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Data transformation from ASB-ING to IFC4x3: Development of a mapping schema

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Abstract

This thesis presents the development of a data mapping schema, designed to map data from ASB-ING to the IFC format. The innovation lies in the schema's ability to facilitate both automatic and manual modeling processes, leveraging data sourced from SIB-Bauwerke and grounded in ASB-ING standards. By employing this data, the thesis pioneers the construction of parameterized bridges within Revit, utilizing the Sofistik Bridge Modeler. This integration culminates in the bridges being cataloged and exported following the IFC4x3 standard, signifying a leap in interoperability of ASB-ING and IFC.

A significant breakthrough of this research is the automated schema implementation through the development of a bespoke Revit ASB-ING extension. This tool innovatively simplifies the bridge mapping process by automatically generating a model for four specific bridge types, upon the input of a structure number, using the Revit API alongside the Sofistik Bridge Modeler API, followed by its exportation as an IFC4 file. The extension, whose codebase is hosted on GitHub for public access, is designed with scalability and adaptability in mind, offering a robust foundation for future enhancements and customizations.

Zusammenfassung

In dieser Arbeit wird die Entwicklung eines Datenmapping-Schemas vorgestellt, mit dem Daten von ASB-ING auf das IFC-Format abgebildet werden können. Der Kern dieser Innovation liegt in der Fähigkeit des Schemas, sowohl automatische als auch manuelle Modellierungsprozesse zu ermöglichen, indem es Daten nutzt, die von SIB-Bauwerke bereitgestellt und die auf den ASB-ING-Standards basiert sind. Durch die Verwendung dieser Daten ebnet die Thesis den Weg für die Konstruktion parametrisierter Brücken in Revit, unter Einsatz des Sofistik Bridge Modelers. Diese Integration führt dazu, dass die Brücken gemäß dem IFC4x3 Schema katalogisiert und exportiert werden, was einen Fortschritt in Bezug auf die Interoperabilität zwischen ASB-ING und IFC darstellt.

Ein wesentlicher Durchbruch dieser Thesis ist die automatisierte Implementierung des Schemas durch die Entwicklung einer ASB-ING Revit-Erweiterung. Dieses Werkzeug vereinfacht den Prozess des Brückendatenmappings innovativ, indem es automatisch ein Modell für spezifische Brückentypen, mit Hilfe der Revit API und der Sofistik Bridge Modeler API, nach Eingabe einer Bauwerksnummer generiert und anschließend als IFC4-Datei exportiert. Die Erweiterung, deren Codebasis auf GitHub für die Öffentlichkeit zugänglich ist, ist mit Blick auf Skalierbarkeit und Anpassungsfähigkeit konzipiert und bietet eine solide Grundlage für zukünftige Erweiterungen und Anpassungen.

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Chapter 1

Introduction and motivation

1.1 Introduction

Industry Foundation Classes (IFC) and ASB-ING ("Anweisung Straßeninformationsbank Segment Bauwerksdaten") represent two pivotal, yet distinct, data systems within the construction and infrastructure sectors. IFC, an open global standard adopted widely, facilitates the exchange of digital information regarding building and construction projects across various countries. This neutral file format supports Building Information Modeling (BIM) by detailing the physical and functional characteristics of building elements, including their geometry, semantics, and interrelationships. Furthermore, the IFC standard has been extended with IfcAlignment and IfcBridge to better address the specific needs of infrastructure projects, especially bridges, enhancing its applicability and usefulness in civil engineering contexts.

In contrast, ASB-ING, a specific data structure used predominantly in Germany, manages the documentation of construction and inspection data for infrastructure elements such as bridges and tunnels. It emphasizes the maintenance and inspection aspects, encapsulating data in a structured textual and tabular format, exclusively utilized within the German infrastructure management framework, SIB-Bauwerke.

IFC's strength lies in its detailed description of relationships and functional interdependencies between building elements, which allows for a more accurate representation of bridges. Additionally, the IFC standard is better documented and internationally disseminated, making its instance data more usable and widely accepted across global projects. Despite IFC's increasing global role and ASB-ING's mainly regional focus, a seamless method for data conversion between these two systems is lacking. This disconnect poses a significant barrier to efficiency and interoperability in infrastructure projects, underscoring the necessity for a novel approach. This thesis addresses this gap by proposing an innovative data mapping scheme aimed at enhancing data integration and management for bridge data.

1.2 Research hypothesis

Infrastructure maintenance systems are becoming critically important, especially in regions like Germany, where approximately 45 percent of bridges were constructed before 1980, designed for a lighter traffic load than they currently endure (Göbels et al., 2023). As these aging structures face increasing demands, the necessity for enhanced maintenance becomes more important. The SIB-Bauwerke system, reliant on the ASB-ING format, primarily documents bridge damage through textual reports from manual inspections. Despite the widespread adoption of IFC in Building Information Modeling (BIM), many legacy systems, including SIB-Bauwerke, remain incompatible with modern standards like IFC. This incompatibility complicates data exchanges with BIM applications, increasing the likelihood of errors and the time required for data processing.

SIB-Bauwerke's reliance on the ASB-ING format further restricts comprehensive data analysis and predictive maintenance capabilities, thus hindering maintenance efficiency and effectiveness. Therefore, there is a critical need for research to develop effective methods for bridging these systems to ensure data interoperability, focusing on:

- **Data Mapping and Transformation Techniques:** Developing strategies to convert data from proprietary or non-standard formats like ASB-ING to IFC-compliant formats, addressing differences in data structures and semantics.
- **Automated Data Exchange/Mapping:** Exploring the creation of scripts, middleware, or APIs that facilitate seamless data transfer and mapping to minimize manual intervention and thereby enhance accuracy and efficiency.

Research in these areas can significantly contribute to modernizing bridge maintenance processes, enabling more precise and predictive maintenance strategies.

1.3 Thesis structure

This thesis is structured into three main sections, each designed to build upon the knowledge and findings of the previous one to present a comprehensive study on data interoperability and mapping between ASB-ING and IFC.

1. **Comparative Analysis of ASB-ING and IFC4x3:** This section critically examines the capabilities of ASB-ING and IFC4x3 standards in accurately depicting bridge structures. The evaluation focuses on assessing their suitability for storing structural bridge components.
2. **Development of a Mapping Schema:** Following the comparative analysis, this section introduces a mapping schema designed to facilitate the conversion of data from ASB-ING to the IFC4x3 format using the Sofistik Bridge Modeler. It details the schema's architecture, the specific challenges addressed in converting between these distinct formats, and the role of the Sofistik software in streamlining this process.
3. **Automation and Practical Application:** The final section explores the automation of the previously developed mapping schema. Utilizing Python for scripting data transformations and employing both the Revit API and the Sofistik Bridge Modeler

API, this part of the thesis presents an automated approach to bridge data mapping from ASB-ING to IFC. The effectiveness of this approach is then demonstrated through a real-world example.

Chapter 2

Literature review

2.1 Introduction

Choosing the right data systems for storing and handling bridge data is not merely a technical decision, but a strategic one that affects every phase of a bridge's lifecycle, from design through to decommissioning. The selection process must consider various factors, including the system's ability to handle complex datasets, compatibility with other industry-standard tools, and adaptability to future technological advancements.

This chapter delves into the specifics of two prominent data systems, ASB-ING and IFC4x3. The discussion is structured into three main parts.

1. **Related Work:** A review of existing literature and practices surrounding bridge data management to establish the context for comparing these systems.
2. **Introduction of ASB-ING and IFC4x3:** An analysis of how bridge data is stored, accessed, and utilized within both ASB-ING and IFC4x3 systems, especially focusing on structural components, highlighting their unique features and operational frameworks.
3. **Comparative Evaluation:** A detailed evaluation based on predefined criteria such as data interoperability and capability of bridge data representation. This section aims to determine which system offers better performance in the context of bridge data storage.

By examining these aspects, this chapter aims to provide a thorough understanding of how well each system meets the demands of storing modern bridge data, and which system might be more appropriate.

2.2 Related work

Related work was done by Aylin Taray in her master thesis "Systematic Evaluation of the IFC Data Model for Infrastructural Assets and BIM Use Cases" (TARAY, 2022). It discusses the transition from IFC2x3. to the new version, IFC4x3. The thesis explores the practical implications of this transition in two steps. First, it compares the documentation of IFC2x3 and IFC4x3 in terms of their suitability for transportation infrastructure. Second, it conducts a case study related to the Ümraniye-Ataşehir-Göztepe subway line in Istanbul, using an evaluation tool to assess data representation. The thesis shows that IFC will become increasingly important in the future and why IFC4x3 with its improvements, such as domain layer expansion, control extension and 4D planning, has become the new standard. For example, 4D planning plays an important role in improving bridge maintenance. Additionally, the introduction of IfcAlignment for linear infrastructure, like bridges, along with IfcBridge, is crucial in determining the most suitable system. These developments have laid the foundation for IFC4x3 to be even more superior to ASB-ING.

Further work was conducted by Anna Göbels in her two papers:
1. Conversion of infrastructure inspection data into Linked Data models (GÖBELS, 2021)
2. Enabling object-based documentation of existing bridge inspection data using Linked Data (GÖBELS, 2022)

The first paper proposes linked data methods to enhance management and analysis of maintenance and inspection data for bridge and tunnel structures, following the ASB-ING standard. This involves converting tabular data from the "SIB-Bauwerke" database into Linked Data models, which enrich information with standardized geometry and enable computer-aided analyses. The translation of ASB-ING into an ontology facilitates the creation of RDF graphs, fostering interoperability with other data sources while preserving compatibility with existing standards. This paper serves as a starting point for my thesis because it proposes geometric models such as IFC for a significant contribution to a clearer definition of objects and localization of damage. It also generates its models based on ASB-ING bridge data from SIB-Bauwerke tables, which is exactly what was done in my thesis.

The second paper proposes an automatic transformation of SIB-Bauwerke data into an object-oriented structure. This enables in-depth inspection analysis, direct links between components and damages, and the definition of damaged areas. The enhanced structure facilitates detailed condition assessments and seamless integration with other digital twins resources, ultimately improving bridge maintenance. This paper is crucial for my thesis because its newly implemented structure enables precise linking with other object-based data models such as IFC models.

Additionally, Anne Göbels co-authored a paper titled "Transfer of Implicit Semi-Formal Textual Location Description in Three-Dimensional Model Contexts" (GÖBELS et al., 2023), which was presented at the 2023 European Conference on Computing in Construction. It presents an approach that automatically translates textual inspection descriptions into clear three-dimensional model elements and conceptual damage representations using rule-based transformations encoded in specialized algorithms. This process ensures unambiguous model-based localization and geometric representation of inspection data, effectively linking legacy information with new model data to facilitate the implementation of digital twins for efficient bridge maintenance. It demonstrates the need for my thesis because it states, mapping between IFC and ASB-ING components has to be extended because her approach assumes, that models already exist, allowing for damage to be precisely located on their components.

In conclusion, all the mentioned papers highlight the advantages of IFC over ASB-ING and underscore the importance of research in developing data mapping schemas to seamlessly transfer data from ASB-ING to IFC. In the following sections, I will delve deeper into the two representations and their methods for storing structural bridge data.

2.3 ASB-ING 2013 and SIB-Bauwerke

ASB-ING, "Anweisung Straßeninformationsbank, Teilsystem Bauwerksdaten" (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013), is a German standard developed for the structured storage and documentation of bridge data, based on DIN 1076 (DIN E.V, 1999).

