128358.205597 1894815.381352</Start>
                                        <End>3128355.815872 1894910.212236</End>
                                        <Feature code="MensuraElementConnection">
                                                <Property label="Connection" value="1 1/1 0"/>
                                        </Feature>
                                </Line>
                        </CoordGeom>
                        <Profile name="Mérimée Estacade">
                                <ProfSurf name="Terrain" state="existing">
                                        <PntList2D> 0.0 103.148177 1.771 103.194407 16.946 103.471059 28.269 103.793723 31.252 103.884528
39.031 104.027933 40.049 104.083543 44.234 104.218874 46.254 104.263708
51.442 104.465215 51.729 104.488455 52.096 104.489061 56.148 104.714965 56.481 104.737674 59.233 104.849204 63.409 105.041094 64.82 105.123522
67.584 105.255109 69.439 105.378324 73.927 105.622813 74.286
105.627469 75.935 105.71846 83.907 106.091729 84.409 106.077718 88.461 106.295227 94.391 106.611915 94.896 106.652656 104.698 107.172182
```

LandXML exported file example

```
105.289 107.171565 115.584 107.696524 115.75 107.727799 115.933
107.725155 116.93 107.865234 117.521 107.907863 127.021 108.319189 127.517 108.293671 127.767 108.336476 128.036 108.31606 128.871 108.336264
129.225 108.360257 137.717 108.54643 138.351 108.541403 138.69
108.496483 148.139 108.572949 148.84 108.613657 149.547 108.623614 160.237 108.505515 162.333 108.444847 166.531 108.247669 168.493 108.177518
170.81 108.018299 173.317 107.961354 175.48 107.799817 177.076
107.727635 179.497 107.719518 183.322 107.601494</PntList2D>
                </ProfSurf>
                <ProfAlign name="Projet" state="proposed">
                    <PVI>0.0 103.148177</PVI>
                    <ParaCurve length="49.323">40.869 103.926872</ParaCurve>
                    <ParaCurve length="45.548">142.445 109.202275</ParaCurve>
                    <PVI>183.322 107.601494</PVI>
                </ProfAlign>
            </Profile>
            <CrossSects name="Mérimée Estacade">
                <CrossSect sta="0.0" name="1">
                    <CrossSectSurf name="Terrain" state="existing">
                        <PntList2D> -20.0 100.488002 -17.895 100.394372 -16.412 100.366953 -14.823 100.38407 -11.614
100.62449 -10.926 100.6428 -10.848 100.642197 -10.844 100.813259 -
10.777 103.211273 -9.093 103.031064 -7.838 102.889453 -7.599 102.865576 -7.594 102.862285 -7.313 102.86296 -5.06 102.848656 -4.295 102.877702
-3.306 102.94652 -0.918 103.080775 -0.437 103.163335 -0.437
103.163338 -0.437 103.16335 -0.406 103.163619 0.0 103.148177 0.297 103.136861 3.684 102.987942 7.494 103.019974 7.495 103.019973 7.495
103.019998 7.496 103.02 11.041 103.135626 12.478 103.106674 12.835
103.096523 12.973 103.095622 15.0 103.329815</PntList2D>
                    </CrossSectSurf>
                    <DesignCrossSectSurf name="Projet - BHNS" side="left" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>0.0 103.148177</CrossSectPnt>
                        <CrossSectPnt>-4.0 103.088177</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - CHAUSSEE - B_Chaussée" side="left" state="proposed"
closedArea="false" desc="project">
                        <CrossSectPnt>-4.0 103.088177</CrossSectPnt>
                        <CrossSectPnt>-7.5 103.035677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - Bordure" side="left" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>-7.5 103.035677</CrossSectPnt>
                        <CrossSectPnt>-7.5 103.175677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - Trottoir" side="left" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>-7.5 103.175677</CrossSectPnt>
                        <CrossSectPnt>-9.5 103.195677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - BHNS" side="right" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>0.0 103.148177</CrossSectPnt>
                        <CrossSectPnt>4.0 103.088177</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - CHAUSSEE - B_Chaussée" side="right" state="proposed"
closedArea="false" desc="project">
                        <CrossSectPnt>4.0 103.088177</CrossSectPnt>
                        <CrossSectPnt>7.5 103.035677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - Bordure" side="right" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>7.5 103.035677</CrossSectPnt>
                        <CrossSectPnt>7.5 103.175677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    <DesignCrossSectSurf name="Projet - Trottoir" side="right" state="proposed" closedArea="false"
desc="project">
                        <CrossSectPnt>7.5 103.175677</CrossSectPnt>
                        <CrossSectPnt>9.5 103.195677</CrossSectPnt>
                    </DesignCrossSectSurf>
                    ...
                </CrossSect>
            </CrossSects>
        </Alignment>
    </Alignments>
    <GradeModel name="Mérimée Estacade">
        <GradeSurface alignmentRef="Mérimée Estacade" surfaceType="finalSurface">
            <Zones side="left">
                <Zone name="Trottoir" priority="300" category="ground" staStart="0.0" startWidth="2.0" startVertValue="1.0"
startVertType="slope" staEnd="183.322" endWidth="0.0"
endVertValue="1.0" endVertType="slope">
                    <ZoneWidth staStart="0.0" staEnd="178.004" startWidth="2.0" endWidth="2.0"/>
                    <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="1.0" startVertType="slope"
endVertValue="1.0" endVertType="slope"/>
                    <ZoneWidth staStart="178.004" staEnd="183.322" startWidth="2.0" endWidth="0.0"/>
                </Zone>
                <Zone name="Bordure" priority="300" category="ground" staStart="0.0" startWidth="0.0" startVertValue="0.0"
startVertType="slope" staEnd="183.322" endWidth="0.0"
endVertValue="0.0" endVertType="slope">
                    <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="0.0" startVertType="slope"
endVertValue="0.0" endVertType="slope"/>
                    <ZoneWidth staStart="0.0" staEnd="183.322" startWidth="0.0" endWidth="0.0"/>
                </Zone>
                <Zone name="CHAUSSEE" priority="200" category="road surface" staStart="0.0" startWidth="3.5"
startVertValue="-1.5" startVertType="slope" staEnd="183.322" endWidth="9.35"
endVertValue="-1.5" endVertType="slope">
```

LandXML exported file example



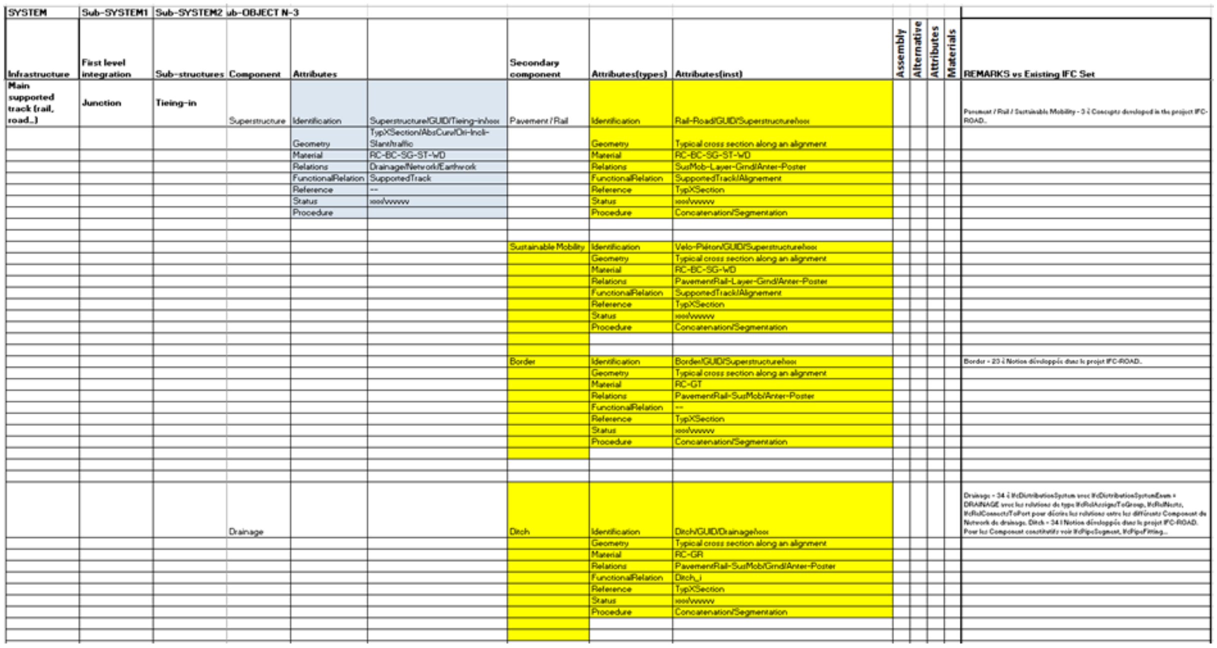
```
                                        <ZoneWidth staStart="0.0" staEnd="173.01" startWidth="3.5" endWidth="3.5"/>
                                        <ZoneWidth staStart="173.01" staEnd="178.004" startWidth="3.5" endWidth="4.6"/>
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="-1.5" startVertType="slope"
endVertValue="-1.5" endVertType="slope"/>
                                        <ZoneWidth staStart="178.004" staEnd="183.322" startWidth="4.6" endWidth="9.35"/>
                                </Zone>
                                <Zone name="BHNS" priority="100" category="ground" staStart="0.0" startWidth="4.0" startVertValue="-1.5"
startVertType="slope" staEnd="183.322" endWidth="4.0" endVertValue="-
1.5" endVertType="slope">
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="-1.5" startVertType="slope"
endVertValue="-1.5" endVertType="slope"/>
                                        <ZoneWidth staStart="0.0" staEnd="183.322" startWidth="4.0" endWidth="4.0"/>
                                </Zone>
                                <Zone name="Piste cyclable" priority="500" category="ground" staStart="59.233" startWidth="0.0"
startVertValue="1.0" startVertType="slope" staEnd="183.322" endWidth="2.0"
endVertValue="1.0" endVertType="slope">
                                        <ZoneWidth staStart="59.233" staEnd="68.197" startWidth="0.0" endWidth="3.0"/>
                                        <ZoneWidth staStart="68.197" staEnd="178.004" startWidth="3.0" endWidth="3.0"/>
                                        <ZoneSlope staStart="59.233" staEnd="183.322" startVertValue="1.0" startVertType="slope"
endVertValue="1.0" endVertType="slope"/>
                                        <ZoneWidth staStart="178.004" staEnd="183.322" startWidth="3.0" endWidth="2.0"/>
                                </Zone>
                        </Zones>
                        <Zones side="right">
                                <Zone name="BHNS" priority="100" category="ground" staStart="0.0" startWidth="4.0" startVertValue="-1.5"
startVertType="slope" staEnd="183.322" endWidth="4.0" endVertValue="-
1.5" endVertType="slope">
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="-1.5" startVertType="slope"
endVertValue="-1.5" endVertType="slope"/>
                                        <ZoneWidth staStart="0.0" staEnd="183.322" startWidth="4.0" endWidth="4.0"/>
                                </Zone>
                                <Zone name="CHAUSSEE" priority="200" category="road surface" staStart="0.0" startWidth="3.5"
startVertValue="-1.5" startVertType="slope" staEnd="183.322" endWidth="5.2"
endVertValue="-1.5" endVertType="slope">
                                        <ZoneWidth staStart="0.0" staEnd="173.01" startWidth="3.5" endWidth="3.5"/>
                                        <ZoneWidth staStart="173.01" staEnd="178.004" startWidth="3.5" endWidth="3.55"/>
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="-1.5" startVertType="slope"
endVertValue="-1.5" endVertType="slope"/>
                                        <ZoneWidth staStart="178.004" staEnd="183.322" startWidth="3.55" endWidth="5.2"/>
                                </Zone>
                                <Zone name="Bordure" priority="300" category="ground" staStart="0.0" startWidth="0.0" startVertValue="0.0"
startVertType="slope" staEnd="183.322" endWidth="0.0"
endVertValue="0.0" endVertType="slope">
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="0.0" startVertType="slope"
endVertValue="0.0" endVertType="slope"/>
                                        <ZoneWidth staStart="0.0" staEnd="183.322" startWidth="0.0" endWidth="0.0"/>
                                </Zone>
                                <Zone name="Trottoir" priority="300" category="ground" staStart="0.0" startWidth="2.0" startVertValue="1.0"
startVertType="slope" staEnd="183.322" endWidth="2.0"
endVertValue="1.0" endVertType="slope">
                                        <ZoneSlope staStart="0.0" staEnd="183.322" startVertValue="1.0" startVertType="slope"
endVertValue="1.0" endVertType="slope"/>
                                        <ZoneWidth staStart="0.0" staEnd="183.322" startWidth="2.0" endWidth="2.0"/>
                                </Zone>
                        </Zones>
                </GradeSurface>
        </GradeModel>
        <Roadways>
                <Roadway name="Mérimée Estacade" alignmentRefs="Mérimée Estacade" gradeModelRefs="Mérimée Estacade"/>
        </Roadways>
</LandXML>
```

LandXML exported file example

1.2 Excel sheet “organic and functional architecture”

An Excel sheet describing the organic and functional architecture is available here: MINnD_UC3-4_IDM_IntegrationLevels V2.2.xlsx

Please find below its preview:



SYSTEM	Sub-SYSTEM1	Sub-SYSTEM2	ub-OBJECT N-3										
Infrastructure	**First level integration**	**Sub-structures**	**Component**	**Attributes**		**Secondary component**	**Attributes(types)**	**Attributes(inst)**	**Assembly**	**Alternative**	**Attributes**	**Materials**	**REMARKS vs Existing IFC Set**
Main supported track (rail, road..)	**Junction**	**Tieing-in**	Superstructure	Identification	Superstructure/GUID/Tieing-in/xxx	Pavement / Rail	Identification	Rail-Road/GUID/Superstructure/xxx					Pavement / Rail / Sustainable Mobility - 3 ¿ Concepts developed in the project IFC-ROAD..
