IFC Schema Extension for BIM-based Automated Code Checking of Korean Design Standards for Bridges

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Abstract –

In Korea, research initiatives have commenced to digitize engineering and construction codes, and automate their compliance using BIM models for mandatory submission in public projects. The initiatives require employing IFC, a neutral and standard data format, to associate individual codes with relevant BIM elements. However, the IFC does not provide explicit extensions to represent the varied codes, which include the Korean Design Standards (KDS) and the Korean Construction Specifications (KCS).

To address this limitation, this study developed an extended IFC schema called 'IFC-KR', focusing initially on bridges. The extensions define subtypes to represent various types of bridges, structures, and elements, along with property sets that capture the relevant attributes and properties of 1,437 KDS codes. Moreover, a specialized extension module named 'IFC-KR Toolkit' has been developed to automate the addition of KDS data relevant to each element within the IFC Physical File.

To validate the functionality of the module, KDS items were applied to an Extradosed (ED) cable-stayed bridge model. The results confirmed that all data were accurately integrated, and the extended data was consistently verified using a third-party IFC viewer, demonstrating its accuracy and interoperability.

Keywords –

BIM; IFC Schema Extension; Automated Code Checking; Korean Design Standards; Bridges

1 Introduction

In Korea, engineering and design submittals for all public projects must be checked for their conformance to Korean Design Standards (KDS) and Construction Specifications (KCS) [8]. However, the current code checking process remains highly inefficient as it relies on engineers manually verifying KDS presented in textual format. Moreover, this manual process significantly hinders the ability to promptly respond to design changes or updates of these codes [17].

The Korean Ministry of Land, Infrastructure, and Transport (MOLIT) is making significant efforts to overcome these limitations by developing a framework for BIM-based automated code checking (ACC) [12]. At the core of these initiatives is the digitalization of KDS, which involves the conversion of individual provisions into digital rules and parameters that can be seamlessly integrated with BIM model data, thereby enable the ACC process.

Associating BIM models with KDS data requires employing the Industry Foundation Classes (IFC), the international standard data format, which allows customized extensions of its schema for local or regional data sharing requirements [11]. However, the standard IFC schema lacks formal definitions for the entities and property sets (Psets) required to integrate KDS tailored to Korea.

The Building and Construction Authority (BCA) in Singapore developed an extended IFC schema, known as 'IFC-SG[1]'. IFC-SG defines custom entities and Psets to ensure that data within IFC models aligns with Singapore's information mandates of BIM models, and is used as the medium for information exchange in CORENET-X [2] [3]. However, IFC-SG is designed exclusively for the building permit domain and is not suitable for accommodating KDS related data that relates to infrastructure assets and engineering specifications.

This study aimed to develop an extended IFC schema, termed 'IFC-KR', specifically tailored to accommodate data related to Korea's design standards while integrating

[1] https://www1.bca.gov.sg/regulatory-info/building-control/corenet-x/resources/ifc-sg-resource-toolkit
[2] https://www1.bca.gov.sg/regulatory-info/building-control/corenet-x

specialized engineering knowledge pertinent to the infrastructure domain. To enhance practical applicability, the study also developed 'IFC-KR Toolkit', a module that enables the insertion of required data into the IFC Physical File (IPF) in accordance with the IFC-KR schema.

This study focuses on bridges, a representative infrastructure facility type, and is structured as follows: Section 2 reviews the development status and limitations of the standard IFC schema and previous studies on IFC schema extensions. Section 3 presents the research methodology. Section 4 details the development process of the IFC-KR schema, and Section 5 outlines the methodology for developing the IFC-KR Toolkit. Section 6 validates the extension results in IFC-KR Toolkit.

2 Research Background

2.1 Current Status and Limitations of the Standard IFC Schema

buildingSMART International (bSI) developed the IFC, a neutral standard model, to enable seamless data exchange between BIM applications. The standard IFC schema provided by bSI encompasses the specification of objects, attributes, and relationships within BIM models and undergoes continuous updates to ensure its adaptability and relevance [10].