The ASB-ING data model specifies the documentation requirements for the construction, inspection, condition, administration, and factual data of bridges and tunnels. It encompasses fifty-four distinct categories that organize information about the structures and their maintenance into specific areas. The key element is the entire structure ("Bauwerk"), each assigned a unique identifier ("Bauwerksnummer") for sorting purposes. A structure may consist of one or more substructures ("Teilbauwerke"), which can include bridges, tunnels, bridge sections, or protective structures. Monitoring processes, damages, and evaluations are linked to each substructure, with every category in ASB-ING having its own set of attributes. For instance, the main bridge structure is characterized by its ID, name, location, overall length, and other specific attributes. (GÖBELS, 2021).

This data model is then implemented in the application SIB-Bauwerke (WPM-INGENIEURE GMBH, 2020), or "Standardisierte Ingenieurbauwerke" (Standardized Engineering Structures).

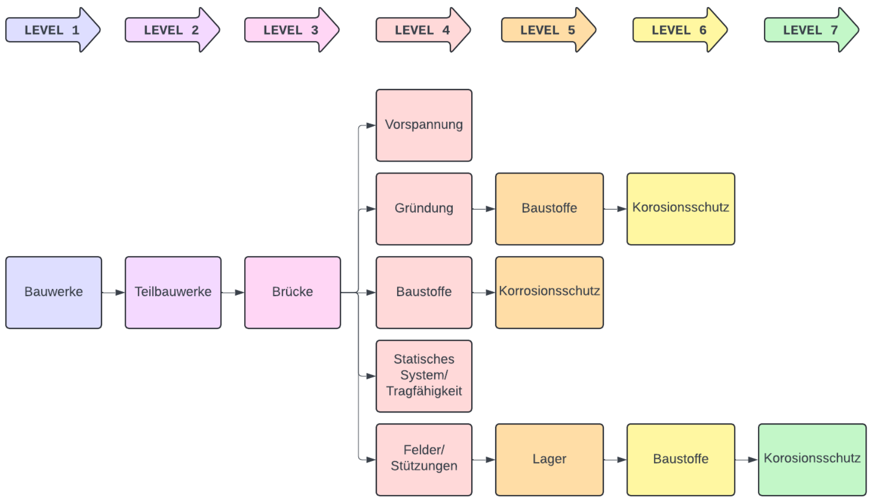


Figure 2.1: SIB-Bauwerke hierachy

The data is organized hierarchically in tables, as illustrated in Figure 2.1. Seven different layers are present, each with its table. At each level, access to data specified by the ASB-ING is possible. For instance, at the "Bauwerke" level, one can retrieve the name and structure number of the bridge, while at the "Brücke" level, the length becomes accessible. Furthermore, keys play a critical role in specifying detailed attributes. These keys consist of 15-digit numbers used to delineate specific features. Encoding a key involves utilizing reference tables that correlate each key with a particular characteristic, such as the type of bridge or the type of pier. In terms of hierarchy, the relationship between components, assemblies, partial structures and structures is as follows. Individual components are grouped into assemblies, which are then organized into partial structures ("Teilbauwerke"). These partial structures collectively form the overall structure ("Bauwerk"). For instance, several beams (components) might create a truss (assembly). A partial structure like a bridge span would be made up of various assemblies, such as trusses, decks, and supports. Combining the spans, abutments, piers, etc. into a single bridge structure would create the overall structure.

2.4 IFC4x3

IFC4x3 refers to Industry Foundation Classes version 4.3. This open standard data format is used in the architecture, engineering, and construction sectors to ensure interoperability between different software applications and tools. The International Organization for Standardization (ISO) regulates it under ISO 16739, and it is developed by the non-profit organization buildingSMART (BUILDINGSMART, 2013).

Until IFC4, the standard predominantly addressed buildings (BORRMANN et al., 2019). However, with IFC4x3, an IfcBridge extension was introduced to cover the creation and management of digital models representing both the physical and functional attributes of bridge structures. This extension enhances the exchange of bridge data across various software platforms used throughout the entire lifecycle of bridge infrastructure projects

When it comes to storing the bridge data in IFC4x3, the data model is structured hierarchically to represent various aspects of the bridge design, construction, operation and maintenance. Given that the thesis focuses on structural elements, the following data model centers specifically on this aspect.

Data Model Description:

- Project: Represents the entire construction project, which may include multiple bridges or structures.

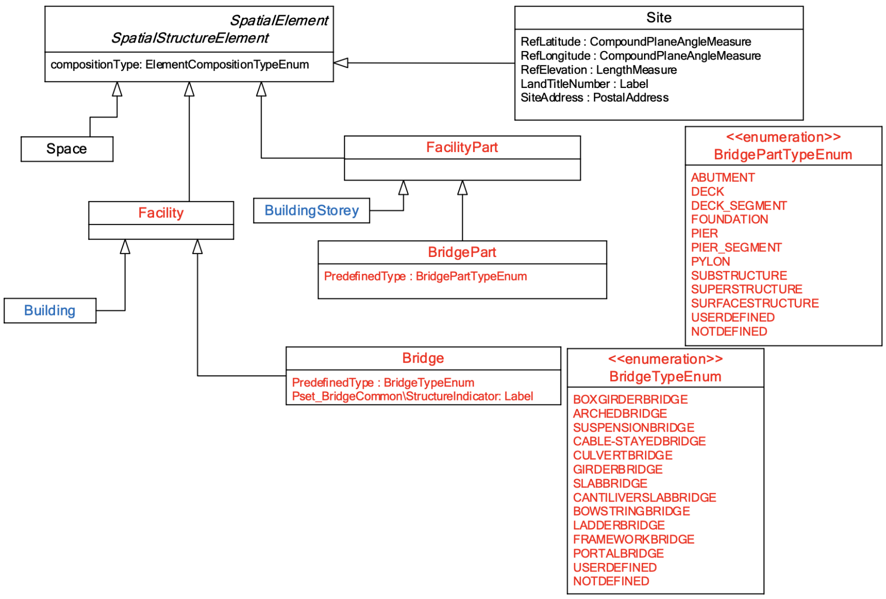
- Bridge Element: Represents the individual components of the bridge, such as decks, piers, abutments, beams, columns, etc.

- Geometry: Describe the geometric properties of each bridge element, including size, shape, and spatial relationships.

- Materials: Specifies the materials used in construction, including properties such as density, strength, and durability.

- Properties: Defines additional attributes of bridge elements, such as color, texture, and other non-geometric characteristics.

- Relations: Establishes relationships between different elements of the bridge, such as connections between beams and columns or supports and decks.



Source: Adapted from (BORRMANN et al., 2019)

Figure 2.2: IfcBridge Extension

Additionally, Figure 2.2 illustrates the spatial component of the IfcBridge extension, providing insight into the data storage structure. The hierarchical order and the distinct classes are readily apparent. For instance, the inheritance relationship between BridgePart and FacilityPart is evident, underscoring the organization's architectural integrity. Furthermore, the introduction of the "bridge" as a new facility showcases the adaptability and expansiveness of the model. Further, IFC allows components to be assigned to these spatial structural elements. The addition of the alignment concept enables linear referencing, which goes beyond the hierarchical structure by describing the locations of components based on their position relative to the axis. This is especially important for linear structures like bridges.

This approach to data storage in IFC4x3 allows a complete and detailed representation of bridge data, allowing also digital reconstruction and maintenance management of bridges.

2.5 Comparative Evaluation of ASB-ING and IFC4x3

When contrasting ASB-ING with IFC4x3 regarding the representation and storage of bridge data, several crucial factors come into play. I'm focusing on the following four key points:

1. **Bridge Structure Representation and Reconstruction:** IFC4x3 offers a more detailed and comprehensive framework suitable for bridge representation and digital reconstruction. With the introduction of IfcBridge and IfcAlignment, it provides the ideal classes for representing bridge data. In contrast, ASB-ING has limitations and lacks certain data necessary for digital bridge reconstruction. For example, a superstructure in ASB-ING is primarily described by its length, width, and minimal and maximal height, which is insufficient for accurate reconstruction. Additional parameters and, crucially, the relationships between components are required. This limitation is highlighted by the fact that ASB-ING compensates for its lack of detailed data with textual descriptions of damage. As a result, it becomes clear that reconstructing a detailed digital bridge based solely on ASB-ING data is not feasible.

2. **Data Model:** IFC4x3 offers a hierarchical data model that includes a broader range of attributes and relationships compared to ASB-ING. Although ASB-ING is also structured hierarchically and might appear more straightforward for users due to its textual data, difficulties arise in understanding how the various parts of the bridge are assembled and connected. The significant advantage of IFC is the capability for linear referencing. This means that bridges do not need to be organized exclusively in a hierarchical spatial manner. For example, the axis alignment specifies which pier supports each part of the superstructure, the distances between the piers, and the predecessor and successor piers, rather than just the station where each pier is located. Additionally, IFC enables the description of geometry relative to the structure's axis, allowing for the modeling of variable superstructure heights—an aspect not addressed in ASB-ING. Therefore, IFC provides a more detailed representation of existing classes, geometric capture of components, and spatial relationships between components, offering a superior data model for storing bridge data. In contrast, ASB-ING lacks these referencing capabilities and compensates with textual descriptions.

3. **Interoperability and Global usage:** IFC 4x3 is designed for global use, ensuring compatibility across different software and international projects. In contrast, ASB-ING is primarily used in Germany and is accessible only through the SIB-Bauwerke software. This limited accessibility restricts its use in international projects and reduces its interoperability with other global standards and software systems.

4. **Extensibility:** One notable advantage of IFC is its ability to support extensions and adaptations to incorporate new technologies and methodologies. While the current version of IFC4x3 includes features like IfcBridge to align with evolving industry

standards, it is possible to release new versions with additional capabilities. Although work is being done to extend ASB-ING, it currently does not match the extensibility and established mechanisms for updates found in IFC.

2.6 Conclusion

In conclusion, this chapter has discussed ASB-ING and IFC4x3 and underscored the importance of developing a solution that can automatically transform ASB-ING bridge data into IFC4x3 classes. Implementing such a solution would significantly improve interoperability and efficiency in bridge maintenance and inspection, in Germany.

The IFC format stands out as a superior choice for storing bridge data due to its capacity for providing extensive detail, linear referencing and facilitating comprehensive bridge reconstructions. Moreover, it enables seamless sharing of bridge data with a global audience and allows for convenient extensions.

The next chapter will explore a method for transforming ASB-ING bridge data into IFC4x3 bridge data. It will detail the mapping techniques developed and discuss the opportunities and challenges involved in this conversion process.

Chapter 3

Development of a data mapping schema

3.1 Introduction and motivation

In the realm of bridge inspection and damage documentation, precise structural data mapping is crucial for accurate modeling and analysis. This chapter concentrates on designing a data mapping schema for structural data elements of bridges, specifically omitting non-structural data such as materials, loads, etc.

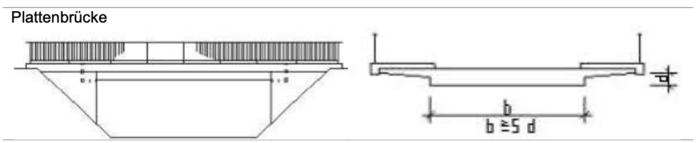
The scope of this analysis is narrowed to girder bridges—a common type of bridge that primarily relies on girders for load support. The discussion will focus on three key structural components: the axis (the main line of orientation), the superstructure (the load-bearing elements), and the substructure (the supporting structures below the deck, such as piers). These elements are fundamental to bridge design and require precise data representation for detailed bridge reconstruction.