				Geometry	TypXSection/AbsCurv/Dri-Incli-Slant/traffic		Geometry	Typical cross section along an alignment					
				Material	RC-BC-SG-ST-WD		Material	RC-BC-SG-ST-WD					
				Relations	Drainage/Network/Earthwork		Relations	SusMob-Layer-Grnd/Anter-Poster					
				FunctionalRelation	SupportedTrack		FunctionalRelation	SupportedTrack/Alignement					
				Reference	--		Reference	TypXSection					
				Status	xxx/vvvvvv		Status	xxx/vvvvvv					
				Procedure			Procedure	Concatenation/Segmentation					
						Sustainable Mobility	Identification	Velo-Piéton/GUID/Superstructure/xxx					
							Geometry	Typical cross section along an alignment					
							Material	RC-BC-SG-WD					
							Relations	PavementRail-Layer-Grnd/Anter-Poster					
							FunctionalRelation	SupportedTrack/Alignement					
							Reference	TypXSection					
							Status	xxx/vvvvvv					
							Procedure	Concatenation/Segmentation					
						Border	Identification	Border/GUID/Superstructure/xxx					Border - 23 ¿ Notion développée dans le projet IFC-ROAD..
							Geometry	Typical cross section along an alignment					
							Material	RC-GT					
							Relations	PavementRail-SusMob/Anter-Poster					
							FunctionalRelation	--					
							Reference	TypXSection					
							Status	xxx/vvvvvv					
							Procedure	Concatenation/Segmentation					
			Drainage			Ditch	Identification	Ditch/GUID/Drainage/xxx					Drainage - 34 ¿ IfcDistributionSystem avec IfcDistributionSystemEnum = DRAINAGE avec les relations de type IfcRelAssignsToGroup, IfcRelNests, IfcRelConnectsToPort pour décrire les relations entre les différents Composant du Network de drainage. Ditch - 34 ! Notion développée dans le projet IFC-ROAD. Pour les Composant constitutifs voir IfcPipeSegment, IfcPipeFitting...
							Geometry	Typical cross section along an alignment					
							Material	RC-GR					
							Relations	PavementRail-SusMob/Grnd/Anter-Poster					
							FunctionalRelation	Ditch_i					
							Reference	TypXSection					
							Status	xxx/vvvvvv					
							Procedure	Concatenation/Segmentation					

Excel sheet “organic and functional architecture preview

I.3 Example for segmental cantilever bridge design

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION($,’2;1’);
FILE_NAME(‘ ‘,’ ‘,(''),(''),’ ‘,’ ‘,'');
FILE_SCHEMA((’IFC2X3’));
ENDSEC;

DATA;

/* Project */

#1= IFCPROJECT('0000000000000000000001’,$,'Project’,’Tendon Systems’,$,$,$,(#2,#3),#4);
#2= IFCGEOMETRICREPRESENTATIONCONTEXT('3D','Model',3,1.0E-05,#6,#7);
#3= IFCGEOMETRICREPRESENTATIONCONTEXT('2D','Plan',2,1.0E-05,#6,#7);
#4= IFCUNITASSIGNMENT((#8,#9,#10,#11,#12,#13));
#5= IFCCARTESIANPOINT((0.,0.,0.));
#6= IFCAXIS2PLACEMENT3D(#5,$,$);
#7= IFCDIRECTION((0.,1.,0.));
#8= IFCSIUNIT(*,.LENGTHUNIT.,$,.METRE.);
#9= IFCSIUNIT(*,.AREAUNIT.,$,.SQUARE_METRE.);
#10= IFCSIUNIT(*,.VOLUMEUNIT.,$,.CUBIC_METRE.);
#11= IFCSIUNIT(*,.MASSUNIT.,.KILO.,.GRAM.);
#12= IFCSIUNIT(*,.TIMEUNIT.,$,.SECOND.);
#13= IFCSIUNIT(*,.PLANEANGLEUNIT.,$,.RADIAN.);

#15= IFCRELAGGREGATES(’0000000000000000000015’,$,$,$,#1,(#16));

/* Site */

#16= IFCSITE('0000000000000000000016’,$,'Site’,’Bridge Site’,$,#17,$,$,.ELEMENT.,$,$,$,$,$);
#17= IFCLOCALPLACEMENT($,#6);

#18= IFCRELAGGREGATES(’0000000000000000000018’,$,$,$,#16,(#19));

/* Bridge */
```

```
#19= IFCBUILDING('0000000000000000000019’,$,'Bridge’,’Test Bridge’,$,#17,$,$,$,$,$,$);

#20= IFCRELAGGREGATES(’0000000000000000000020’,$,$,$,#19,(#21,#24));


/* Cantilever part */


#21= IFCBUILDINGSTOREY('0000000000000000000021’,$,'Cantilever’,’Test BridgePart’,$,#17,$,$,$,$);


#22= IFCRELCONTAINEDINSPATIALSTRUCTURE(’0000000000000000000022’,$,$,$,( #51, #71, #91, #111, #141, #161, #191, #221, #251, #281, #321, #361, #401, #441, #481, #521, #561),#21);
#23= IFCRELCONTAINEDINSPATIALSTRUCTURE(’0000000000000000000023’,$,$,$,(#2000,#2020,#2040,#2060,#2080,#2100,#2120,#2140,#2160,#2180,#2200,#2220,#2240,#2260,#2280,#2300,#2320,#2340,#2360,#2380,#2400),#21);


/* Joint part */


#24= IFCBUILDINGSTOREY('0000000000000000000024’,$,'Joint Part’,’Test BridgePart’,$,#17,$,$,$,$);


#25= IFCRELCONTAINEDINSPATIALSTRUCTURE(’0000000000000000000025’,$,$,$,(#601,#621,#651,#671,#691,#711,#731,#751,#791),#24);



/* Tendons */


#51= IFCTENDON('0000000000000000000051',$,'F0401N',$,$,#17,#52,$,$,$,$,$,$,$,$,$,$);
#52= IFCPRODUCTDEFINITIONSHAPE($,$,(#53));
#53= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#54));
#54= IFCSWEPTDISKSOLID(#55,0.03,$,$,$);
#55= IFCPOLYLINE((#56,#57,#58,#59,#60,#61));
#56= IFCCARTESIANPOINT((59.686,-3.873,-0.300));
#57= IFCCARTESIANPOINT((60.953,-3.668,-0.300));
#58= IFCCARTESIANPOINT((62.038,-3.581,-0.150));
#59= IFCCARTESIANPOINT((67.962,-3.581,-0.150));
#60= IFCCARTESIANPOINT((69.047,-3.668,-0.300));
#61= IFCCARTESIANPOINT((70.314,-3.873,-0.300));

#71= IFCTENDON('0000000000000000000071',$,'F0402N',$,$,#17,#72,$,$,$,$,$,$,$,$,$,$);
#72= IFCPRODUCTDEFINITIONSHAPE($,$,(#73));
#73= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#74));
```

```
#74= IFCSWEPTDISKSOLID(#75,0.03,$,$,$);
#75= IFCPOLYLINE((#76,#77,#78,#79,#80,#81,#82,#83,#84,#85));
#76= IFCCARTESIANPOINT((56.531,-3.873,-0.300));
#77= IFCCARTESIANPOINT((57.798,-3.668,-0.300));
#78= IFCCARTESIANPOINT((58.883,-3.581,-0.150));
#79= IFCCARTESIANPOINT((60.429,-3.581,-0.150));
#80= IFCCARTESIANPOINT((62.006,-3.361,-0.150));
#81= IFCCARTESIANPOINT((67.994,-3.361,-0.150));
#82= IFCCARTESIANPOINT((69.571,-3.581,-0.150));
#83= IFCCARTESIANPOINT((71.117,-3.581,-0.150));
#84= IFCCARTESIANPOINT((72.202,-3.668,-0.300));
#85= IFCCARTESIANPOINT((73.469,-3.873,-0.300));

#91= IFCTENDON('0000000000000000000091',$,'F0403N',$,$,#17,#92,$,$,$,$,$,$,$,$,$,$);
#92= IFCPRODUCTDEFINITIONSHAPE($,$,(#93));
#93= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#94));
#94= IFCSWEPTDISKSOLID(#95,0.03,$,$,$);
#95= IFCPOLYLINE((#96,#97,#98,#99,#100,#101,#102,#103,#104,#105,#106,#107,#108,#109));
#96= IFCCARTESIANPOINT((53.376,-3.873,-0.300));
#97= IFCCARTESIANPOINT((54.643,-3.668,-0.300));
#98= IFCCARTESIANPOINT((55.728,-3.581,-0.150));
#99= IFCCARTESIANPOINT((57.274,-3.581,-0.150));
#100= IFCCARTESIANPOINT((58.851,-3.361,-0.150));
#101= IFCCARTESIANPOINT((60.911,-3.361,-0.150));
#102= IFCCARTESIANPOINT((62.079,-2.881,-0.150));
#103= IFCCARTESIANPOINT((67.921,-2.881,-0.150));
#104= IFCCARTESIANPOINT((69.089,-3.361,-0.150));
#105= IFCCARTESIANPOINT((71.149,-3.361,-0.150));
#106= IFCCARTESIANPOINT((72.726,-3.581,-0.150));
#107= IFCCARTESIANPOINT((74.272,-3.581,-0.150));
#108= IFCCARTESIANPOINT((75.272,-3.668,-0.300));
#109= IFCCARTESIANPOINT((76.624,-3.873,-0.300));

#111= IFCTENDON('0000000000000000000111',$,'F0404N',$,$,#17,#112,$,$,$,$,$,$,$,$,$,$);
#112= IFCPRODUCTDEFINITIONSHAPE($,$,(#113));
#113= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#114));
#114= IFCSWEPTDISKSOLID(#115,0.03,$,$,$);
```

```
#115= IFCPOLYLINE((#116,#117,#118,#119,#120,#121,#122,#123,#124,#125,#126,#127,#128,#129,#130,#131,#132,#133));
#116= IFCCARTESIANPOINT((50.221,-3.873,-0.300));
#117= IFCCARTESIANPOINT((51.488,-3.668,-0.300));
#118= IFCCARTESIANPOINT((52.573,-3.581,-0.150));
#119= IFCCARTESIANPOINT((54.601,-3.581,-0.150));
#120= IFCCARTESIANPOINT((55.769,-3.361,-0.150));
#121= IFCCARTESIANPOINT((57.274,-3.361,-0.150));
#122= IFCCARTESIANPOINT((58.851,-2.881,-0.150));
#123= IFCCARTESIANPOINT((60.429,-2.881,-0.150));
#124= IFCCARTESIANPOINT((62.006,-2.581,-0.150));
#125= IFCCARTESIANPOINT((67.994,-2.581,-0.150));
#126= IFCCARTESIANPOINT((69.571,-2.881,-0.150));
#127= IFCCARTESIANPOINT((71.076,-2.881,-0.150));
#128= IFCCARTESIANPOINT((72.244,-3.361,-0.150));
#129= IFCCARTESIANPOINT((74.304,-3.361,-0.150));