The initial IFC schema was primarily designed to represent the architectural domain [9]. However, the release of IFC4 in 2013 introduced support for infrastructure-related objects, focusing primarily on bridge facilities. In particular, bridge-related elements were formally integrated, with the addition of the *IfcBridge* and *IfcBridgePart* entities, geometric representations for horizontal structures and structural connectivity, and data attributes for load conditions. This was further expanded with IFC4.3 in 2021, which added entities and attributes to accommodate a broader range of infrastructure facilities, including railways, and roads [4].

Despite the continuous updates to the IFC schema, several factors still hinder its practical application. The main challenges include: 1) limited scope of application, 2) difficulties in adopting national and regional requirements, and 3) incomplete representation of domain-specific data requirements. The detailed issues for each challenge are as follows:

1) Limited scope of application

While the IFC schema has been updated to include new entities, its initial development was heavily focused on the architectural domain. Consequently, other domains, such as infrastructure, often had to adopt architectural entities to represent their specific objects. This limitation has been identified as a major barrier to achieving interoperability in non-architectural domains [14, 18]. In particular, Korean infrastructure projects frequently include tunnels, yet the IFC schema does not provide explicit definitions for tunnel-related entities. As a result, architectural entities must still be adopted to represent tunnels, which limits their practical application and interoperability.

2) Difficulties in adopting national and regional requirements

Although the IFC schema is designed as a standardized data structure, it has limitations in adopting the diverse requirements of various nations and regions. Furthermore, updates to the schema must undergo a rigorous review process by the bSI Standards Committee, which is time-consuming and makes it challenging to promptly incorporate necessary data into the schema [2]. This limitation is particularly evident in Korean infrastructure projects, where the KDS require detailed structural analysis and geometric attributes. However, the current IFC schema lacks predefined entity types and attributes for these requirements, making it difficult to directly integrate KDS compliance into BIM-based workflows.

3) Incomplete representation of domain-specific data requirements

bSI has continuously expanded the scope of IFC to address the evolving requirements of the construction industry. Initially, structural elements and analysis domains were introduced, followed by MEP domains, and more recently, infrastructure domains such as roads and railways. However, throughout this process, many newly defined entities have failed to fully capture the semantic representations and attributes required by their respective domains. Such limitations in representing essential information hinder the full utility of IFC, posing significant constraints on its applicability. For instance, while IFC4 introduced bridge-related entities, essential elements widely used in Korean bridge projects, such as joints and approach slabs, are still missing. This absence limits the accuracy and completeness of bridge models within the IFC schema, necessitating extensive customization to meet Korean infrastructure project requirements. Additionally, gaps in representation, interoperability, and compliance with engineering standards were identified based on practical application cases [13]. These limitations highlight the need for extensions such as IFC-KR to enhance adaptability while maintaining compatibility with the existing IFC framework.

2.2 Approaches for IFC Schema Extension

To address the limitations of the standard IFC, many studies have proposed to extend its schema. These extensions are broadly classified into two methods: Entity Extension, which involves the definition of new entities, and Property Extension, which focuses on integrating and associating additional data with existing entities.

2.2.1 Entity Extension

This method involves defining new entities within the existing schema to represent previously unsupported elements and processes. By enabling the detailed representation of domains and entities that were not previously addressed, it provides the advantage of supporting tailored and highly precise data modeling [6]. However, the outcomes of this method are often not officially incorporated into the standard IFC schema. As a result, the added entities can only be utilized in BIM authoring tools and IFC viewers specifically modified to recognize these custom entities, presenting a significant limitation.

2.2.2 Property Extension

This method involves adding new properties, attributes, or subtypes to existing entities, primarily utilizing Type entities (e.g., *IfcBuiltElementType*) or Property sets (Psets). For example, the *IfcColumn* entity can be further specified using *IfcColumnType* entity, a subtype of *IfcBuiltElementType* entity. Additionally, when further detailed classifications are required, new types can be added using the USERDEFINED type.

Psets are employed to define general attributes, such as dimensions or materials, and are linked with *IfcObject* entities using *IfcRelDefinesByProperties* entity. This method preserves the original IFC schema while allowing new data to be added, minimizing compatibility issues across BIM authoring tools and IFC viewers.