3.2 Data mapping

3.2.1 Bridge types

In the following four types of girder bridges are introduced. It's important to note that all types differ (significantly) because of their cross-sections.

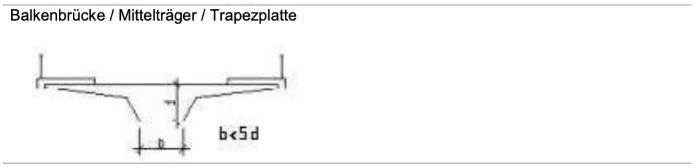
Slab bridge (type 1): These are the simplest form of girder bridges, consisting of a flat slab of concrete that spans the gap between two points. This type is used primarily for short spans and is favored for its simplicity and cost-effectiveness.



Source: Adapted from (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013)

Figure 3.1: Side view and cross-section slab bridge

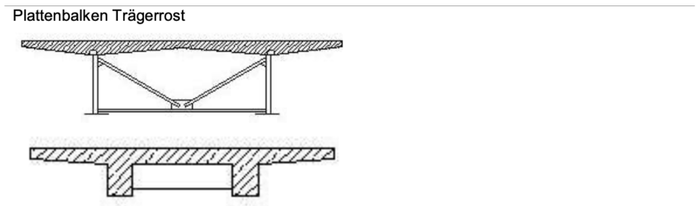
Beam Bridges with Central Girders or Trapezoidal Plates (type 2): This category includes bridges that utilize a central beam or trapezoidal plates as support. These elements are crucial for distributing loads and ensuring stability, particularly in bridges that span larger distances.



Source: Adapted from (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013)

Figure 3.2: Cross section beam bridge

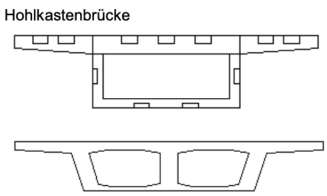
T-beam Bridges (type 3): These bridges combine a slab with a girder to form a T shape in cross-section. This design allows for longer spans than a simple slab bridge by effectively distributing loads to the girders, offering a balance between structural efficiency and material use.



Source: Adapted from (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013)

Figure 3.3: Cross section t-beam bridge

Box Girder Bridges (type 4): These bridges feature a hollow box-like cross-section, making them suitable for long spans. The box girder's design allows for efficient use of materials while accommodating large loads, making it a preferred choice for major infrastructure projects.



Source: Adapted from (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013)

Figure 3.4: Cross section box girder bridge

When creating the bridge models, it will therefore be crucial to reproduce and differentiate these different cross sections to replicate the four types of bridge.

3.2.2 Sofistik Bridge Modeler

The Sofistik Bridge Modeler 2023 (SOFiSTiK AG, 2023a) is a software application utilized in structural engineering for bridge design and analysis. It enables users to develop 3D models of bridge structures within the Revit platform.

This bridge modeling process is systematic and always follows the same steps to build bridge models. It begins with the creation of an axis, followed by the development of the superstructure, and concludes with the construction of the substructure. Each step requires defining specific parameters, selecting from predefined properties, and choosing appropriate family types or models. This structured approach allows for detailed customization and accuracy in the modeling process. For detailed documentation of this bridge modelling process please refer to SOFiSTiK AG, 2023b.

The Sofistik Bridge Modeler plays a crucial role in the application of the developed mapping schema. This schema aims to connect ASB-ING and IFC bridge data, by constructing bridges using ASB-ING data, facilitated by the Sofistik Bridge Modeler bridge modeling process in Revit, and integrating them into the IFC data model. The task involves selecting the appropriate data from ASB-ING, transforming it, choosing the correct Sofistik structural types, and setting the necessary parameters to construct the bridge.

3.2.3 Assumptions

To establish a mapping schema, specific assumptions are crucial. Initially, the focus will be on four specific types of bridges, although it is plausible to expand the schema to include additional bridge types in the future.
Secondly, the mapping schema adheres to the ASB-ING definitions of "Teilbauwerke," "Brücke," and "Brückenfelder/-stützungen." To incorporate more intricate details, exploring other ASB-ING definitions is necessary to extract relevant additional data.
Furthermore, all parameter values are assumed to remain constant along the axis. This includes parameters for both the superstructure cross-section and the substructure, as well as the constant span or placement setting along the axis.
Additionally, the focus is exclusively on bridges with a single superstructure, which simplifies the modeling process and can later be extended to more complex structures.
Moreover, all types of angles, whether along or across the bridge, are disregarded. This includes angle parameters in both the superstructure and substructure, as well as any potential shifting of the bridge itself.
Furthermore, symmetry is assumed for all parts of the bridge structure along a plane that passes through the axis.
Some assumptions are made to simplify the process, while others are due to limitations in the ASB-ING data. These assumptions are valid because the goal of my thesis is to demonstrate that mapping bridges from ASB-ING to IFC is possible. My models confirm this feasibility and can be used to enhance the mapping process. Further details on these

challenges and potential improvements will be discussed in the challenges and outlook section.

3.2.4 Model creation process

The general mapping schema is depicted in Figure 3.5. This diagram illustrates the construction of each component of the bridge—axis, superstructure, and substructure—independently, based on the unique overall construction number ("BWNR"), using the Sofistik Bridge Modeler. It also details the steps involved in assembling these bridge components. Additionally, it references the specific mapping tables, which are included in the appendices. After the individual parts are constructed, they are all integrated using the axis to form the complete bridge model. Later in this chapter, I will discuss the creation of the axis, superstructure, and substructure in detail.

Disclaimer: Items not explicitly mentioned will remain at their default settings and will not be adjusted.

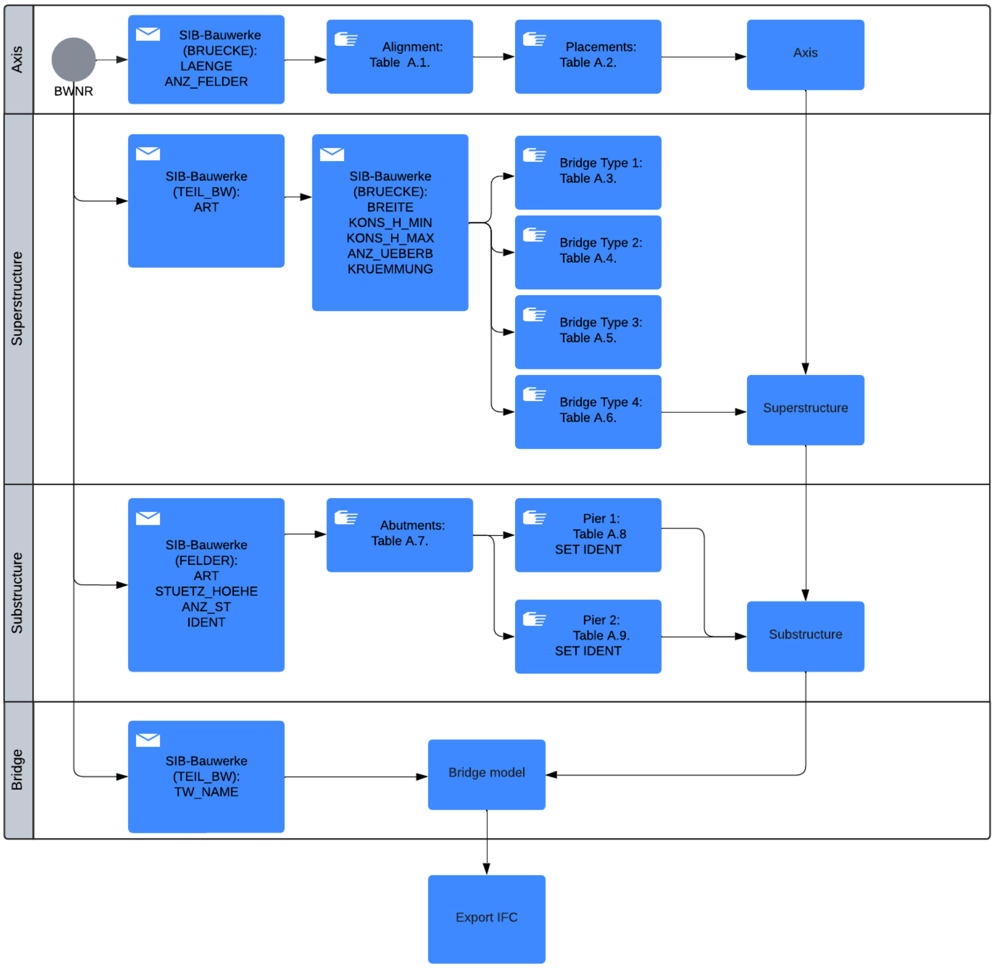


Figure 3.5: General mapping schema

Axis

To construct a bridge using the SOFiSTiK Bridge Modeler, the initial and fundamental step is to create an axis. This axis acts as the primary guiding line for the entire bridge construction process and is determined by three key elements: alignment ("Trassierung"), placements, and vertical positioning. In this framework, we omit considerations of variables and secondary axes for simplicity. It is important to note that the process of mapping the axis remains consistent across all types of bridges.

Initially, defining the alignment is essential. Within the mapping schema, every bridge is composed of three alignment elements. Given that angles and radians are not considered, I always choose the "Line" ("Linie") option. The first alignment element is defined by the span length, which is calculated as the total length ("LAENGE") divided by the number of fields ("ANZ_FELDER"). The second element corresponds to the total length of the bridge ("LAENGE"), and the third element mirrors the first, representing the span length again (Figure 3.8). This data can be retrieved from the "Brücken" section in the ASB-ING, which is stored in the BRUECKE table in SIB-Bauwerke (Figure 3.6).

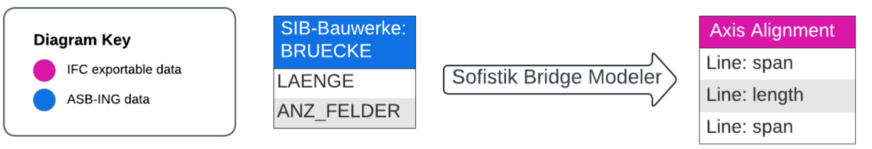


Figure 3.6: Alignment mapping

For exact parameter mapping, please refer to Table A.1.

Although it is possible to implement vertical axis positioning within the Sofistik Bridge Modeler, it is not established within this mapping schema due to a lack of reference data, which is not provided by ASB-ING.

Regarding placements, these are designated positions along the axis and are all oriented perpendicular to it. To calculate the number of placements, we take the number of fields (ANZ_FELDER), and increment this figure by three. Consequently, for bridges lacking pillars, which means one field, the minimum number of placements derived is always four. Each placement is spaced apart by the average span length, commencing from zero (Figure 3.8). This structured approach ensures a systematic and coherent framework for bridge construction, allowing for precise and consistent positioning of structural elements along the axis. The first and last placements are of the overhang type (which is not implemented yet in the automated solution), while the intermediate placements are of the bearing type. As can be seen, no additional data is needed; one can again use the "LAENGE" and "ANZ_FELDER" from the "BRUECKE" table of the SIB-Bauwerke. Nevertheless, this time a more sophisticated algorithm is required to determine the placement positions (Figure 3.7).