#130= IFCCARTESIANPOINT((75.881,-3.581,-0.150));
#131= IFCCARTESIANPOINT((77.427,-3.581,-0.150));
#132= IFCCARTESIANPOINT((78.512,-3.668,-0.300));
#133= IFCCARTESIANPOINT((79.779,-3.873,-0.300));

#141= IFCTENDON('0000000000000000000141',$,'F0405N',$,$,#17,#142,$,$,$,$,$,$,$,$,$,$);
#142= IFCPRODUCTDEFINITIONSHAPE($,$,(#143));
#143= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#144));
#144= IFCSWEPTDISKSOLID(#145,0.03,$,$,$);
#145= IFCPOLYLINE((#146,#147,#148,#149,#150,#151,#152,#153,#154,#155,#156,#157,#158,#159));
#146= IFCCARTESIANPOINT((47.480,-3.873,-0.300));
#147= IFCCARTESIANPOINT((48.315,-3.671,-0.300));
#148= IFCCARTESIANPOINT((49.254,-3.581,-0.350));
#149= IFCCARTESIANPOINT((50.175,-3.581,-0.350));
#150= IFCCARTESIANPOINT((53.330,-3.581,-0.350));
#151= IFCCARTESIANPOINT((56.485,-3.581,-0.350));
#152= IFCCARTESIANPOINT((59.640,-3.581,-0.350));
#153= IFCCARTESIANPOINT((70.359,-3.581,-0.350));
#154= IFCCARTESIANPOINT((73.514,-3.581,-0.350));
#155= IFCCARTESIANPOINT((76.669,-3.581,-0.350));
#156= IFCCARTESIANPOINT((79.824,-3.581,-0.350));
#157= IFCCARTESIANPOINT((80.476,-3.581,-0.350));
```

```
#158= IFCCARTESIANPOINT((81.685,-3.671,-0.300));
#159= IFCCARTESIANPOINT((82.934,-3.873,-0.300));

#161= IFCTENDON('0000000000000000000161',$,'F0406N',$,$,#17,#162,$,$,$,$,$,$,$,$,$,$);
#162= IFCPRODUCTDEFINITIONSHAPE($,$,(#163));
#163= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#164));
#164= IFCSWEPTDISKSOLID(#165,0.03,$,$,$);
#165= IFCPOLYLINE((#166,#167,#168,#169,#170,#171,#172,#173,#174,#175,#176,#177,#178,#179,#180,#181,#182,#183));
#166= IFCCARTESIANPOINT((44.325,-3.873,-0.300));
#167= IFCCARTESIANPOINT((45.160,-3.671,-0.300));
#168= IFCCARTESIANPOINT((46.369,-3.581,-0.350));
#169= IFCCARTESIANPOINT((47.809,-3.581,-0.350));
#170= IFCCARTESIANPOINT((49.386,-3.361,-0.350));
#171= IFCCARTESIANPOINT((50.175,-3.361,-0.350));
#172= IFCCARTESIANPOINT((53.330,-3.361,-0.350));
#173= IFCCARTESIANPOINT((56.485,-3.361,-0.350));
#174= IFCCARTESIANPOINT((59.640,-3.361,-0.350));
#175= IFCCARTESIANPOINT((70.359,-3.361,-0.350));
#176= IFCCARTESIANPOINT((73.514,-3.361,-0.350));
#177= IFCCARTESIANPOINT((76.669,-3.361,-0.350));
#178= IFCCARTESIANPOINT((79.824,-3.361,-0.350));
#179= IFCCARTESIANPOINT((80.614,-3.361,-0.350));
#180= IFCCARTESIANPOINT((82.191,-3.581,-0.350));
#181= IFCCARTESIANPOINT((83.631,-3.581,-0.350));
#182= IFCCARTESIANPOINT((84.840,-3.671,-0.300));
#183= IFCCARTESIANPOINT((86.089,-3.873,-0.300));

#191= IFCTENDON('0000000000000000000191',$,'F0407N',$,$,#17,#192,$,$,$,$,$,$,$,$,$,$);
#192= IFCPRODUCTDEFINITIONSHAPE($,$,(#193));
#193= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#194));
#194= IFCSWEPTDISKSOLID(#195,0.03,$,$,$);
#195= IFCPOLYLINE((#196,#197,#198,#199,#200,#201,#202,#203,#204,#205,#206,#207,#208,#209,#210,#211,#212,#213));
#196= IFCCARTESIANPOINT((40.756,-3.889,-0.300));
#197= IFCCARTESIANPOINT((42.147,-4.114,-0.300));
#198= IFCCARTESIANPOINT((43.353,-4.226,-0.350));
#199= IFCCARTESIANPOINT((43.865,-4.226,-0.350));
```

```
#200= IFCCARTESIANPOINT((47.020,-4.226,-0.350));
#201= IFCCARTESIANPOINT((50.175,-4.226,-0.350));
#202= IFCCARTESIANPOINT((53.330,-4.226,-0.350));
#203= IFCCARTESIANPOINT((56.485,-4.226,-0.350));
#204= IFCCARTESIANPOINT((59.640,-4.226,-0.350));
#205= IFCCARTESIANPOINT((70.359,-4.226,-0.350));
#206= IFCCARTESIANPOINT((73.514,-4.226,-0.350));
#207= IFCCARTESIANPOINT((76.669,-4.226,-0.350));
#208= IFCCARTESIANPOINT((79.824,-4.226,-0.350));
#209= IFCCARTESIANPOINT((82.979,-4.226,-0.350));
#210= IFCCARTESIANPOINT((86.134,-4.226,-0.350));
#211= IFCCARTESIANPOINT((86.647,-4.226,-0.350));
#212= IFCCARTESIANPOINT((87.853,-4.114,-0.300));
#213= IFCCARTESIANPOINT((89.244,-3.889,-0.300));

#221= IFCTENDON('0000000000000000000221',$,'F0408N',$,$,#17,#222,$,$,$,$,$,$,$,$,$,$);
#222= IFCPRODUCTDEFINITIONSHAPE($,$,(#223));
#223= IFCSHAPEREPRESENTATION(#2,‘Body’,‘AdvancedSweptSolid’,(#224));
#224= IFCSWEPTDISKSOLID(#225,0.03,$,$,$);
#225= IFCPOLYLINE((#226,#227,#228,#229,#230,#231,#232,#233,#234,#235,#236,#237,#238,#239,#240,#241,#242,#243,#244,#245,#246,#247));
#226= IFCCARTESIANPOINT((37.601,-3.889,-0.300));
#227= IFCCARTESIANPOINT((38.992,-4.114,-0.300));
#228= IFCCARTESIANPOINT((40.198,-4.226,-0.350));
#229= IFCCARTESIANPOINT((41.499,-4.226,-0.350));
#230= IFCCARTESIANPOINT((43.076,-4.446,-0.350));
#231= IFCCARTESIANPOINT((43.865,-4.446,-0.350));
#232= IFCCARTESIANPOINT((47.020,-4.446,-0.350));
#233= IFCCARTESIANPOINT((50.175,-4.446,-0.350));
#234= IFCCARTESIANPOINT((53.330,-4.446,-0.350));
#235= IFCCARTESIANPOINT((56.485,-4.446,-0.350));
#236= IFCCARTESIANPOINT((59.640,-4.446,-0.350));
#237= IFCCARTESIANPOINT((70.359,-4.446,-0.350));
#238= IFCCARTESIANPOINT((73.514,-4.446,-0.350));
#239= IFCCARTESIANPOINT((76.669,-4.446,-0.350));
#240= IFCCARTESIANPOINT((79.824,-4.446,-0.350));
#241= IFCCARTESIANPOINT((82.979,-4.446,-0.350));
```

```
#242= IFCCARTESIANPOINT((86.134,-4.446,-0.350));
#243= IFCCARTESIANPOINT((86.924,-4.446,-0.350));
#244= IFCCARTESIANPOINT((88.501,-4.226,-0.350));
#245= IFCCARTESIANPOINT((89.802,-4.226,-0.350));
#246= IFCCARTESIANPOINT((91.008,-4.114,-0.300));
#247= IFCCARTESIANPOINT((92.399,-3.889,-0.300));

#251= IFCTENDON('0000000000000000000251',$,'F0409N',$,$,#17,#252,$,$,$,$,$,$,$,$,$,$);
#252= IFCPRODUCTDEFINITIONSHAPE($,$,(#253));
#253= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#254));
#254= IFCSWEPTDISKSOLID(#255,0.03,$,$,$);
#255= IFCPOLYLINE((#256,#257,#258,#259,#260,#261,#262,#263,#264,#265,#266,#267,#268,#269,#270,#271,#272,#273,#274,#275,#276,#277));
#256= IFCCARTESIANPOINT((34.446,-3.889,-0.300));
#257= IFCCARTESIANPOINT((35.837,-4.114,-0.300));
#258= IFCCARTESIANPOINT((37.043,-4.226,-0.150));
#259= IFCCARTESIANPOINT((37.555,-4.226,-0.150));
#260= IFCCARTESIANPOINT((40.710,-4.226,-0.150));
#261= IFCCARTESIANPOINT((43.865,-4.226,-0.150));
#262= IFCCARTESIANPOINT((47.020,-4.226,-0.150));
#263= IFCCARTESIANPOINT((50.175,-4.226,-0.150));
#264= IFCCARTESIANPOINT((53.330,-4.226,-0.150));
#265= IFCCARTESIANPOINT((56.485,-4.226,-0.150));
#266= IFCCARTESIANPOINT((59.640,-4.226,-0.150));
#267= IFCCARTESIANPOINT((70.359,-4.226,-0.150));
#268= IFCCARTESIANPOINT((73.514,-4.226,-0.150));
#269= IFCCARTESIANPOINT((76.669,-4.226,-0.150));
#270= IFCCARTESIANPOINT((79.824,-4.226,-0.150));
#271= IFCCARTESIANPOINT((82.979,-4.226,-0.150));
#272= IFCCARTESIANPOINT((86.134,-4.226,-0.150));
#273= IFCCARTESIANPOINT((89.289,-4.226,-0.150));
#274= IFCCARTESIANPOINT((92.444,-4.226,-0.150));
#275= IFCCARTESIANPOINT((92.957,-4.226,-0.150));
#276= IFCCARTESIANPOINT((94.163,-4.114,-0.300));
#277= IFCCARTESIANPOINT((95.554,-3.889,-0.300));

#281= IFCTENDON('0000000000000000000281',$,'F0410N',$,$,#17,#282,$,$,$,$,$,$,$,$,$,$);
```

```
#282= IFCPRODUCTDEFINITIONSHAPE($,$,(#283));
#283= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#284));
#284= IFCSWEPTDISKSOLID(#285,0.03,$,$,$);
#285= IFCPOLYLINE((#286,#287,#288,#289,#290,#291,#292,#293,#294,#295,#296,#297,#298,#299,#300,#301,#302,#303,#304,#305,#306,#307,#308,#309,#310,#311));
#286= IFCCARTESIANPOINT((31.291,-3.889,-0.300));
#287= IFCCARTESIANPOINT((32.585,-4.098,-0.300));
#288= IFCCARTESIANPOINT((33.792,-4.184,-0.150));
#289= IFCCARTESIANPOINT((35.452,-4.299,-0.150));
#290= IFCCARTESIANPOINT((37.028,-4.446,-0.150));
#291= IFCCARTESIANPOINT((37.555,-4.446,-0.150));
#292= IFCCARTESIANPOINT((40.710,-4.446,-0.150));
#293= IFCCARTESIANPOINT((43.865,-4.446,-0.150));
#294= IFCCARTESIANPOINT((47.020,-4.446,-0.150));
#295= IFCCARTESIANPOINT((50.175,-4.446,-0.150));
#296= IFCCARTESIANPOINT((53.330,-4.446,-0.150));
#297= IFCCARTESIANPOINT((56.485,-4.446,-0.150));