Recently, the ‘Linked Data Approach’ has emerged as a method to effectively connect external data to the IFC schema while maintaining data integrity. This method links external data stored in the buildingSMART Data Dictionary (bSDD) and Object-Type Libraries (OTLs) to the IFC schema, enabling connectivity between IFC models and various data sources [16].

bSI does not recommend creating new entities that may be limited to specific use cases. Rather, it prioritizes the use of property extensions by using predefined classifications, types, and Psets within the standard IFC schema [1].

3 Research Methodology

This study aims to develop an extended IFC schema and extension module to facilitate BIM-based automated code checking in the bridge domain. As illustrated in Figure 1, the research is structured into three phases: 1) development of an extended IFC schema, ‘IFC-KR’, 2) development of a module for creating IFC-KR extensions, and 3) validation of the extended IFC using the extension module.

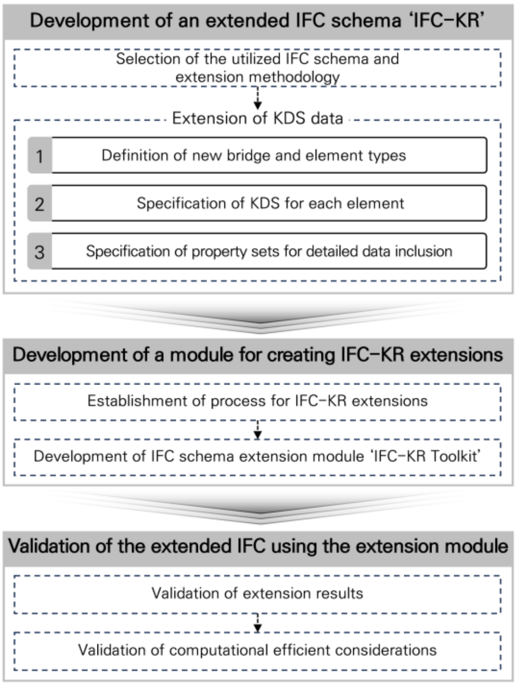


Figure 1. Research process

4 Development of ‘IFC-KR’

4.1 Selection of the Utilized IFC Schema and Extension Methodology

IFC-KR is an extended IFC schema specialized for incorporating data related to the KDS. We developed the optimal IFC schema and extension method based on the extension approaches discussed in Section 2. Additionally, appropriate software was selected to implement the IFC-KR Toolkit, a module designed to extend the IFC schema and incorporate KDS data for individual elements into the IPF.

The standard IFC schema targeted for extension was selected as IFC4.3, which effectively represents bridge structures and infrastructural characteristics. IFC4.3 includes the *IfcBridge* entity for representing bridges, and bridge types such as Arch, Truss, and Girder bridges can be defined using the *IfcBridgeTypeEnum* entity. Additionally, structural elements of bridges, such as Abutments, Piers, and Superstructures, can be defined using the *IfcBridgePartTypeEnum* entity.

The property extension approach was adopted to incorporate the KDS data. Individual properties served as the basic units of data for this extension, while Pset was utilized to organize and extend the schema when multiple KDS data items needed to be included.

This approach allows additional data to be incorporated without altering the standard IFC schema, ensuring that IFC-KR remains compatible with existing IFC-supported applications. Since the extensions are structured as additional Psets rather than modifications to core schema entities, software that supports the base IFC schema can still process IFC-KR schema without interoperability issues.

In the process of applying the Property Extension methodology, the Data Linkage Approach, inspired by the Linked Data Approach, was utilized. Similar to conventional methods, this approach connects external data to Psets. However, instead of relying on bSDD or OTLs, it is specifically designed to directly link to external files (e.g., .xml, .csv) containing digitized KDS. For this study, Autodesk Revit 2025, equipped with an IFC Exporter capable of extracting in the IFC4.3 format, was utilized as the BIM authoring tool. For the IFC viewer, KBim Assess-Lite[3], an open-source application with a proprietary parser enabling fast data exchange, was employed. The IFC-KR Toolkit, the module developed specifically for this study, was developed as an add-in in KBim Assess-Lite.