For exact parameter mapping and placement setting, please refer to Table A.2.

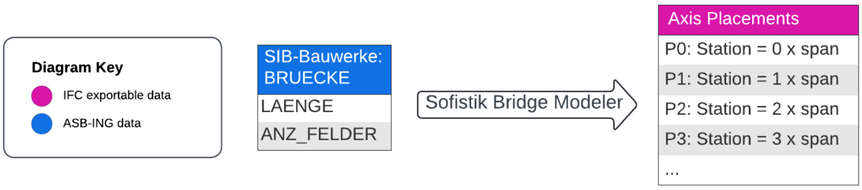


Figure 3.7: Placements mapping

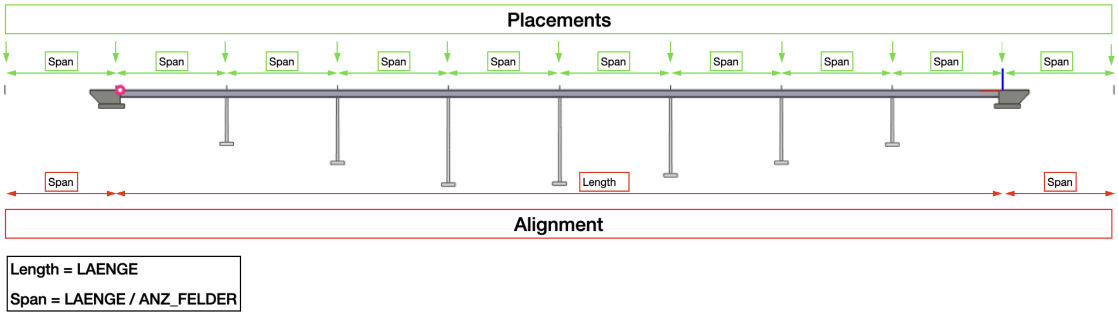


Figure 3.8: Positioning of Placements, Alignment Segments and Bridge Elements

Superstructure

Following the establishment of the axis, the next step is to construct the superstructure. The Sofistik Bridge Modeler provides a selection of generic superstructure families along with their specific types. For each bridge type, it is necessary to select an appropriate family and type, followed by the configuration of their parameters.

Additionally, it is crucial to define the start and end points of the superstructure by utilizing the placements previously established. This step ensures the superstructure is accurately positioned along the bridge's axis. While currently not implemented, there is also a provision for setting the material of the superstructure, which would add more semantics and realism to the bridge model. In the following, I am discussing the general superstructure mapping approach and will introduce the chosen Sofistik types to model the four different bridge superstructures.

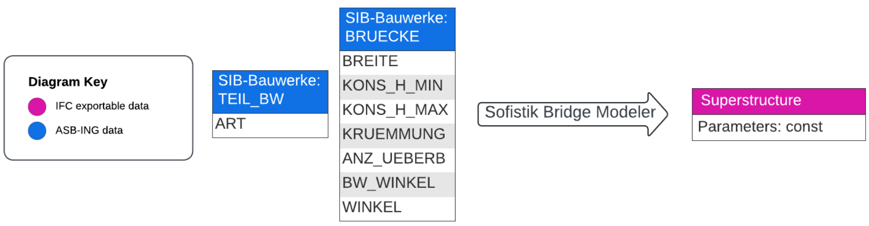


Figure 3.9: Superstructure mapping

To determine the type of bridge, we first need to identify it by searching for "ART" in the TEIL_BW table. Following this identification, one can construct one of the four types of bridges. Each bridge type's superstructure utilizes the same data retrieved from the SIB-

Bauwerke database. Parameters such as "BREITE" (width), "KONS_H_MIN" (minimum height), and "KONS_H_MAX" (maximum height) are used to approximate the characteristic cross-section of each superstructure type (Figure 3.9). It is also important to note that all approximated parameters are assumed to be constant along the superstructure.

Bridge Type 1: Slab Bridges

For Bridge Type 1, the schema uses the generic superstructure, "SOFITSIK_Profile_T-BEAM" with the type "Profile_T-Beam_Type-1". The data is transformed according to Table A.3.

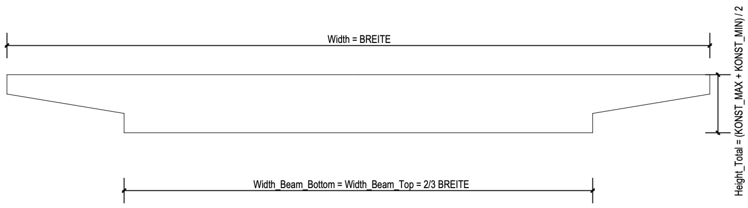


Figure 3.10: Slab bridge parameter mapping

In Figure 3.10 one can see how the most important SIB-Bauwerke values influence the cross-section of Bridge Type 1. Please note that not all necessary parameters are referenced here for the sake of clarity.

Bridge Type 2: Beam Bridges with Central Girders or Trapezoidal Plates

For Bridge Type 2, it utilizes the same generic superstructure, "SOFITSIK_Profile_T-BEAM" with the type "Profile_T-Beam_Type-1". However, the data is transformed differently to yield a distinct superstructure cross-section . The ASB-ING data has to be mapped and approximated according to Table A.4.

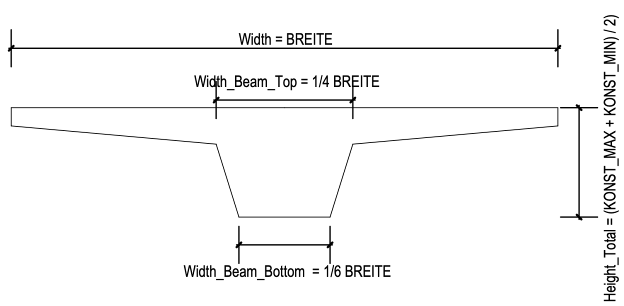


Figure 3.11: Beam bridge parameter mapping

In Figure 3.11 one can see how the most important SIB-Bauwerke values influence the cross-section of Bridge Type 2. Please note that not all necessary parameters are referenced here for the sake of clarity.

Bridge Type 3: T-beam Bridges

For Bridge Type 3, it utilizes the predefined generic superstructure family

"SOFiTSiK_2_T_Beam_single-slope" with the type "Control Width Beam" and defines the parameters as follows A.5.

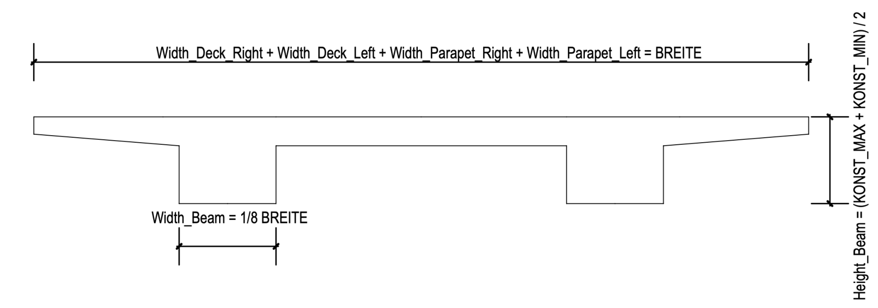


Figure 3.12: T-Beam bridge parameter mapping

In Figure 3.12 one can see how the most important SIB-Bauwerke values influence the cross-section of Bridge Type 3. Please note that not all necessary parameters are referenced here for the sake of clarity.

Bridge Type 4: Box Girder Bridges

For Bridge Type 4, the schema uses the predefined generic superstructure family "SOFiSTiK_HOLLOW_single_slope" and the type "Control with Slap Bottom". The parameter definitions can be found in Table A.6.

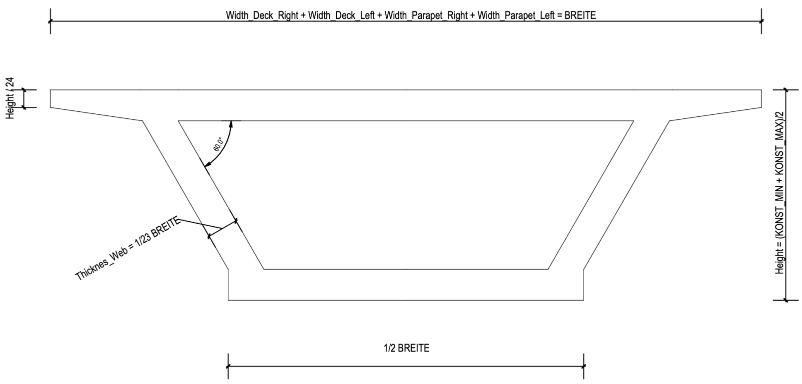


Figure 3.13: Box girder bridge parameter mapping

In Figure 3.13 one can see how the most important SIB-Bauwerke values influence the cross-section of Bridge Type 4. Please note that not all necessary parameters are referenced here for the sake of clarity.

After setting and approximating all parameters within each family and superstructure type, one must define the start and end points of the superstructure. This step is consistent across all superstructure types. The beginning of the superstructure is established at the second axis placement, while the end is designated at the second-to-last placement. This can be observed in Figure 3.8.

Substructure

The final phase in bridge construction within the Sofistik Bridge Modeler involves creating the substructure. For every substructure component, a specific set of parameters must be defined, ensuring the precise and intended configuration of each element. At both the beginning and the end of the bridge (superstructure), an abutment is invariably present. The position of the first abutment is always the second placement, whereas the second abutment is positioned using the second-to-last placement (Figure 3.8) and requires a 180-degree rotation for correct orientation. Abutments are constructed using the "STUETZ_HOEHE" and "BREITE" parameters (Figure 3.15) from the "FELDER" and "BRUECKE" tables of SIB-Bauwerke (Figure 3.14).

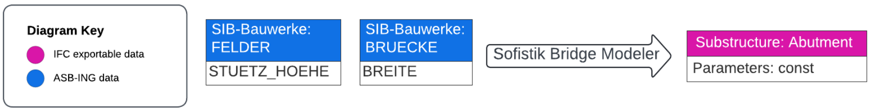


Figure 3.14: Abutment mapping

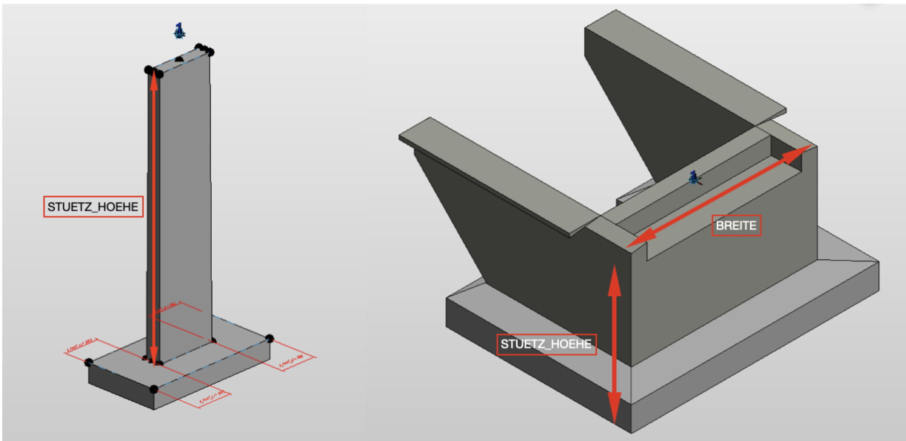


Figure 3.15: Substructure mapping: Note that only the key parameters are highlighted

For this purpose, the "SOFiSTiK_Generic_Abutment-01" family and type "Default" are employed and the parameters are set according to Table A.7.