#298= IFCCARTESIANPOINT((59.640,-4.446,-0.150));
#299= IFCCARTESIANPOINT((70.359,-4.446,-0.150));
#300= IFCCARTESIANPOINT((73.514,-4.446,-0.150));
#301= IFCCARTESIANPOINT((76.669,-4.446,-0.150));
#302= IFCCARTESIANPOINT((79.824,-4.446,-0.150));
#303= IFCCARTESIANPOINT((82.979,-4.446,-0.150));
#304= IFCCARTESIANPOINT((86.134,-4.446,-0.150));
#305= IFCCARTESIANPOINT((89.289,-4.446,-0.150));
#306= IFCCARTESIANPOINT((92.444,-4.446,-0.150));
#307= IFCCARTESIANPOINT((92.972,-4.446,-0.150));
#308= IFCCARTESIANPOINT((94.548,-4.299,-0.150));
#309= IFCCARTESIANPOINT((96.208,-4.184,-0.150));
#310= IFCCARTESIANPOINT((97.415,-4.098,-0.300));
#311= IFCCARTESIANPOINT((98.709,-3.889,-0.300));

#321= IFCTENDON('0000000000000000000321',$,'F0411N',$,$,#17,#322,$,$,$,$,$,$,$,$,$,$);
#322= IFCPRODUCTDEFINITIONSHAPE($,$,(#323));
#323= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#324));
#324= IFCSWEPTDISKSOLID(#325,0.03,$,$,$);
```

```
#325= IFCPOLYLINE((#326,#327,#328,#329,#330,#331,#332,#333,#334,#335,#336,#337,#338,#339,#340,#341,#342,#343,#344,#345,#346,#347,#348,#349,#350,#351));
#326= IFCCARTESIANPOINT((28.136,-3.889,-0.300));
#327= IFCCARTESIANPOINT((29.430,-4.098,-0.300));
#328= IFCCARTESIANPOINT((30.637,-4.184,-0.150));
#329= IFCCARTESIANPOINT((35.452,-4.519,-0.150));
#330= IFCCARTESIANPOINT((37.028,-4.666,-0.150));
#331= IFCCARTESIANPOINT((37.555,-4.666,-0.150));
#332= IFCCARTESIANPOINT((40.710,-4.666,-0.150));
#333= IFCCARTESIANPOINT((43.865,-4.666,-0.150));
#334= IFCCARTESIANPOINT((47.020,-4.666,-0.150));
#335= IFCCARTESIANPOINT((50.175,-4.666,-0.150));
#336= IFCCARTESIANPOINT((53.330,-4.666,-0.150));
#337= IFCCARTESIANPOINT((56.485,-4.666,-0.150));
#338= IFCCARTESIANPOINT((59.640,-4.666,-0.150));
#339= IFCCARTESIANPOINT((70.359,-4.666,-0.150));
#340= IFCCARTESIANPOINT((73.514,-4.666,-0.150));
#341= IFCCARTESIANPOINT((76.669,-4.666,-0.150));
#342= IFCCARTESIANPOINT((79.824,-4.666,-0.150));
#343= IFCCARTESIANPOINT((82.979,-4.666,-0.150));
#344= IFCCARTESIANPOINT((86.134,-4.666,-0.150));
#345= IFCCARTESIANPOINT((89.289,-4.666,-0.150));
#346= IFCCARTESIANPOINT((92.444,-4.666,-0.150));
#347= IFCCARTESIANPOINT((92.972,-4.666,-0.150));
#348= IFCCARTESIANPOINT((94.548,-4.519,-0.150));
#349= IFCCARTESIANPOINT((99.363,-4.184,-0.150));
#350= IFCCARTESIANPOINT((100.570,-4.098,-0.300));
#351= IFCCARTESIANPOINT((101.864,-3.889,-0.300));

#361= IFCTENDON('0000000000000000000361',$,'F0412N',$,$,#17,#362,$,$,$,$,$,$,$,$,$,$);
#362= IFCPRODUCTDEFINITIONSHAPE($,$,(#363));
#363= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#364));
#364= IFCSWEPTDISKSOLID(#365,0.03,$,$,$);
#365= IFCPOLYLINE((#366,#367,#368,#369,#370,#371,#372,#373,#374,#375,#376,#377,#378,#379,#380,#381,#382,#383,#384,#385,#386,#387,#388,#389,#390,#391));
#366= IFCCARTESIANPOINT((24.981,-3.889,-0.300));
#367= IFCCARTESIANPOINT((26.275,-4.098,-0.300));
```

```
#368= IFCCARTESIANPOINT((27.482,-4.184,-0.150));
#369= IFCCARTESIANPOINT((35.452,-4.739,-0.150));
#370= IFCCARTESIANPOINT((37.028,-4.886,-0.150));
#371= IFCCARTESIANPOINT((37.555,-4.886,-0.150));
#372= IFCCARTESIANPOINT((40.710,-4.886,-0.150));
#373= IFCCARTESIANPOINT((43.865,-4.886,-0.150));
#374= IFCCARTESIANPOINT((47.020,-4.886,-0.150));
#375= IFCCARTESIANPOINT((50.175,-4.886,-0.150));
#376= IFCCARTESIANPOINT((53.330,-4.886,-0.150));
#377= IFCCARTESIANPOINT((56.485,-4.886,-0.150));
#378= IFCCARTESIANPOINT((59.640,-4.886,-0.150));
#379= IFCCARTESIANPOINT((70.359,-4.886,-0.150));
#380= IFCCARTESIANPOINT((73.514,-4.886,-0.150));
#381= IFCCARTESIANPOINT((76.669,-4.886,-0.150));
#382= IFCCARTESIANPOINT((79.824,-4.886,-0.150));
#383= IFCCARTESIANPOINT((82.979,-4.886,-0.150));
#384= IFCCARTESIANPOINT((86.134,-4.886,-0.150));
#385= IFCCARTESIANPOINT((89.289,-4.886,-0.150));
#386= IFCCARTESIANPOINT((92.444,-4.886,-0.150));
#387= IFCCARTESIANPOINT((92.972,-4.886,-0.150));
#388= IFCCARTESIANPOINT((94.548,-4.739,-0.150));
#389= IFCCARTESIANPOINT((102.518,-4.184,-0.150));
#390= IFCCARTESIANPOINT((103.725,-4.098,-0.300));
#391= IFCCARTESIANPOINT((105.019,-3.889,-0.300));

#401= IFCTENDON('0000000000000000000401',$,'F0413N',$,$,#17,#402,$,$,$,$,$,$,$,$,$,$);
#402= IFCPRODUCTDEFINITIONSHAPE($,$,(#403));
#403= IFCSHAPEREPRESENTATION(#2,‘Body’,’AdvancedSweptSolid’,(#404));
#404= IFCSWEPTDISKSOLID(#405,0.03,$,$,$);
#405= IFCPOL-
YLINE((#406,#407,#408,#409,#410,#411,#412,#413,#414,#415,#416,#417,#418,#419,#420,#421,#422,#423,#
424,#425,#426,#427,#428,#429,#430,#431));
#406= IFCCARTESIANPOINT((21.826,-3.889,-0.300));
#407= IFCCARTESIANPOINT((23.120,-4.098,-0.300));
#408= IFCCARTESIANPOINT((24.327,-4.184,-0.150));
#409= IFCCARTESIANPOINT((35.452,-4.959,-0.150));
#410= IFCCARTESIANPOINT((37.028,-5.106,-0.150));
#411= IFCCARTESIANPOINT((37.555,-5.106,-0.150));
```

```
#412= IFCCARTESIANPOINT((40.710,-5.106,-0.150));
#413= IFCCARTESIANPOINT((43.865,-5.106,-0.150));
#414= IFCCARTESIANPOINT((47.020,-5.106,-0.150));
#415= IFCCARTESIANPOINT((50.175,-5.106,-0.150));
#416= IFCCARTESIANPOINT((53.330,-5.106,-0.150));
#417= IFCCARTESIANPOINT((56.485,-5.106,-0.150));
#418= IFCCARTESIANPOINT((59.640,-5.106,-0.150));
#419= IFCCARTESIANPOINT((70.359,-5.106,-0.150));
#420= IFCCARTESIANPOINT((73.514,-5.106,-0.150));
#421= IFCCARTESIANPOINT((76.669,-5.106,-0.150));
#422= IFCCARTESIANPOINT((79.824,-5.106,-0.150));
#423= IFCCARTESIANPOINT((82.979,-5.106,-0.150));
#424= IFCCARTESIANPOINT((86.134,-5.106,-0.150));
#425= IFCCARTESIANPOINT((89.289,-5.106,-0.150));
#426= IFCCARTESIANPOINT((92.444,-5.106,-0.150));
#427= IFCCARTESIANPOINT((92.972,-5.106,-0.150));
#428= IFCCARTESIANPOINT((94.548,-4.959,-0.150));
#429= IFCCARTESIANPOINT((105.673,-4.184,-0.150));
#430= IFCCARTESIANPOINT((106.880,-4.098,-0.300));
#431= IFCCARTESIANPOINT((108.174,-3.889,-0.300));

#441= IFCTENDON('0000000000000000000441',$,'F0414N',$,$,#17,#442,$,$,$,$,$,$,$,$,$,$);
#442= IFCPRODUCTDEFINITIONSHAPE($,$,(#443));
#443= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#444));
#444= IFCSWEPTDISKSOLID(#445,0.03,$,$,$);
#445= IFCPOLYLINE((#446,#447,#448,#449,#450,#451,#452,#453,#454,#455,#456,#457,#458,#459,#460,#461,#462,#463,#464,#465,#466,#467,#468,#469,#470,#471));
#446= IFCCARTESIANPOINT((18.671,-3.889,-0.300));
#447= IFCCARTESIANPOINT((19.965,-4.098,-0.300));
#448= IFCCARTESIANPOINT((21.172,-4.184,-0.150));
#449= IFCCARTESIANPOINT((35.452,-5.179,-0.150));
#450= IFCCARTESIANPOINT((37.028,-5.326,-0.150));
#451= IFCCARTESIANPOINT((37.555,-5.326,-0.150));
#452= IFCCARTESIANPOINT((40.710,-5.326,-0.150));
#453= IFCCARTESIANPOINT((43.865,-5.326,-0.150));
#454= IFCCARTESIANPOINT((47.020,-5.326,-0.150));
#455= IFCCARTESIANPOINT((50.175,-5.326,-0.150));
```

```
#456= IFCCARTESIANPOINT((53.330,-5.326,-0.150));
#457= IFCCARTESIANPOINT((56.485,-5.326,-0.150));
#458= IFCCARTESIANPOINT((59.640,-5.326,-0.150));
#459= IFCCARTESIANPOINT((70.359,-5.326,-0.150));
#460= IFCCARTESIANPOINT((73.514,-5.326,-0.150));
#461= IFCCARTESIANPOINT((76.669,-5.326,-0.150));
#462= IFCCARTESIANPOINT((79.824,-5.326,-0.150));
#463= IFCCARTESIANPOINT((82.979,-5.326,-0.150));
#464= IFCCARTESIANPOINT((86.134,-5.326,-0.150));
#465= IFCCARTESIANPOINT((89.289,-5.326,-0.150));
#466= IFCCARTESIANPOINT((92.444,-5.326,-0.150));
#467= IFCCARTESIANPOINT((92.972,-5.326,-0.150));
#468= IFCCARTESIANPOINT((94.548,-5.179,-0.150));
#469= IFCCARTESIANPOINT((108.828,-4.184,-0.150));
#470= IFCCARTESIANPOINT((110.035,-4.098,-0.300));
#471= IFCCARTESIANPOINT((111.329,-3.889,-0.300));

#481= IFCTENDON('0000000000000000000481',$,'F0415N',$,$,#17,#482,$,$,$,$,$,$,$,$,$,$);
#482= IFCPRODUCTDEFINITIONSHAPE($,$,(#483));
#483= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#484));