Between the abutments, the bridge may feature one of two types of piers, determined by the "ANZAHL_ST" (number of supports) value retrieved from the "FELDER" table. When the "number of supports" value is one, the "SOFISTIK_Generic_Pier-01" family of type "Default" is used, resulting in a pier consisting of a single pillar. Detailed parameter mapping can be found in Table A.8.

Conversely, if the "number of supports" value exceeds one, the "SOFISTIK_Generic_Pier-02" family of type "Default" is selected (Table A.9), which yields a pier supported by two pillars. It is important to note that, as of now, the creation of piers with more than two pillars is not supported.

Generally, the parameter setting of piers relies solely on the "STUETZ_HOEHE" value (Figure 3.15), which can also be found in the "FELDER" table. Other parameters are

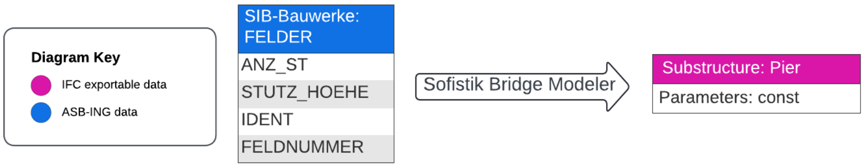


Figure 3.16: Pier mapping

either not computed, constants, or multiples of this value. The piers are positioned between the abutments (Figure 3.8). Having already established all placements using the bridge's length and the number of fields, the placement of the piers is straightforward. The "FELDNUMMER" from the "FELDER" table is used to determine the corresponding placement along the axis of each pier. The pier with the lowest field number is positioned at the placement immediately after the abutment. The second pier at following placement corresponds to the next lowest field number , and this sequence continues accordingly.

For the piers, there is a special consideration: I also retrieve the "IDENT" (from the "FELDER" table), which is a unique number different for each component. This identifier is stored under the comment property within the Revit project. It enables precise identification of each pier in the SIB-Bauwerke database later on, facilitating more detailed information retrieval, like the type of the pier, reference bridges and fields, and the responsible authority. This setup allows for interaction between the two systems and provides clear traceability of the data's origin. In addition, a single source of truth (SSOT) is maintained because no semantics are copied directly. Figure 3.16 depicts this general substructure mapping process.

IFC export

The bridge has been successfully constructed using the Sofistik Bridge Modeler. Leveraging the capabilities of Revit, the project can now be seamlessly exported to an IFC4 file format. This IFC4 file provides a bridge model for model-based structural inspection that is vendor-neutral and based on an internationally established standard, unlike ASB-ING. It is important to note that this schema was developed using Revit 2023. Currently, Revit 2023 does not support IFC4x3 export. However, it will be effortless in the future to switch to IFC4x3 export once it becomes available.

3.3 Challenges

Challenges in bridge reconstruction arise from the previously discussed differences in bridge structure representation and the data model itself. There are two major challenges:

1. **Lack of detail:** Many values representing crucial geometrical information for detailed bridge design and construction are not provided by the ASB-ING. Two particularly

clear examples illustrate this limitation. Firstly, regarding the construction height of the superstructure, ASB-ING only specifies the maximum and minimum values. However, it does not elucidate how the height varies in between these extremes or at which positions the maximal and minimal values occur prominently. Secondly, ASB-ING solely offers the maximal slope along and across the bridge. However, it remains ambiguous at which specific points these maximal values occur. That's why, incorporating vertical alignments and angles proves challenging and unfeasible solely based on the ASB-ING data. To deal with that, one has to assume or approximate missing values.

2. **Missing of spatial relations:** Frequently, there is a lack of clarity regarding the relationship between individual bridge elements and their precise positioning. While ASB-ING offers brief descriptions of bridge parts, these descriptions are limited in scope. The parts can only be connected through their construction numbers ("BWNR"), leaving much to the user's imagination. Although the association between elements is implicitly indicated by the construction numbers and can be derived, the exact spatial relationships are not explicitly available for evaluation. Consequently, reconstructing the bridge from ASB-ING data proves to be exceptionally challenging. Because of that, precise bridge maintenance management in ASB-ING is limited in practice and is compensated by textual descriptions and human intervention.

3.4 Summary

In this chapter, I introduced an application of the data mapping schema utilizing the Sofistik Bridge Modeler. The process facilitates the manual implementation of four specific types of girder bridges, leveraging data from ASB-ING and converting it to an IFC representation using mapping tables and generic Sofistik Bridge Modeler families and types.

In the following chapter, I will explore the transition to an automated implementation. This advancement aims to significantly enhance the efficiency of the process, reduce the potential for human error, and streamline data integration. I will discuss different aspects of the automation technique, including the use of scripting in Python and API integration.

Chapter 4

Implementation of the data mapping schema

4.1 Introduction and motivation

The advancement of structural engineering and bridge design practices demands more efficient, accurate, and scalable solutions for data management and analysis. An automated implementation of the data mapping scheme addresses this need by significantly enhancing the efficiency of mapping bridge data across ASB-ING and IFC formats.

Manual data mapping can be done, but it is a slow and error-prone process. As modern engineering projects become larger and more complex, this approach becomes increasingly impractical. In addition, according to ASB-ING (BUNDESMINISTERIUM FÜR VERKEHR, BAU UND STADTENTWICKLUNG, 2013), there were approximately 65,000 bridges in Germany as of 2013. This number is far too large to manage without the automation of the mapping process. Automation stands out as a critical innovation, enabling rapid, accurate, and repeatable data transformations that can keep pace with the demands of contemporary bridge design and construction.

To seamlessly transform data from ASB-ING to IFC, a Revit extension was developed. This ASB-ING extension enables the construction of a bridge with just one click by entering the construction number ('BWNR').

This extension aims to:

- Streamline the manual data mapping process, reducing both time and effort.
- Minimize the risk of human error by ensuring the accuracy and reliability of data transferred between ASB-ING and IFC.
- Foster project extension and contributions by establishing a clear, comprehensible, and easily extensible structure.

The following chapter delves into the technical implementation of the data mapping schema. It is structured to guide the reader through the general process of retrieving ASB-ING data from SIB-Bauwerke via a Microsoft SQL Server, mapping the data using Python, and constructing the actual bridge in Revit with the Revit API and the Sofistik Bridge Modeler API. This chapter will also illustrate a real-world example and showcase the functionality of the extension through that example.

By the end of this chapter, the reader will have a brief overview of the automated data mapping process. For detailed information, one must refer to the repository on GitHub. To use the extension, it is also important to follow the instructions provided there.

4.2 Data: SIB-Bauwerke and Microsoft SQL-Server

In the initial phase, it is crucial to gather the necessary data from the SIB-Bauwerke database. The system uses a Microsoft SQL Server and replicates the database to facilitate querying. To extract data relevant for the developed data mapping schema, queries are performed on the TEIL_BW, FELDER, and BRUECKE tables in the database, using the common construction number ('BWNR'). This is implemented in the Main_file.py. This data is subsequently used to build the bridges and generate the IFC file. This part of the code is highly extendable. If additional data retrieval from SIB-Bauwerke is desired, it simply entails incorporating more SQL queries.

4.3 Mapping: Python

In the second phase, the transformation of data retrieved from the SIB-Bauwerke data bank into a format compatible with the Sofistik Bridge Modeler is crucial. To achieve this, a Python mapping framework was developed. This framework was designed to convert the extracted data into parameters or settings that align with the requirements of the Sofistik Bridge Modeler families and types. All Python mapping files are contained in the 'lib' folder and are structured as follows:

- First, the bridge type is classified (in Main_file.py) based on the keys stored in the keys.py file. To introduce more keys, one can easily extend this file. It is important to note, that the retrieved data is present Main_file.py.
- Second, the bridge data is mapped inside the data_mapping.py file according to its type, following the key bridge-building elements of the Sofistik Bridge Modeler.
    1. The axis data is transformed in axis.py
    2. The superstructure data is transformed in superstructure.py. Additionally, there are different files for each Sofistik superstructure family/type
    3. The substructure data is transformed in substructure.py
- Lastly, the transformed data is transferred to the extension Button_script.py. in the "Test" folder.

The functions implemented in these mapping files are essentially implementations of the mapping tables.

4.4 Building: Revit API and Sofistik Bridge Modeler API

In the third step, bridge construction is carried out using the transformed data, in conjunction with the Revit API and the Sofistik Bridge Modeler API within the Button_script.py file in the 'Test' folder. This process includes the creation of an axis, superstructure, and substructure within the modeling environment. Each component of the bridge is constructed according to the Sofistik bridge modeling process by utilizing the capabilities of these APIs and the mapped data. It is important to note that while modifications through the Sofistik Bridge Modeler API do not require transactions, changes made via the Revit API do. Additionally, the identifier (IDENT) of the pier is noted as a comment in the Revit document. This annotation allows users to easily locate the specific pier element within the SIB-Bauwerke after the bridge has been constructed. This section of the code is also extensible for incorporating new features and more details such as different families and types.

4.5 Export: IFC4 file

The final step is to export the constructed bridge into an IFC4 file, which is done automatically. The file is saved on the computer and is named after the corresponding bridge name in the TEIL_BW table. Users can specify both the desired path and the preferred IFC version. Currently, it is only possible to specify IFC4 as the latest version.

4.6 ASB Extension

The ABS-ING extension will be available on Git-Hub: ABS-ING Extension. Contributions and usage are highly encouraged and welcomed.

Figure 4.1 summarizes the most important elements and functionalities of the extension.

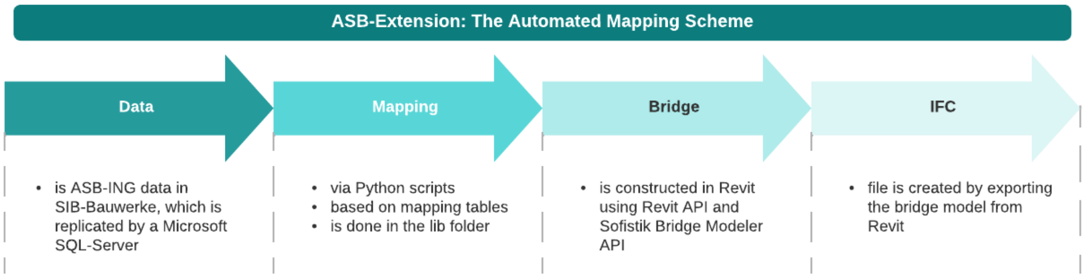


Figure 4.1: ASB-Extension Summary

4.7 Example: Box Girder Bridge

To illustrate the mapping schema, let's delve into a specific example: the bridge "Brücke B 285 über Mahlbachtal u. DB b. Mellrichstadt." This particular bridge is classified as a box girder bridge. The objective is to construct this bridge utilizing the ASB-ING extension designed for Revit while applying the principles of the newly developed mapping schema.

Let's begin with the user interface in Revit (Figure 4.2). To access the ASB-ING extension, navigate within Revit to the extension. Here, one will find several buttons; one of these, the Test Automatic Bridge Modeler, is specifically used to generate the bridge.

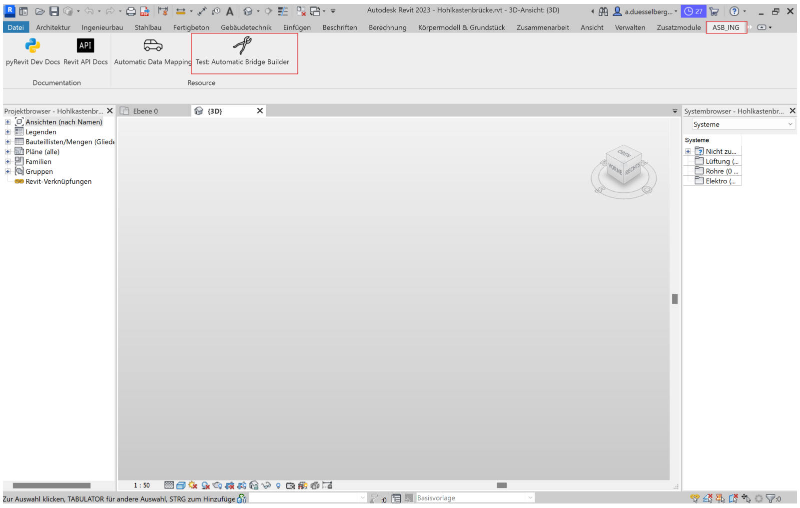


Figure 4.2: Revit with ASB-ING Extension

After pressing the button, a user interface window opens where the user is required to enter a specific construction number ("Bauwerksnummer = BWNR"). For this example, the BWNR number is 5527532, which is unique for each bridge (Figure 4.3). This number is used to retrieve the relevant ASB-ING data from the SIB-Bauwerke database using SQL queries. This entire process occurs automatically.

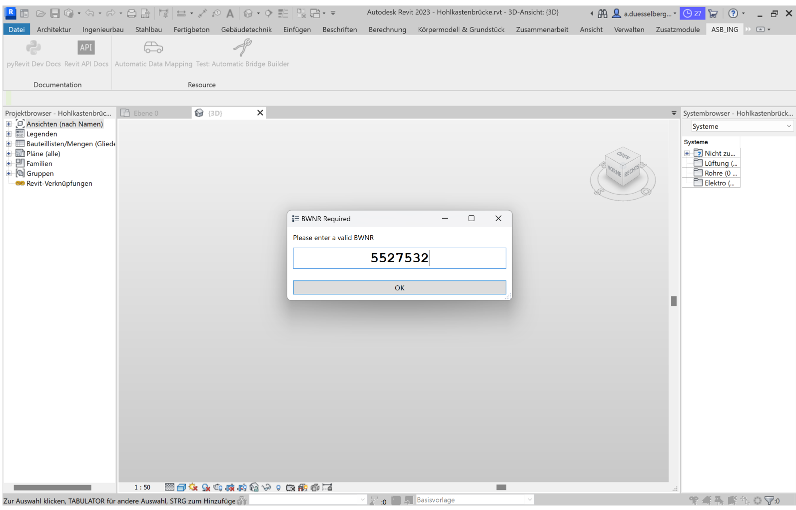


Figure 4.3: User input BWNR

4.7.1 Axis

After retrieving the data, it is automatically transformed using various Python scripts in the lib folder. With the transformed data, first, the axis is constructed, which consists of alignment and placements. Vertical positioning ("Vertikale Lage") and other potential adjustable properties, such as secondary axes ("Sekundärachsen") and variables ("Variablen") are not considered.

The alignment for the bridge is as follows:

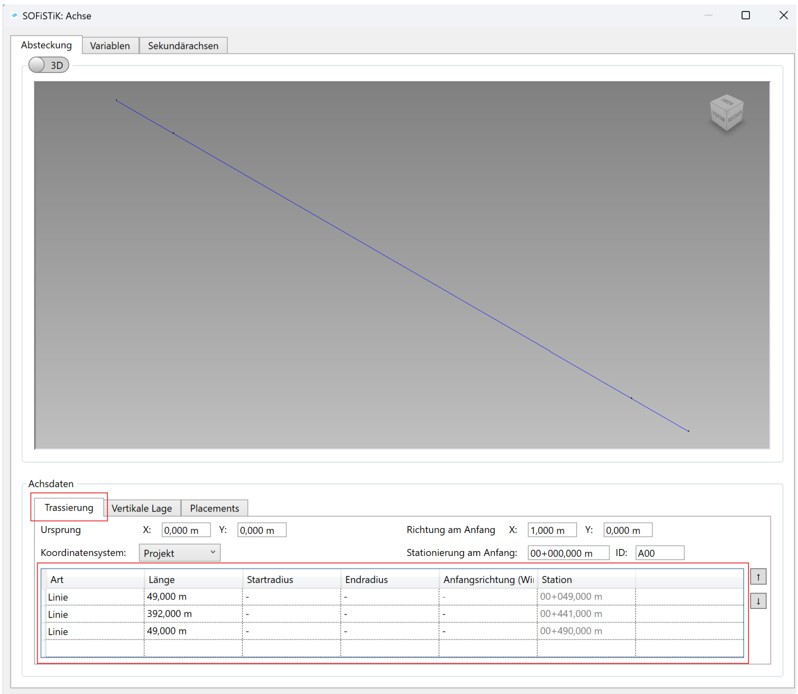


Figure 4.4: Axis Alignment

One can observe in Figure 4.4 the three different line segments ("Linie") that adhere to the developed mapping schema in Table A.1. The span (LAENGE/ANZ_FELDER = 49m) determines the length of the first and third segments, while the length of the bridge (LAENGE = 392m) defines the second segment. In conclusion the number of fields (ANZ_FELDER) is 8.

The placements for the bridge are as follows:

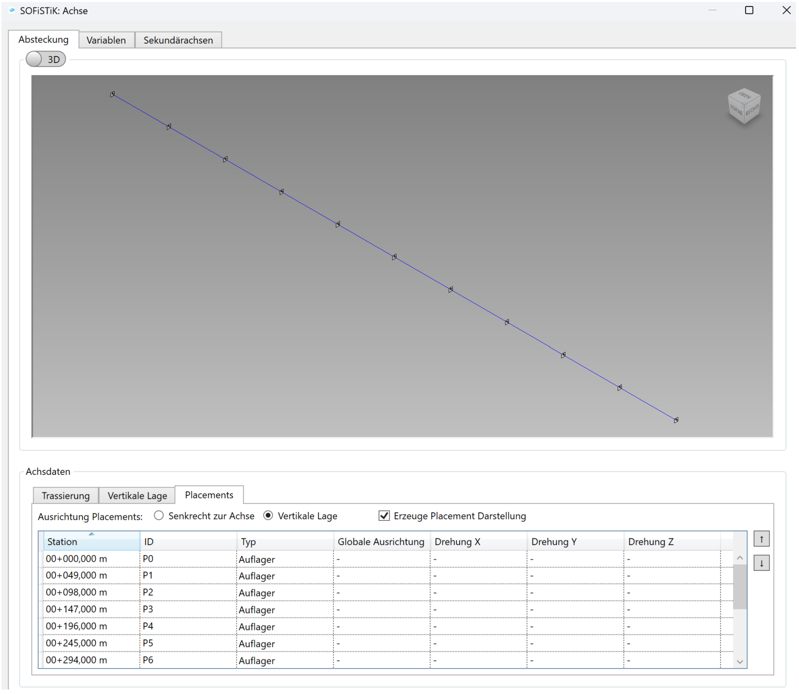


Figure 4.5: Axis Placements

In Figure 4.5 one can see how the first seven placements are set up. Each placement is spaced at intervals equal to the span (49m), starting from zero. Each has its ID, beginning with P0, P1, and so on up to P10. Unfortunately, the types of placements have not been implemented correctly up to this point. The first and the last placements should be of type Overhang ("Überstand") and not bearing ("Auflager). Please refer to Table A.2. Additionally, their vertical/perpendicular orientation ("Vertikale Lage") to the axis is set with the Sofistik Bridge Modeler API. Other parameters or properties remain unchanged or unaffected.

In the end, after setting the relevant parameters and properties according to the mapping schema, the axis is fully built automatically. One can see an axis with eleven placements, each separated by the span.

4.7.2 Superstructure

Following the schema, after constructing the axis, the superstructure must be built. Since the bridge is a box girder bridge, the program automatically selects the corresponding superstructure family and type.

The family and type are highlighted in red in Figure 4.6. It is the SOFiSTiK_Hollow_single_slope family with the "Control width slab bottom" type. The parameter variation type ("Variationstyp") is always set to constant ("fest"). The parameter values are then established, according to the mapping schema, specified in Table A.6. Other parameter properties are not considered. The parameters are selected such that the cross-section resembles a typical box girder bridge. In addition, the start and end points of the superstructure are selected, which correspond to the second (P1) and second-to-last (P9) placements (also marked in red). One can also see that it would be quite straightforward to select additional properties such as material or categories. Unfortunately, this functionality has not been implemented yet.

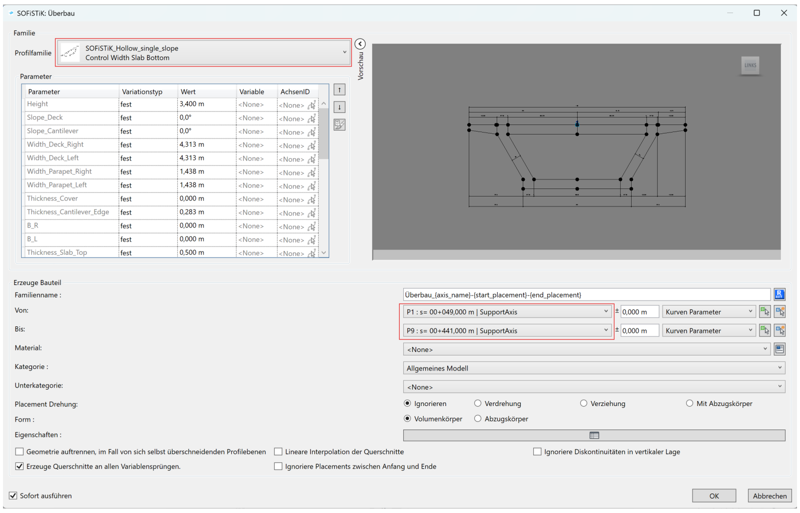


Figure 4.6: Superstructure parameters and cross section

After all parameters are set automatically, the superstructure is constructed along the axis (Figure 4.7). Since the placements and alignment have been established following the span and length of the bridge, the superstructure achieves the desired length. It is also obvious that it begins at the second placement (P1) and ends at the second-to-last one (P9).

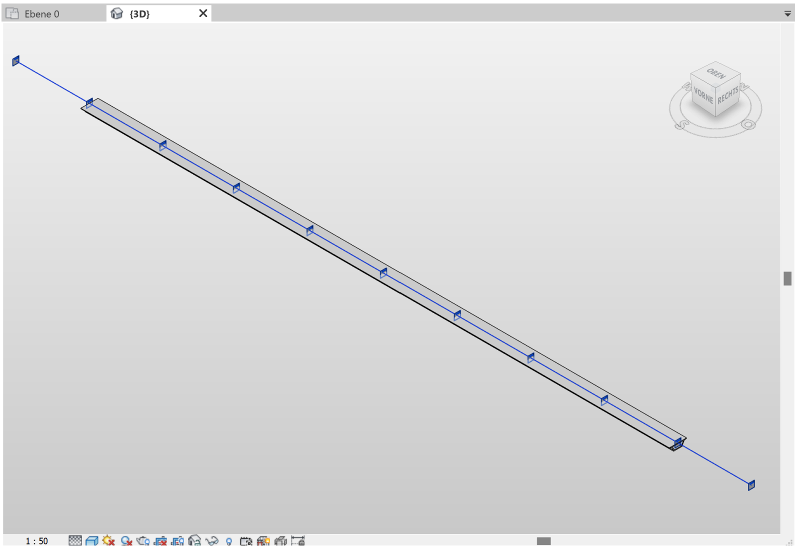


Figure 4.7: Superstructure along the axis

4.7.3 Substructure

Third, one must construct the substructure, which is the most complex part of the bridge mapping schema. It involves choosing the type of pier and calculating the parameters for each pier as well as the two abutments. In the following explanation, one abutment and one pier are described for demonstration purposes. The remaining piers and the other abutment adhere to the same rules.