#484= IFCSWEPTDISKSOLID(#485,0.03,$,$,$);
#485= IFCPOLYLINE((#486,#487,#488,#489,#490,#491,#492,#493,#494,#495,#496,#497,#498,#499,#500,#501,#502,#503,#504,#505,#506,#507,#508,#509,#510,#511));
#486= IFCCARTESIANPOINT((15.141,-3.889,-0.300));
#487= IFCCARTESIANPOINT((16.522,-4.112,-0.300));
#488= IFCCARTESIANPOINT((17.926,-4.177,-0.150));
#489= IFCCARTESIANPOINT((35.452,-5.399,-0.150));
#490= IFCCARTESIANPOINT((37.028,-5.546,-0.150));
#491= IFCCARTESIANPOINT((37.555,-5.546,-0.150));
#492= IFCCARTESIANPOINT((40.710,-5.546,-0.150));
#493= IFCCARTESIANPOINT((43.865,-5.546,-0.150));
#494= IFCCARTESIANPOINT((47.020,-5.546,-0.150));
#495= IFCCARTESIANPOINT((50.175,-5.546,-0.150));
#496= IFCCARTESIANPOINT((53.330,-5.546,-0.150));
#497= IFCCARTESIANPOINT((56.485,-5.546,-0.150));
#498= IFCCARTESIANPOINT((59.640,-5.546,-0.150));
#499= IFCCARTESIANPOINT((70.359,-5.546,-0.150));
```

```
#500= IFCCARTESIANPOINT((73.514,-5.546,-0.150));
#501= IFCCARTESIANPOINT((76.669,-5.546,-0.150));
#502= IFCCARTESIANPOINT((79.824,-5.546,-0.150));
#503= IFCCARTESIANPOINT((82.979,-5.546,-0.150));
#504= IFCCARTESIANPOINT((86.134,-5.546,-0.150));
#505= IFCCARTESIANPOINT((89.289,-5.546,-0.150));
#506= IFCCARTESIANPOINT((92.444,-5.546,-0.150));
#507= IFCCARTESIANPOINT((92.972,-5.546,-0.150));
#508= IFCCARTESIANPOINT((94.548,-5.399,-0.150));
#509= IFCCARTESIANPOINT((112.074,-4.177,-0.150));
#510= IFCCARTESIANPOINT((113.478,-4.112,-0.300));
#511= IFCCARTESIANPOINT((114.859,-3.889,-0.300));

#521= IFCTENDON('0000000000000000000521',$,'F0416N',$,$,#17,#522,$,$,$,$,$,$,$,$,$,$);
#522= IFCPRODUCTDEFINITIONSHAPE($,$,(#523));
#523= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#524));
#524= IFCSWEPTDISKSOLID(#525,0.03,$,$,$);
#525= IFCPOLYLINE((#526,#527,#528,#529,#530,#531,#532,#533,#534,#535,#536,#537,#538,#539,#540,#541,#542,#543,#544,#545,#546,#547,#548,#549,#550,#551,#552,#553,#554,#555));
#526= IFCCARTESIANPOINT((11.611,-3.889,-0.300));
#527= IFCCARTESIANPOINT((12.997,-4.113,-0.300));
#528= IFCCARTESIANPOINT((14.398,-4.183,-0.150));
#529= IFCCARTESIANPOINT((16.272,-4.299,-0.150));
#530= IFCCARTESIANPOINT((18.037,-4.405,-0.150));
#531= IFCCARTESIANPOINT((35.452,-5.619,-0.150));
#532= IFCCARTESIANPOINT((37.028,-5.766,-0.150));
#533= IFCCARTESIANPOINT((37.555,-5.766,-0.150));
#534= IFCCARTESIANPOINT((40.710,-5.766,-0.150));
#535= IFCCARTESIANPOINT((43.865,-5.766,-0.150));
#536= IFCCARTESIANPOINT((47.020,-5.766,-0.150));
#537= IFCCARTESIANPOINT((50.175,-5.766,-0.150));
#538= IFCCARTESIANPOINT((53.330,-5.766,-0.150));
#539= IFCCARTESIANPOINT((56.485,-5.766,-0.150));
#540= IFCCARTESIANPOINT((59.640,-5.766,-0.150));
#541= IFCCARTESIANPOINT((70.359,-5.766,-0.150));
#542= IFCCARTESIANPOINT((73.514,-5.766,-0.150));
#543= IFCCARTESIANPOINT((76.669,-5.766,-0.150));
```

```
#544= IFCCARTESIANPOINT((79.824,-5.766,-0.150));
#545= IFCCARTESIANPOINT((82.979,-5.766,-0.150));
#546= IFCCARTESIANPOINT((86.134,-5.766,-0.150));
#547= IFCCARTESIANPOINT((89.289,-5.766,-0.150));
#548= IFCCARTESIANPOINT((92.444,-5.766,-0.150));
#549= IFCCARTESIANPOINT((92.972,-5.766,-0.150));
#550= IFCCARTESIANPOINT((94.548,-5.619,-0.150));
#551= IFCCARTESIANPOINT((111.963,-4.405,-0.150));
#552= IFCCARTESIANPOINT((113.728,-4.299,-0.150));
#553= IFCCARTESIANPOINT((115.603,-4.183,-0.150));
#554= IFCCARTESIANPOINT((117.003,-4.113,-0.300));
#555= IFCCARTESIANPOINT((118.389,-3.889,-0.300));


#561= IFCTENDON('0000000000000000000561',$,'F0417N',$,$,#17,#562,$,$,$,$,$,$,$,$,$,$);
#562= IFCPRODUCTDEFINITIONSHAPE($,$,(#563));
#563= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#564));
#564= IFCSWEPTDISKSOLID(#565,0.03,$,$,$);
#565= IFCPOLYLINE((#566,#567,#568,#569,#570,#571,#572,#573,#574,#575,#576,#577,#578,#579,#580,#581,#582,#583,#584,#585,#586,#587,#588,#589,#590,#591,#592,#593,#594,#595));
#566= IFCCARTESIANPOINT((8.081,-3.889,-0.300));
#567= IFCCARTESIANPOINT((9.467,-4.113,-0.300));
#568= IFCCARTESIANPOINT((10.868,-4.183,-0.150));
#569= IFCCARTESIANPOINT((16.272,-4.519,-0.150));
#570= IFCCARTESIANPOINT((18.037,-4.625,-0.150));
#571= IFCCARTESIANPOINT((35.452,-5.839,-0.150));
#572= IFCCARTESIANPOINT((37.028,-5.986,-0.150));
#573= IFCCARTESIANPOINT((37.555,-5.986,-0.150));
#574= IFCCARTESIANPOINT((40.710,-5.986,-0.150));
#575= IFCCARTESIANPOINT((43.865,-5.986,-0.150));
#576= IFCCARTESIANPOINT((47.020,-5.986,-0.150));
#577= IFCCARTESIANPOINT((50.175,-5.986,-0.150));
#578= IFCCARTESIANPOINT((53.330,-5.986,-0.150));
#579= IFCCARTESIANPOINT((56.485,-5.986,-0.150));
#580= IFCCARTESIANPOINT((59.640,-5.986,-0.150));
#581= IFCCARTESIANPOINT((70.359,-5.986,-0.150));
#582= IFCCARTESIANPOINT((73.514,-5.986,-0.150));
#583= IFCCARTESIANPOINT((76.669,-5.986,-0.150));
```

```
#584= IFCCARTESIANPOINT((79.824,-5.986,-0.150));
#585= IFCCARTESIANPOINT((82.979,-5.986,-0.150));
#586= IFCCARTESIANPOINT((86.134,-5.986,-0.150));
#587= IFCCARTESIANPOINT((89.289,-5.986,-0.150));
#588= IFCCARTESIANPOINT((92.444,-5.986,-0.150));
#589= IFCCARTESIANPOINT((92.972,-5.986,-0.150));
#590= IFCCARTESIANPOINT((94.548,-5.839,-0.150));
#591= IFCCARTESIANPOINT((111.963,-4.625,-0.150));
#592= IFCCARTESIANPOINT((113.728,-4.519,-0.150));
#593= IFCCARTESIANPOINT((119.132,-4.183,-0.150));
#594= IFCCARTESIANPOINT((120.533,-4.113,-0.300));
#595= IFCCARTESIANPOINT((121.919,-3.889,-0.300));

#601= IFCTENDON('0000000000000000000601',$,'C0101N',$,$,#17,#602,$,$,$,$,$,$,$,$,$,$);
#602= IFCPRODUCTDEFINITIONSHAPE($,$,(#603));
#603= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#604));
#604= IFCSWEPTDISKSOLID(#605,0.03,$,$,$);
#605= IFCPOLYLINE((#606,#607,#608,#609,#610,#611,#612,#613,#614,#615,#616,#617,#618));
#606= IFCCARTESIANPOINT((0.399,-3.133,-2.674));
#607= IFCCARTESIANPOINT((1.668,-3.100,-2.850));
#608= IFCCARTESIANPOINT((2.400,-3.100,-2.850));
#609= IFCCARTESIANPOINT((4.255,-3.100,-2.850));
#610= IFCCARTESIANPOINT((4.505,-3.100,-2.850));
#611= IFCCARTESIANPOINT((8.035,-3.096,-2.868));            /* fin V17 */
#612= IFCCARTESIANPOINT((11.565,-3.086,-2.920));           /* fin V16 */
#613= IFCCARTESIANPOINT((15.095,-3.069,-3.006));           /* fin V15 */
#614= IFCCARTESIANPOINT((18.625,-3.045,-3.126));           /* fin V14 */
#615= IFCCARTESIANPOINT((21.780,-3.018,-3.262));           /* fin V13 */
#616= IFCCARTESIANPOINT((24.935,-2.985,-3.425));           /* fin V12 */
#617= IFCCARTESIANPOINT((25.938,-2.973,-3.485));
#618= IFCCARTESIANPOINT((27.245,-2.654,-2.960));

#621= IFCTENDON('0000000000000000000621',$,'C0102N',$,$,#17,#622,$,$,$,$,$,$,$,$,$,$);
#622= IFCPRODUCTDEFINITIONSHAPE($,$,(#623));
#623= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#624));
#624= IFCSWEPTDISKSOLID(#625,0.03,$,$,$);
#625= IFCPOLYLINE((#626,#627,#628,#629,#630,#631,#632,#633,#634,#635,#636,#637,#638,#639,#640,#641,#642,#643));
```

```
#626= IFCCARTESIANPOINT((0.399,-2.639,-2.674));
#627= IFCCARTESIANPOINT((1.668,-2.672,-2.850));
#628= IFCCARTESIANPOINT((2.400,-2.672,-2.850));
#629= IFCCARTESIANPOINT((4.255,-2.672,-2.850));
#630= IFCCARTESIANPOINT((4.505,-2.672,-2.850));
#631= IFCCARTESIANPOINT((8.035,-2.672,-2.868));          /* fin V17 */
#632= IFCCARTESIANPOINT((11.565,-2.658,-2.920));          /* fin V16 */
#633= IFCCARTESIANPOINT((15.095,-2.641,-3.006));          /* fin V15 */
#634= IFCCARTESIANPOINT((18.625,-2.617,-3.126));          /* fin V14 */
#635= IFCCARTESIANPOINT((19.414,-2.610,-3.160));
#636= IFCCARTESIANPOINT((20.991,-2.810,-3.228));
#637= IFCCARTESIANPOINT((21.780,-2.804,-3.262));          /* fin V13 */
#638= IFCCARTESIANPOINT((24.935,-2.771,-3.425));          /* fin V12 */
#639= IFCCARTESIANPOINT((25.917,-2.759,-3.484));