For the abutments, I consistently choose the same type. There is always an abutment at both the beginning and the end of the superstructure of the bridge, specifically at the second (P1) and second-to-last (P9) placements. In this example, the abutment at the beginning is demonstrated, which is why the second placement, P1 (marked in red) at station 49m, is selected. The parameters for both abutments follow the mapping schema in Table A.7 and are primarily based on the width ("BREITE") and height ("STUETZ_HOEHE"), retrieved from the SIB-Bauwerke database. The abutment at the end (second to last placement = P9) of the bridge has always one exception: the rotation (marked in red) is set to 180 degrees.

One can see the parameters and the position of the abutment in the following Figures 4.8, 4.9.

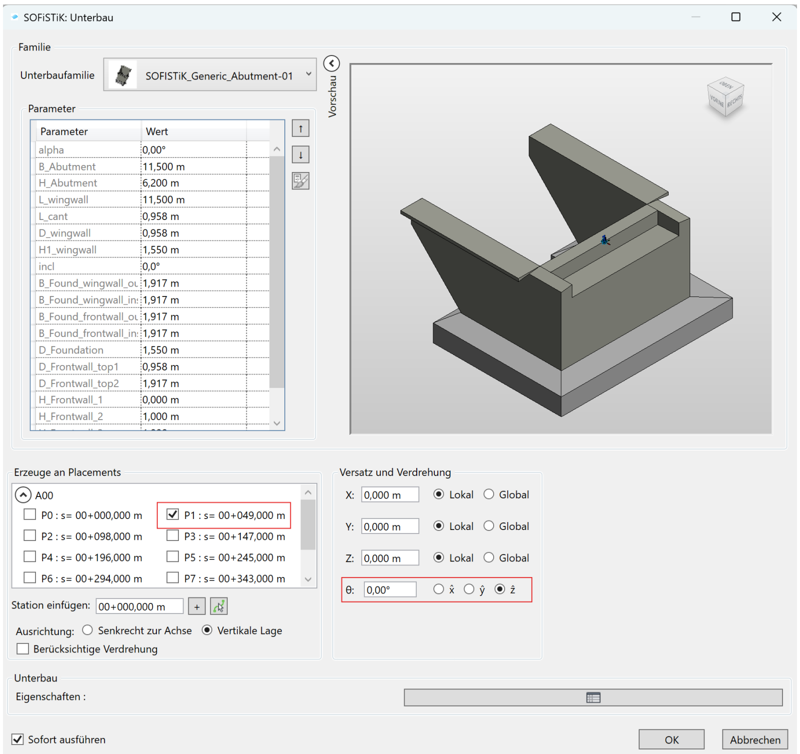


Figure 4.8: Abutment parameters

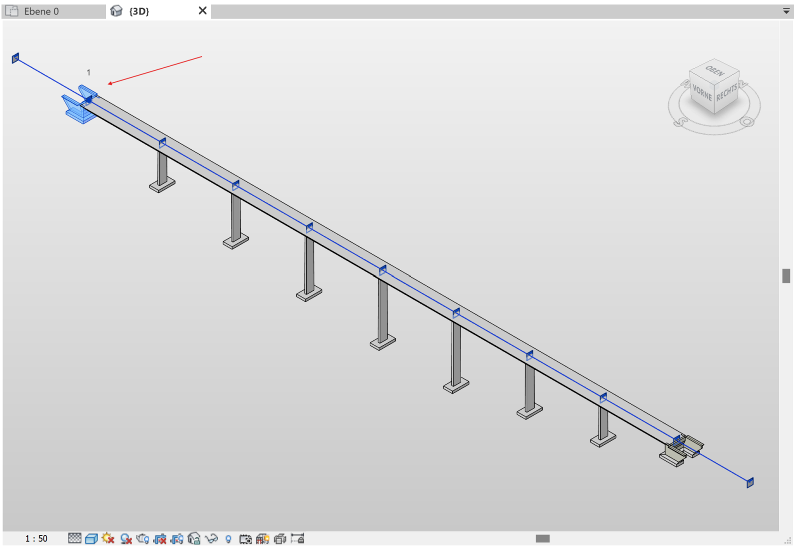


Figure 4.9: Abutment at the beginning (P1)

For the piers, there are two types available, but in this example, a pier with a single pillar is consistently chosen. This pier belongs to the family type SOFiSTiK_Generic_Pier-01. Each pier is constructed individually between the two abutments, according to the mapping schema in Table A.8. The selected pier is placed at P2 (highlighted in red in Figure 4.10), which is the first pier after the abutment, indicating it belongs to the lowest field number. Its shape is primarily determined by its height (highlighted in red), which is retrieved from the "STUETZ_HOEHE" parameter in SIB-Bauwerke.

In the following Figures 4.10, 4.11 one can see the parameter settings and the position of the pier.

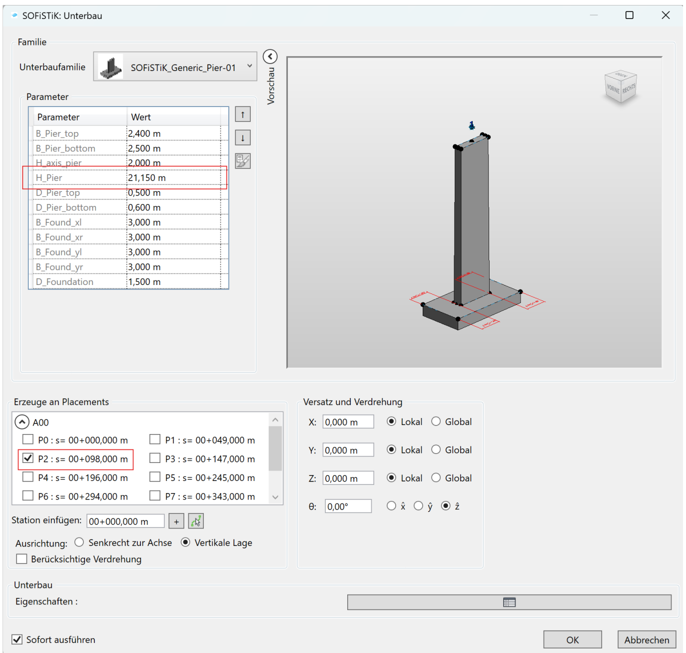


Figure 4.10: Pier parameters

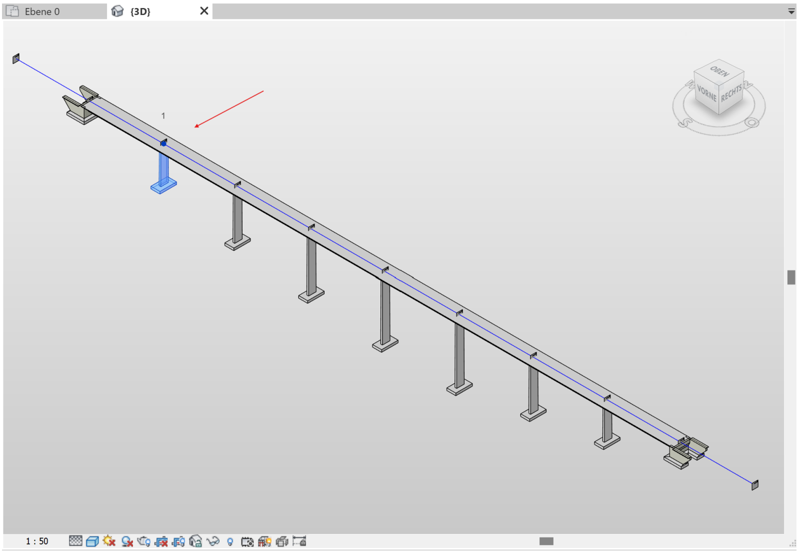


Figure 4.11: Pier at P2

4.7.4 IFC4 file

The basic structure of the bridge is now constructed, and it is time to export the bridge and create an IFC4 file. This process is also automated, resulting in a complete IFC4 file of the example bridge, automatically saved on the computer. It has the name of the example bridge and can be transferred to any other computer.

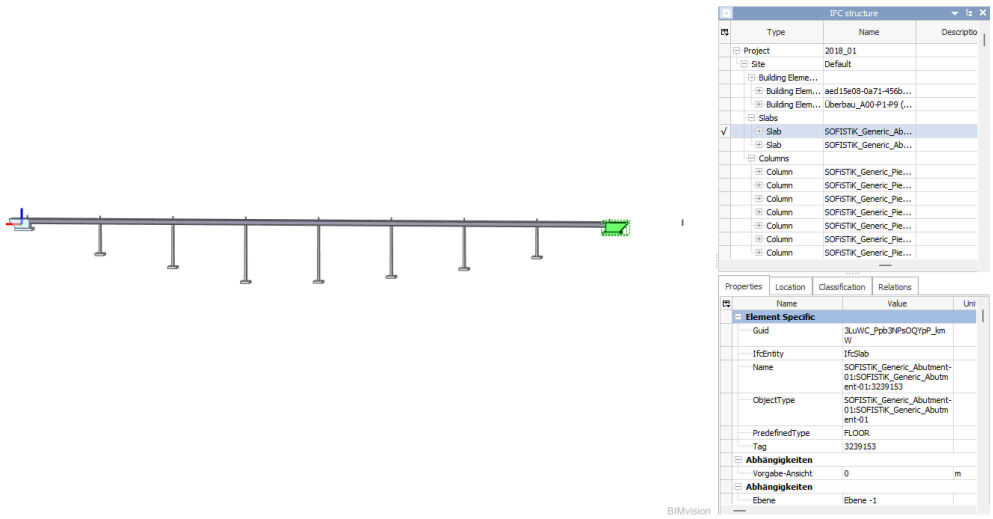


Figure 4.12: IFC file in BIMVision

When opening the IFC4 file with BIMVision, as shown in Figure 4.12, the geometry of the bridge is represented. This confirms that the geometric details are accurately captured in the model. The IFC4 file includes comprehensive geometric data, ensuring a precise representation of the bridge structure, encompassing all crucial elements such as piers, abutments, and superstructure.

The attributes assigned to the bridge components are also displayed. For instance, some attributes of the abutment marked in green are shown in the Figure. Each component is associated with specific IFC classes, providing detailed metadata about the structure. For example, piers are classified under IfcColumn, while abutments are categorized under IfcSlab. These classifications facilitate the organization and retrieval of information within the model.

Additionally, the complete hierarchical structure of the project is visible. The top layer is the IfcProject class, followed by the IfcSite class. The third layer consists of Building Element Proxies, Slabs, and Columns. This hierarchical organization ensures that each part of the bridge is accurately represented and easily accessible for further analysis or modification.

This example visually demonstrates the steps performed automatically using the developed ASB extension in Revit 2023. It is tested with 10 different bridges of each type. To fully understand the functionality, one must review the code provided on GitHub. Other bridge types are constructed following the same procedure.

4.8 Summary

This chapter demonstrates the implementation of the developed mapping schema in an ASB extension in Revit 2023 and its potential applications. It also highlights areas within the code that can be modified to refine or expand the overall scheme.

Currently, the system is capable of automatically constructing the axis, superstructure, and substructure for one of four bridge types, after entering a construction number ("BWNR"). Additionally, an IFC4 file is generated and saved. It is also possible to locate a specific pier later in the SIB-Bauwerke database since the specific identifier ("IDENT") is saved as a comment within the IFC document.

Leveraging the established mapping framework, introducing additional features to the extension would not be difficult. This groundwork not only showcases the practicality and flexibility of the mapping schema but also opens up avenues for future enhancements, making it a robust foundation for further development in bridge modeling using ASB-ING data. In the next chapter, I will discuss potential improvements that could further enhance this project.

Chapter 5

Conclusion

5.1 Summary

To conclude, this thesis presented a data mapping schema, which was designed to map data from ASB-ING to the IFC4x3 format. The novelty lies in the schema's capacity to facilitate both automated and manual modeling procedures, utilizing data sourced from SIB-Bauwerke and grounded in ASB-ING standards. The data allows the construction of parameterized bridges within Revit, using the Sofistik Bridge Modeler. This integration results in the bridges being cataloged and exported following the IFC4x3 standard, which signifies a leap in interoperability between ASB-ING and IFC.

This research achieved a significant breakthrough by automating the mapping schema through the development of a bespoke Revit ASB-ING extension, an innovative tool, which streamlines the data mapping schema by automatically generating a model for four distinct bridge types, utilizing both the Revit API and the Sofistik Bridge Modeler API, upon the input of a structure number, followed by its export as an IFC4 file. The extension, whose codebase is hosted on GitHub for public access, was developed with a focus on scalability and adaptability, providing a robust foundation for future enhancements and customizations.

5.2 Outlook

The successful development of a data mapping schema for transitioning bridge data between the ASB-ING and IFC4x3 (IFC4) formats sets the stage for further enhancements and broader applications. The next steps are aimed at refining and expanding the schema to elevate its utility and effectiveness in bridge modeling.

1. **Enhancing Detailing in the Mapping Schema:** The immediate goal is to enrich the data mapping schema by incorporating additional structural details. This involves a more nuanced representation of structural elements, such as various span lengths, as well as specific geometric features like railings. It would lead to an improved accuracy and fidelity of the data mapping schema. This enhancement includes better parameter approximations, integrating more structural parameters from ASB-ING, and utilizing a broader range of Sofistik Bridge Modeler types.

2. **Expanding Bridge Type Coverage:** While this thesis focused on specific bridge types, future projects could aim to encompass a broader array of bridge types. This

expansion will enable a more extensive application of the mapping schema. It would involve developing new mapping strategies for various bridge types by incorporating additional Sofistik Bridge Modeler families and types.

3. **Incorporating Non-Structural Elements:** Moving beyond strictly structural components, there is a clear opportunity to include data related to materials, finishes, and other semantics. This approach would enable a more complete and informative bridge model, enhancing the mapping from ASB-ING to IFC by incorporating additional data.

4. **Implementation Refinements:** Further development could also focus on refining the ASB-ING extension using the Revit API and the Sofistik Bridge Modeler API. Enhancements could aim at optimizing efficiency, user-friendliness, and most important extend integration capabilities, ensuring that the automated mapping schema would become more powerful and accessible to users. Additionally, it would be beneficial if it would be possible to convert multiple bridges into an IFC file simultaneously. Further, error handling is something, one has to include.

5. **Challenges:** While it is relatively straightforward to include more bridge types, enhancing structural detailing presents significant challenges. The ASB-ING is limited, lacks spatial references, and the data is imprecise. Achieving detailed mapping requires either more precise data or the use of scientific algorithms to approximate the missing data values. It is crucial to determine whether such an effort is worthwhile.

By undertaking these next steps, the project will not only enrich the depth and scope of the data mapping schema but also contribute to the field of bridge maintenance and inspection in Germany. However, although mapping the principal bridge structure from ASB-ING to IFC is possible, further research is necessary to identify use cases, assess their necessary level of mapping detail, and evaluate their overall value.

Appendix A

Mapping Tables

Here are the specific mapping tables included. They clearly show which parameters are needed and how they are computed, based on the data provided by the SIB-Bauwerke tables.

Axis

Table A.1: Alignment

Type	Length	Startradius	Endradius
Line	STUETZ_WEITE	None	None
Line	LAENGE	None	None
Line	STUETZ_WEITE	None	None

Table A.2: Placements (where n = ANZ_FELDER + 2)

Station	Placement type
0 * STUETZ_WEITE	Overhang (Not implemented)
1 * STUETZ_WEITE	Bearing
2 * STUETZ_WEITE	Bearing
3 * STUETZ_WEITE	Bearing
......	
n * STUETZ_WEITE	Overhang (Not implemented)

Superstructure

Table A.3: SOFiTSiK_Profile_T-BEAM (Profile_T-Beam_Type-1)

Parameter	Variation type	Value
Width	const	BREITE
Width_Beam_Bottom	const	2/3 BREITE
Width_Beam_Top	const	2/3 BREITE
Thickness_Deck_Side	const	(KONST_MAX + KONST_MIN) / 6
Thicknes_Deck_Middle	const	(KONST_MAX + KONST_MIN) / 3
Height_Total	const	(KONST_MAX + KONST_MIN) / 2

Table A.4: SOFiTSiK_Profile_T-BEAM (Profile_T-Beam_Type-1)

Parameter	Variation type	Value
Width	const	BREITE
Width_Beam_Bottom	const	1/6 BREITE
Width_Beam_Top	const	1/4 BREITE
Thickness_Deck_Side	const	(KONST_MAX + KONST_MIN) / 12
Thicknes_Deck_Middle	const	(KONST_MAX + KONST_MIN) / 6
Height_Total	const	(KONST_MAX + KONST_MIN) / 2

Table A.5: SOFiSTiK_2_T_Beam_single_slope (Control Width Beam)

Parameter	Variation type	Value
Slope_Deck	const	0 (no angles)
Slope_Cantilever	const	0 (no angles)
Width_Deck_Right	const	1/3 BREITE
Width_Deck_Left	const	1/3 BREITE
Width_Parapet_Right	const	1/6 BREITE
Width_Parapet_Left	const	1/6 BREITE
Thickness_Cover	const	0
Thickness_Cantilever_Edge	const	(KONST_MAX + KONST_MIN) / 10
Width_Beam	const	1/8 BREITE
Thickness_Deck	const	(KONST_MAX + KONST_MIN) / 6
Height_Beam	const	(KONST_MAX + KONST_MIN) / 2
Width_Cantilever_Right	const	0
Width_Cantilever_Left	const	0
Width_Beam_Axis_Right	const	1/4 BREITE
Width_Beam_Axis_Left	const	1/4 BREITE
Thickness_Cantilever_Right	const	(KONST_MAX + KONST_MIN) / 6
Thickness_Cantilever_Left	const	(KONST_MAX + KONST_MIN) / 6
Thickness_Slab_Edge_Beam_Left	const	(KONST_MAX + KONST_MIN) / 6
Thickness_Slab_Edge_Beam_Right	const	(KONST_MAX + KONST_MIN) / 6
Offset_Beam_Cantilever	const	0
Offset_Beam_Slab	const	0
Width_Slab_Transition_Left	const	0
Width_Slab_Transition_Right	const	0
B_R	const	0
L_R	const	0
Width_Drainage	const	0
Offset_Axis_Horizontal	const	0
Offset_Axis_Vertical	const	0

Table A.6: SOFiSTiK_HOLLOW_single_slope (Control with Slap Bottom)

Parameter	Variation type	Value
Height	const	(KONST_MAX + KONST_MIN) / 2
Slope_Deck	const	0 (no angles)
Slope_Cantilever	const	0 (no angles)
Width_Deck_Right	const	3/8 BREITE
Width_Deck_Left	const	3/8 BREITE
Width_Parapet_Right	const	1/8 BREITE
Width_Parapet_Left	const	1/8 BREITE
Thickness_Cover	const	0
Thickness_Cantilever_Edge	const	(KONST_MAX + KONST_MIN) / 24
B_R	const	0
B_L	const	0
Thickness_Slab_Top	const	1/23 BREITE
Thickness_Slab_Bottom	const	1/23 BREITE
Width_Slab_Bottom_Right	const	1/4 BREITE
Width_Slab_Bottom_Left	const	1/4 BREITE
Width_Cantilever_Right	const	0
Width_Cantilever_Left	const	0
Thickness_Web	const	1/23 BREITE
Angle_Web	const	60
Thickness_Cantilever	const	1/23 BREITE
Thickness_Haunch_Top	const	1/23 BREITE
Width_Haunch_Top	const	0
Width_Haunch_Transition_Top	const	0
Thickness_Haunch_Bottom	const	1/23 BREITE
Width_Haunch_Bottom	const	0
Width_Haunch_Transition_Bottom	const	0
Angle_Haunch_Bottom	const	60
Width_Drainage	const	0
Offset_Axis_Horizontal	const	0
Offset_Axis_Vertical	const	0

Substructure

Table A.7: SOFiSTiK_Generic_Abutment-01

Parameter	Value
alpha	const = 0
B_Abutment	BREITE
H_Abutment	STUETZ_HOEHE
L_wingwall	BREITE
L_cant	1/12 BREITE
D_wingwall	1/12 BREITE
H1_wingwall	1/4 STUETZ_HOEHE
incl	const = 0
B_Found_wingwall_outside	1/6 BREITE
B_Found_wingwall_inside	1/6 BREITE
B_Found_frontwall_outside	1/6 BREITE
B_Found_frontwall_inside	1/6 BREITE
D_Foundation	1/4 STUETZ_HOEHE
D_Frontwall_top1	1/12 BRREITE
D_Frontwall_top2	1/6 BREITE
H_Frontwall_1	const = 0
H_Frontwall_2	const = 1
H_Frontwall_3	const = 1
H_Frontwall_4	1/3 STUETZ_HOEHE

Table A.8: SOFiSTiK_Generic_Pier-01

Parameter	Value
B_Pier_Top	const=2.4
B_Pier_Bottom	const=2.5
H_axis_pier	const=2.0
H_Pier	STUETZ_HOEHE
D_Pier_Top	const=0.5
D_Pier_Bottom	const=0.6
B_Found_xl	const=3.0
B_Found_xr	const=3.0
B_Found_yl	const=3.0
B_Found_yr	const=3.0
D_Foundation	1/4 STUETZ_HOEHE

Table A.9: SOFiSTiK_Generic_Pier-02

Parameter	Value
B1	const=2.0
H_axis_pier	const=2.0
H_Pier	STUETZ_HOEHE
R_top	const=0.5
R_bottom	const=0.5
B_Found_xl	const=3.0
B_Found_xr	const=3.0
B_Found_yl	const=3.0
B_Found_yr	const=3.0
D_Foundation	1/4 STUETZ_HOEHE

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Declaration

I hereby affirm that I have independently written the thesis submitted by me and have not used any sources or aids other than those indicated.

Location, Date, Signature