#640= IFCCARTESIANPOINT((27.368,-2.956,-3.571));
#641= IFCCARTESIANPOINT((28.090,-2.947,-3.615));
#642= IFCCARTESIANPOINT((29.084,-2.933,-3.683));
#643= IFCCARTESIANPOINT((30.400,-2.615,-3.157));

#651= IFCTENDON('0000000000000000000651',$,'CS0118N',$,$,#17,#652,$,$,$,$,$,$,$,$,$,$);
#652= IFCPRODUCTDEFINITIONSHAPE($,$,(#653));
#653= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#654));
#654= IFCSWEPTDISKSOLID(#655,0.03,$,$,$);
#655= IFCPOLYLINE((#656,#657,#658,#659,#660,#661,#662,#663,#664,#665,#666,#667));
#656= IFCCARTESIANPOINT((0.397,-3.581,-0.616));
#657= IFCCARTESIANPOINT((1.455,-3.581,-0.350));
#658= IFCCARTESIANPOINT((2.100,-3.581,-0.350));
#659= IFCCARTESIANPOINT((4.255,-3.581,-0.350));
#660= IFCCARTESIANPOINT((4.505,-3.581,-0.350));
#661= IFCCARTESIANPOINT((8.035,-3.581,-0.350));          /* fin V17 */
#662= IFCCARTESIANPOINT((11.565,-3.581,-0.350));          /* fin V16 */
#663= IFCCARTESIANPOINT((15.095,-3.581,-0.350));          /* fin V15 */
#664= IFCCARTESIANPOINT((18.625,-3.581,-0.350));          /* fin V14 */
#665= IFCCARTESIANPOINT((21.780,-3.581,-0.350));          /* fin V13 */
#666= IFCCARTESIANPOINT((22.828,-3.581,-0.350));
#667= IFCCARTESIANPOINT((24.085,-3.218,-0.750));
```

```
#671= IFCTENDON('0000000000000000000671',$,'C0201N',$,$,#17,#672,$,$,$,$,$,$,$,$,$,$);
#672= IFCPRODUCTDEFINITIONSHAPE($,$,(#673));
#673= IFCSHAPEREPRESENTATION(#2,‘Body’,’AdvancedSweptSolid’,(#674));
#674= IFCSWEPTDISKSOLID(#675,0.03,$,$,$);
#675= IFCPOLYLINE((#676,#677,#678,#679,#680,#681));
#676= IFCCARTESIANPOINT((116.123,-2.762,-2.425));
#677= IFCCARTESIANPOINT((117.395,-3.081,-2.946));
#678= IFCCARTESIANPOINT((118.431,-3.086,-2.920));
#679= IFCCARTESIANPOINT((121.964,-3.096,-2.868));
#680= IFCCARTESIANPOINT((125.495,-3.100,-2.850));
#681= IFCCARTESIANPOINT((125.744,-3.100,-2.850));

#691= IFCTENDON('0000000000000000000691',$,'C0202N',$,$,#17,#692,$,$,$,$,$,$,$,$,$,$);
#692= IFCPRODUCTDEFINITIONSHAPE($,$,(#693));
#693= IFCSHAPEREPRESENTATION(#2,‘Body’,’AdvancedSweptSolid’,(#694));
#694= IFCSWEPTDISKSOLID(#695,0.03,$,$,$);
#695= IFCPOLYLINE((#696,#697,#698,#699,#700,#701,#702,#703,#704));
#696= IFCCARTESIANPOINT((112.593,-2.743,-2.520));
#697= IFCCARTESIANPOINT((113.875,-3.062,-3.041));
#698= IFCCARTESIANPOINT((114.905,-3.069,-3.006));
#699= IFCCARTESIANPOINT((115.704,-3.074,-2.979));
#700= IFCCARTESIANPOINT((117.306,-2.866,-2.948));
#701= IFCCARTESIANPOINT((118.431,-2.872,-2.920));
#702= IFCCARTESIANPOINT((121.964,-2.882,-2.868));
#703= IFCCARTESIANPOINT((125.495,-2.886,-2.850));
#704= IFCCARTESIANPOINT((125.744,-2.886,-2.850));

#711= IFCTENDON('0000000000000000000711',$,'C0203N',$,$,#17,#712,$,$,$,$,$,$,$,$,$,$);
#712= IFCPRODUCTDEFINITIONSHAPE($,$,(#713));
#713= IFCSHAPEREPRESENTATION(#2,‘Body’,’AdvancedSweptSolid’,(#714));
#714= IFCSWEPTDISKSOLID(#715,0.03,$,$,$);
#715= IFCPOLYLINE((#716,#717,#718,#719,#720,#721,#722,#723,#724,#725,#726,#727,#728,#729));
#716= IFCCARTESIANPOINT((102.755,-2.655,-2.955));
#717= IFCCARTESIANPOINT((104.064,-2.973,-3.485));
#718= IFCCARTESIANPOINT((105.065,-2.985,-3.425));
#719= IFCCARTESIANPOINT((108.220,-3.018,-3.262));
#720= IFCCARTESIANPOINT((109.009,-3.024,-3.228));
```

```
#721= IFCCARTESIANPOINT((110.586,-2.824,-3.160));
#722= IFCCARTESIANPOINT((111.375,-2.831,-3.126));
#723= IFCCARTESIANPOINT((112.187,-2.836,-3.098));
#724= IFCCARTESIANPOINT((113.799,-2.633,-3.044));
#725= IFCCARTESIANPOINT((114.905,-2.641,-3.006));
#726= IFCCARTESIANPOINT((118.431,-2.658,-2.920));
#727= IFCCARTESIANPOINT((121.964,-2.668,-2.868));
#728= IFCCARTESIANPOINT((125.495,-2.672,-2.850));
#729= IFCCARTESIANPOINT((125.744,-2.672,-2.850));

#731= IFCTENDON('0000000000000000000731',$,'C0204N',$,$,#17,#732,$,$,$,$,$,$,$,$,$,$);
#732= IFCPRODUCTDEFINITIONSHAPE($,$,(#733));
#733= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#734));
#734= IFCSWEPTDISKSOLID(#735,0.03,$,$,$);
#735= IFCPOLYLINE((#736,#737,#738,#739,#740,#741,#742,#743,#744,#745,#746,#747,#748));
#736= IFCCARTESIANPOINT((99.600,-2.615,-3.157));
#737= IFCCARTESIANPOINT((100.916,-2.933,-3.683));
#738= IFCCARTESIANPOINT((101.909,-2.947,-3.615));
#739= IFCCARTESIANPOINT((102.635,-2.956,-3.571));
#740= IFCCARTESIANPOINT((104.083,-3.187,-3.484));
#741= IFCCARTESIANPOINT((105.065,-3.199,-3.425));
#742= IFCCARTESIANPOINT((108.220,-3.232,-3.262));
#743= IFCCARTESIANPOINT((111.375,-3.259,-3.126));
#744= IFCCARTESIANPOINT((114.905,-3.283,-3.006));
#745= IFCCARTESIANPOINT((118.431,-3.300,-2.920));
#746= IFCCARTESIANPOINT((121.964,-3.310,-2.868));
#747= IFCCARTESIANPOINT((125.495,-3.314,-2.850));
#748= IFCCARTESIANPOINT((125.744,-3.314,-2.850));

#751= IFCTENDON('0000000000000000000751',$,'C0205N',$,$,#17,#752,$,$,$,$,$,$,$,$,$,$);
#752= IFCPRODUCTDEFINITIONSHAPE($,$,(#753));
#753= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#754));
#754= IFCSWEPTDISKSOLID(#755,0.03,$,$,$);
#755= IFCPOLYLINE((#756,#757,#758,#759,#760,#761,#762,#763,#764,#765,#766,#767,#768,#769,#770,#771));
#756= IFCCARTESIANPOINT((96.446,-2.570,-3.381));
#757= IFCCARTESIANPOINT((97.770,-2.888,-3.908));
#758= IFCCARTESIANPOINT((98.755,-2.905,-3.827));
```

```
#759= IFCCARTESIANPOINT((99.483,-2.914,-3.782));
#760= IFCCARTESIANPOINT((100.940,-2.720,-3.682));
#761= IFCCARTESIANPOINT((101.909,-2.733,-3.615));
#762= IFCCARTESIANPOINT((105.065,-2.771,-3.425));
#763= IFCCARTESIANPOINT((108.220,-2.804,-3.262));
#764= IFCCARTESIANPOINT((109.008,-2.810,-3.228));
#765= IFCCARTESIANPOINT((110.587,-2.360,-3.160));
#766= IFCCARTESIANPOINT((111.375,-2.367,-3.126));
#767= IFCCARTESIANPOINT((114.905,-2.391,-3.006));
#768= IFCCARTESIANPOINT((118.431,-2.408,-2.920));
#769= IFCCARTESIANPOINT((121.964,-2.418,-2.868));
#770= IFCCARTESIANPOINT((125.495,-2.422,-2.850));
#771= IFCCARTESIANPOINT((125.744,-2.422,-2.850));

#791= IFCTENDON('00000000000000000000000791',$,'C0206N',$,$,#17,#792,$,$,$,$,$,$,$,$,$,$);
#792= IFCPRODUCTDEFINITIONSHAPE($,$,(#793));
#793= IFCSHAPEREPRESENTATION(#2,’Body’,’AdvancedSweptSolid’,(#794));
#794= IFCSWEPTDISKSOLID(#795,0.03,$,$,$);
#795= IFCPOLYLINE((#796,#797,#798,#799,#800,#801,#802,#803));
#796= IFCCARTESIANPOINT((109.183,-2.720,-2.637));
#797= IFCCARTESIANPOINT((110.399,-3.062,-2.968));
#798= IFCCARTESIANPOINT((111.374,-3.071,-2.926));
#799= IFCCARTESIANPOINT((114.904,-3.095,-2.806));
#800= IFCCARTESIANPOINT((118.426,-3.112,-2.720));
#801= IFCCARTESIANPOINT((121.964,-3.122,-2.668));
#802= IFCCARTESIANPOINT((125.495,-3.126,-2.650));
#803= IFCCARTESIANPOINT((125.744,-3.126,-2.650));


/* Segments */

#1800= IFCCARTESIANPOINT((-7.000, 0.000));
#1801= IFCCARTESIANPOINT(( 0.000, 0.000));
#1802= IFCCARTESIANPOINT(( 0.000,-0.250));
#1803= IFCCARTESIANPOINT((-1.800,-0.250));
#1804= IFCCARTESIANPOINT((-3.250,-0.500));
#1805= IFCCARTESIANPOINT((-3.500,-1.000));
```

```
#1806= IFCCARTESIANPOINT((-3.100,-3.000));
#1807= IFCCARTESIANPOINT((-3.450,-3.000));
#1808= IFCCARTESIANPOINT((-3.845,-1.000));
#1809= IFCCARTESIANPOINT((-4.450,-0.500));
#1810= IFCCARTESIANPOINT((-6.400,-0.250));
#1811= IFCCARTESIANPOINT((-7.000,-0.250));
#1999= IFCPOLYLINE((#1800,#1801,#1802,#1803,#1804,#1805,#1806,#1807,#1808,#1809,#1810,#1811,#1800));

#2000= IFCSLAB('0000000000000000002000',$,'V0400E',$,$,#2003,#2014,$,$);
#2001= IFCCARTESIANPOINT((65.,0.,0.));
#2002= IFCAXIS2PLACEMENT3D(#2001,$,$);
#2003= IFCLOCALPLACEMENT($,#2002);
#2005= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2006= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2007= IFCEXTRUDEDAREASOLID(#2005,#2006,#2019,1.7);
#2008= IFCCOLOURRGB($,1.,0.,0.);
#2009= IFCSURFACESTYLERENDERING(#2008,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2010= IFCSURFACESTYLE('Post',.BOTH.,(#2009));
#2011= IFCPRESENTATIONSTYLEASSIGNMENT((#2010));
#2012= IFCSTYLEDITEM(#2007,(#2011),$);
#2013= IFCSHAPEREPRESENTATION(#2,‘Body’,‘SweptSolid’,(#2007));
#2014= IFCPRODUCTDEFINITIONSHAPE($,$,(#2013));
#2015= IFCCARTESIANPOINT((0.,0.,0.));
#2016= IFCDIRECTION((0.,1.,0.));
#2018= IFCDIRECTION((1.,0.,0.));
#2019= IFCDIRECTION((0.,0.,1.));

#2020= IFCSLAB('0000000000000000002020',$,'V0400W',$,$,#2023,#2034,$,$);
#2021= IFCCARTESIANPOINT((63.30,0.,0.));
#2022= IFCAXIS2PLACEMENT3D(#2021,$,$);
#2023= IFCLOCALPLACEMENT($,#2022);
#2025= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2026= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2027= IFCEXTRUDEDAREASOLID(#2025,#2026,#2019,1.7);
#2028= IFCCOLOURRGB($,0.,0.,1.);
```

```
#2029= IFCSURFACESTYLERENDERING(#2028,0.,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);

#2030= IFCSURFACESTYLE('Post',.BOTH.,(#2029));

#2031= IFCPRESENTATIONSTYLEASSIGNMENT((#2030));

#2032= IFCSTYLEDITEM(#2027,(#2031),$);

#2033= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2027));

#2034= IFCPRODUCTDEFINITIONSHAPE($,$,(#2033));


#2040= IFCSLAB('0000000000000000002040',$,'V0401E',$,$,#2043,#2054,$,$);

#2041= IFCCARTESIANPOINT((66.7,0.,0.));

#2042= IFCAXIS2PLACEMENT3D(#2041,$,$);

#2043= IFCLOCALPLACEMENT($,#2042);

#2045= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);

#2046= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);

#2047= IFCEXTRUDEDAREASOLID(#2045,#2046,#2019,3.659);

#2048= IFCCOLOURRGB($,0.,0.,1.);

#2049= IFCSURFACESTYLERENDERING(#2048,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);

#2050= IFCSURFACESTYLE('Post',.BOTH.,(#2049));

#2051= IFCPRESENTATIONSTYLEASSIGNMENT((#2050));

#2052= IFCSTYLEDITEM(#2047,(#2051),$);

#2053= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2047));

#2054= IFCPRODUCTDEFINITIONSHAPE($,$,(#2053));


#2060= IFCSLAB('0000000000000000002060',$,'V0402E',$,$,#2063,#2074,$,$);

#2061= IFCCARTESIANPOINT((70.36,0.,0.));

#2062= IFCAXIS2PLACEMENT3D(#2061,$,$);

#2063= IFCLOCALPLACEMENT($,#2062);

#2065= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);

#2066= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);

#2067= IFCEXTRUDEDAREASOLID(#2065,#2066,#2019,3.154);

#2068= IFCCOLOURRGB($,1.,0.,0.);

#2069= IFCSURFACESTYLERENDERING(#2068,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);

#2070= IFCSURFACESTYLE('Post',.BOTH.,(#2069));

#2071= IFCPRESENTATIONSTYLEASSIGNMENT((#2070));

#2072= IFCSTYLEDITEM(#2067,(#2071),$);

#2073= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2067));
```

```
#2074= IFCPRODUCTDEFINITIONSHAPE($,$,(#2073));


#2080= IFCSLAB('0000000000000000002080',$,'V0403E',$,$,#2083,#2094,$,$);
#2081= IFCCARTESIANPOINT((73.515,0.,0.));
#2082= IFCAXIS2PLACEMENT3D(#2081,$,$);
#2083= IFCLOCALPLACEMENT($,#2082);
#2085= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2086= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2087= IFCEXTRUDEDAREASOLID(#2085,#2086,#2019,3.154);
#2088= IFCCOLOURRGB($,0.,0.,1.);
#2089= IFCSURFACESTYLERENDERING(#2088,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2090= IFCSURFACESTYLE('Post',.BOTH.,(#2089));
#2091= IFCPRESENTATIONSTYLEASSIGNMENT((#2090));
#2092= IFCSTYLEDITEM(#2087,(#2091),$);
#2093= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2087));
#2094= IFCPRODUCTDEFINITIONSHAPE($,$,(#2093));


#2100= IFCSLAB('0000000000000000002100',$,'V0404E',$,$,#2103,#2114,$,$);
#2101= IFCCARTESIANPOINT((76.67,0.,0.));
#2102= IFCAXIS2PLACEMENT3D(#2101,$,$);
#2103= IFCLOCALPLACEMENT($,#2102);
#2105= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2106= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2107= IFCEXTRUDEDAREASOLID(#2105,#2106,#2019,3.154);
#2108= IFCCOLOURRGB($,1.,0.,0.);
#2109= IFCSURFACESTYLERENDERING(#2108,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2110= IFCSURFACESTYLE('Post',.BOTH.,(#2109));
#2111= IFCPRESENTATIONSTYLEASSIGNMENT((#2110));
#2112= IFCSTYLEDITEM(#2107,(#2111),$);
#2113= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2107));
#2114= IFCPRODUCTDEFINITIONSHAPE($,$,(#2113));


#2120= IFCSLAB('0000000000000000002120',$,'V0405E',$,$,#2123,#2134,$,$);
#2121= IFCCARTESIANPOINT((79.825,0.,0.));
#2122= IFCAXIS2PLACEMENT3D(#2121,$,$);
#2123= IFCLOCALPLACEMENT($,#2122);
```

```
#2125= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2126= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2127= IFCEXTRUDEDAREASOLID(#2125,#2126,#2019,3.154);
#2128= IFCCOLOURRGB($,0.,0.,1.);
#2129= IFCSURFACESTYLERENDERING(#2128,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2130= IFCSURFACESTYLE('Post',.BOTH.,(#2129));
#2131= IFCPRESENTATIONSTYLEASSIGNMENT((#2130));
#2132= IFCSTYLEDITEM(#2127,(#2131),$);
#2133= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2127));
#2134= IFCPRODUCTDEFINITIONSHAPE($,$,(#2133));

#2140= IFCSLAB('0000000000000000002140',$,'V0406E',$,$,#2143,#2154,$,$);
#2141= IFCCARTESIANPOINT((82.980,0.,0.));
#2142= IFCAXIS2PLACEMENT3D(#2141,$,$);
#2143= IFCLOCALPLACEMENT($,#2142);
#2145= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2146= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2147= IFCEXTRUDEDAREASOLID(#2145,#2146,#2019,3.154);
#2148= IFCCOLOURRGB($,1.,0.,0.);
#2149= IFCSURFACESTYLERENDERING(#2148,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2150= IFCSURFACESTYLE('Post',.BOTH.,(#2149));
#2151= IFCPRESENTATIONSTYLEASSIGNMENT((#2150));
#2152= IFCSTYLEDITEM(#2147,(#2151),$);
#2153= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2147));
#2154= IFCPRODUCTDEFINITIONSHAPE($,$,(#2153));

#2160= IFCSLAB('0000000000000000002160',$,'V0407E',$,$,#2163,#2174,$,$);
#2161= IFCCARTESIANPOINT((86.135,0.,0.));
#2162= IFCAXIS2PLACEMENT3D(#2161,$,$);
#2163= IFCLOCALPLACEMENT($,#2162);
#2165= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2166= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2167= IFCEXTRUDEDAREASOLID(#2165,#2166,#2019,3.154);
#2168= IFCCOLOURRGB($,0.,0.,1.);
#2169= IFCSURFACESTYLERENDERING(#2168,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
```

```
#2170= IFCSURFACESTYLE('Post',.BOTH.,(#2169));
#2171= IFCPRESENTATIONSTYLEASSIGNMENT((#2170));
#2172= IFCSTYLEDITEM(#2167,(#2171),$);
#2173= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2167));
#2174= IFCPRODUCTDEFINITIONSHAPE($,$,(#2173));

#2180= IFCSLAB('0000000000000000002180',$,'V0408E',$,$,#2183,#2194,$,$);
#2181= IFCCARTESIANPOINT((89.290,0.,0.));
#2182= IFCAXIS2PLACEMENT3D(#2181,$,$);
#2183= IFCLOCALPLACEMENT($,#2182);
#2185= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2186= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2187= IFCEXTRUDEDAREASOLID(#2185,#2186,#2019,3.154);
#2188= IFCCOLOURRGB($,1.,0.,0.);
#2189= IFCSURFACESTYLERENDERING(#2188,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2190= IFCSURFACESTYLE('Post',.BOTH.,(#2189));
#2191= IFCPRESENTATIONSTYLEASSIGNMENT((#2190));
#2192= IFCSTYLEDITEM(#2187,(#2191),$);
#2193= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2187));
#2194= IFCPRODUCTDEFINITIONSHAPE($,$,(#2193));

#2200= IFCSLAB('0000000000000000002200',$,'V0409E',$,$,#2203,#2214,$,$);
#2201= IFCCARTESIANPOINT((92.445,0.,0.));
#2202= IFCAXIS2PLACEMENT3D(#2201,$,$);
#2203= IFCLOCALPLACEMENT($,#2202);
#2205= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2206= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2207= IFCEXTRUDEDAREASOLID(#2205,#2206,#2019,3.154);
#2208= IFCCOLOURRGB($,0.,0.,1.);
#2209= IFCSURFACESTYLERENDERING(#2208,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2210= IFCSURFACESTYLE('Post',.BOTH.,(#2209));
#2211= IFCPRESENTATIONSTYLEASSIGNMENT((#2210));
#2212= IFCSTYLEDITEM(#2207,(#2211),$);
#2213= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2207));
#2214= IFCPRODUCTDEFINITIONSHAPE($,$,(#2213));
```

```
#2220= IFCSLAB('0000000000000000002220',$,'V0410E',$,$,#2223,#2234,$,$);
#2221= IFCCARTESIANPOINT((95.600,0.,0.));
#2222= IFCAXIS2PLACEMENT3D(#2221,$,$);
#2223= IFCLOCALPLACEMENT($,#2222);
#2225= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2226= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2227= IFCEXTRUDEDAREASOLID(#2225,#2226,#2019,3.154);
#2228= IFCCOLOURRGB($,1.,0.,0.);
#2229= IFCSURFACESTYLERENDERING(#2228,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2230= IFCSURFACESTYLE('Post',.BOTH.,(#2229));
#2231= IFCPRESENTATIONSTYLEASSIGNMENT((#2230));
#2232= IFCSTYLEDITEM(#2227,(#2231),$);
#2233= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2227));
#2234= IFCPRODUCTDEFINITIONSHAPE($,$,(#2233));

#2240= IFCSLAB('0000000000000000002240',$,'V0411E',$,$,#2243,#2254,$,$);
#2241= IFCCARTESIANPOINT((98.755,0.,0.));
#2242= IFCAXIS2PLACEMENT3D(#2241,$,$);
#2243= IFCLOCALPLACEMENT($,#2242);
#2245= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2246= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2247= IFCEXTRUDEDAREASOLID(#2245,#2246,#2019,3.154);
#2248= IFCCOLOURRGB($,0.,0.,1.);
#2249= IFCSURFACESTYLERENDERING(#2248,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2250= IFCSURFACESTYLE('Post',.BOTH.,(#2249));
#2251= IFCPRESENTATIONSTYLEASSIGNMENT((#2250));
#2252= IFCSTYLEDITEM(#2247,(#2251),$);
#2253= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2247));
#2254= IFCPRODUCTDEFINITIONSHAPE($,$,(#2253));

#2260= IFCSLAB('0000000000000000002260',$,'V0412E',$,$,#2263,#2274,$,$);
#2261= IFCCARTESIANPOINT((101.910,0.,0.));
#2262= IFCAXIS2PLACEMENT3D(#2261,$,$);
#2263= IFCLOCALPLACEMENT($,#2262);
#2265= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2266= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
```

```
#2267= IFCEXTRUDEDAREASOLID(#2265,#2266,#2019,3.154);
#2268= IFCCOLOURRGB($,1.,0.,0.);
#2269= IFCSURFACESTYLERENDERING(#2268,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2270= IFCSURFACESTYLE('Post',.BOTH.,(#2269));
#2271= IFCPRESENTATIONSTYLEASSIGNMENT((#2270));
#2272= IFCSTYLEDITEM(#2267,(#2271),$);
#2273= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2267));
#2274= IFCPRODUCTDEFINITIONSHAPE($,$,(#2273));

#2280= IFCSLAB('0000000000000000002280',$,'V0413E',$,$,#2283,#2294,$,$);
#2281= IFCCARTESIANPOINT((105.065,0.,0.));
#2282= IFCAXIS2PLACEMENT3D(#2281,$,$);
#2283= IFCLOCALPLACEMENT($,#2282);
#2285= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2286= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2287= IFCEXTRUDEDAREASOLID(#2285,#2286,#2019,3.154);
#2288= IFCCOLOURRGB($,0.,0.,1.);
#2289= IFCSURFACESTYLERENDERING(#2288,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2290= IFCSURFACESTYLE('Post',.BOTH.,(#2289));
#2291= IFCPRESENTATIONSTYLEASSIGNMENT((#2290));
#2292= IFCSTYLEDITEM(#2287,(#2291),$);
#2293= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2287));
#2294= IFCPRODUCTDEFINITIONSHAPE($,$,(#2293));

#2300= IFCSLAB('0000000000000000002300',$,'V0414E',$,$,#2303,#2314,$,$);
#2301= IFCCARTESIANPOINT((108.220,0.,0.));
#2302= IFCAXIS2PLACEMENT3D(#2301,$,$);
#2303= IFCLOCALPLACEMENT($,#2302);
#2305= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2306= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2307= IFCEXTRUDEDAREASOLID(#2305,#2306,#2019,3.154);
#2308= IFCCOLOURRGB($,1.,0.,0.);
#2309= IFCSURFACESTYLERENDERING(#2308,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2310= IFCSURFACESTYLE('Post',.BOTH.,(#2309));
#2311= IFCPRESENTATIONSTYLEASSIGNMENT((#2310));
```

```
#2312= IFCSTYLEDITEM(#2307,(#2311),$);
#2313= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2307));
#2314= IFCPRODUCTDEFINITIONSHAPE($,$,(#2313));

#2320= IFCSLAB('0000000000000000002320',$,'V0415E',$,$,#2323,#2334,$,$);
#2321= IFCCARTESIANPOINT((111.375,0.,0.));
#2322= IFCAXIS2PLACEMENT3D(#2321,$,$);
#2323= IFCLOCALPLACEMENT($,#2322);
#2325= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2326= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2327= IFCEXTRUDEDAREASOLID(#2325,#2326,#2019,3.529);
#2328= IFCCOLOURRGB($,0.,0.,1.);
#2329= IFCSURFACESTYLERENDERING(#2328,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2330= IFCSURFACESTYLE('Post',.BOTH.,(#2329));
#2331= IFCPRESENTATIONSTYLEASSIGNMENT((#2330));
#2332= IFCSTYLEDITEM(#2327,(#2331),$);
#2333= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2327));
#2334= IFCPRODUCTDEFINITIONSHAPE($,$,(#2333));

#2340= IFCSLAB('0000000000000000002340',$,'V0416E',$,$,#2343,#2354,$,$);
#2341= IFCCARTESIANPOINT((114.905,0.,0.));
#2342= IFCAXIS2PLACEMENT3D(#2341,$,$);
#2343= IFCLOCALPLACEMENT($,#2342);
#2345= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2346= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2347= IFCEXTRUDEDAREASOLID(#2345,#2346,#2019,3.529);
#2348= IFCCOLOURRGB($,1.,0.,0.);
#2349= IFCSURFACESTYLERENDERING(#2348,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2350= IFCSURFACESTYLE('Post',.BOTH.,(#2349));
#2351= IFCPRESENTATIONSTYLEASSIGNMENT((#2350));
#2352= IFCSTYLEDITEM(#2347,(#2351),$);
#2353= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2347));
#2354= IFCPRODUCTDEFINITIONSHAPE($,$,(#2353));

#2360= IFCSLAB('0000000000000000002360',$,'V0417E',$,$,#2363,#2374,$,$);
#2361= IFCCARTESIANPOINT((118.435,0.,0.));
```

```
#2362= IFCAXIS2PLACEMENT3D(#2361,$,$);
#2363= IFCLOCALPLACEMENT($,#2362);
#2365= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2366= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2367= IFCEXTRUDEDAREASOLID(#2365,#2366,#2019,3.529);
#2368= IFCCOLOURRGB($,0.,0.,1.);
#2369= IFCSURFACESTYLERENDERING(#2368,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2370= IFCSURFACESTYLE('Post',.BOTH.,(#2369));
#2371= IFCPRESENTATIONSTYLEASSIGNMENT((#2370));
#2372= IFCSTYLEDITEM(#2367,(#2371),$);
#2373= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2367));
#2374= IFCPRODUCTDEFINITIONSHAPE($,$,(#2373));

#2380= IFCSLAB('0000000000000000002380',$,'V0418E',$,$,#2383,#2394,$,$);
#2381= IFCCARTESIANPOINT((121.960,0.,0.));
#2382= IFCAXIS2PLACEMENT3D(#2381,$,$);
#2383= IFCLOCALPLACEMENT($,#2382);
#2385= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2386= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2387= IFCEXTRUDEDAREASOLID(#2385,#2386,#2019,3.529);
#2388= IFCCOLOURRGB($,1.,0.,0.);
#2389= IFCSURFACESTYLERENDERING(#2388,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2390= IFCSURFACESTYLE('Post',.BOTH.,(#2389));
#2391= IFCPRESENTATIONSTYLEASSIGNMENT((#2390));
#2392= IFCSTYLEDITEM(#2387,(#2391),$);
#2393= IFCSHAPEREPRESENTATION(#2,’Body’,’SweptSolid’,(#2387));
#2394= IFCPRODUCTDEFINITIONSHAPE($,$,(#2393));

#2400= IFCSLAB('0000000000000000002400',$,'CLA45E',$,$,#2403,#2414,$,$);
#2401= IFCCARTESIANPOINT((125.495,0.,0.));
#2402= IFCAXIS2PLACEMENT3D(#2401,$,$);
#2403= IFCLOCALPLACEMENT($,#2402);
#2405= IFCARBITRARYCLOSEDPROFILEDEF(.AREA.,’Chaussee Retab’,#1999);
#2406= IFCAXIS2PLACEMENT3D(#2015,#2018,#2016);
#2407= IFCEXTRUDEDAREASOLID(#2405,#2406,#2019,0.249);
#2408= IFCCOLOURRGB($,0.,0.,1.);
```

```
#2409= IFCSURFACESTYLERENDERING(#2408,0.9,$,$,$,$,IFCNORMALISEDRATIOMEASURE(0.5),IFCSPECULAREXPONENT(64.),.NOTDEFINED.);
#2410= IFCSURFACESTYLE('Post',.BOTH.,(#2409));
#2411= IFCPRESENTATIONSTYLEASSIGNMENT((#2410));
#2412= IFCSTYLEDITEM(#2407,(#2411),$);
#2413= IFCSHAPEREPRESENTATION(#2,‘Body’,’SweptSolid’,(#2407));
#2414= IFCPRODUCTDEFINITIONSHAPE($,$,(#2413));

ENDSEC;

END-ISO-10303-21;
```