4.2 Extension of KDS Data

4.2.1 Definition of New Bridge and Element Types

This study focused on three bridge types most commonly utilized in Korea: PSC girder bridges, Steel girder bridges, and Extradosed (ED) cable-stayed bridges. In IFC4.3, the *IfcBridge* entity defines bridge types using the predefined type, *IfcBridgeTypeEnum* entity. However, the aforementioned three bridge types are not included within the predefined options. Thus, these bridge types were newly defined under the USERDEFINED type in *IfcBridgeTypeEnum* entity.

For elements, the *IfcElement* entity was used, with detailed subtypes defined by the enumeration type of the *IfcElementType* entity. For this study, 16 subtypes already defined in the standard IFC schema and applicable to the three bridge types were utilized without modification. For the nine element types not covered by the standard IFC schema, new subtypes were introduced as USERDEFINED types (Table 1).

Table 1. Subtypes by Elements in IFC-KR

Element (IFC4.3 entity)	Subtypes (*=USERDEFINED)
Anchor (*IfcTendonAnchor*)	TENSIONING_END
Approach slab (*IfcSlab*)	*APPROACH_SLAB
Base plate (*IfcPlate*)	BASE_PLATE
Bearing (*IfcBearing*)	ELASTOMERIC
Bracing (*IfcMember*)	BRACE
Bracing wall (*IfcWall*)	*BRACING_WALL
Cable (*IfcMechanicalFastener*)	*CABLE
Cast in place pile (*IfcPile*)	BORED
Column (*IfcColumn*)	PIERSTEM
Continuous slab (*IfcSlab*)	*CONTINUOUS_SLAB
Covering (*IfcCovering*)	COPING
Cross beam (*IfcBeam*)	*CROSSBEAM
Deck plate (*IfcPlate*)	BASE_PLATE
Diaphragm (*IfcBeam*)	DIAPHRAGM
Girder (*IfcBeam*)	GIRDER_SEGMENT
Parapet wall (*IfcWall*)	PARAPET
Pile foundation (*IfcPile*)	SUPPORT
Pylon (*IfcElementAssembly*)	PYLON
Steel pipe pile (*IfcPile*)	*STEEL_PIPE
Wall (*IfcWall*)	STANDARD
Wing wall (*IfcWall*)	RETAININGWALL
Joint (*IfcMember*)	*JOINT
Shear connector (*IfcMechanicalFastener*)	SHEARCONNECTOR
K-braced Diaphragm (*IfcBeam*)	*KBRACED_DAPHRAGM
PC_HOUSE (*IfcBuildingElementProxy*)	*PCHOUSE

4.2.2 Specification of KDS for Each Element

[15] developed a ‘standards map’ based on bridge design and construction processes that visualizes the code checking sequence and conditions for each element, and links them to the applicable KDS. This study utilized these standards maps to identify the required KDS for each element type and categorized KDS items by considering both element units and code checking procedures (Table 2).

Table 2. Classification of KDS items by elements and code checking procedures

Bridge type	Element type	Code checking procedure	KDS item
PSC girder bridge	Cross beam	Selection of design conditions	KDS 24 14 21_ 4.2.1.2_Table 4.2-1
			KDS 24 14 21_ 4.2.1.2_Table 4.2-2
		Load calculation and combination	KDS 24 12 21
			KDS 24 12 11
		Review of cross beam cross-section	KDS 24 17 11_ 4.6.3.3
			KDS 24 14 21_ 4.2.3.3
ED cable-stayed bridge	Pylon	Selection of design conditions	KDS 24 14 21_ 4.4.4.2_Table 4.4-3
			KDS 24 14 21_ 4.4.1_Table 4.4-1
		Load calculation and combination	KDS 24 12 22
			KDS 24 12 12
		Design of pylon cross-section	KDS 24 14 21_ 4.1.2.1
			KDS 24 14 21_ 4.6.2.6 (5)

4.2.3 Specification of Psets for Detailed Data Inclusion

[5, 7] classified the specific KDS codes for bridge

[3] Open-source IFC viewer developed by the national research project (https://www.inno-lab.co.kr/Home/kr/product-KBim_Assess- Lite.html)

structures based on quantitative and qualitative characteristics. They identified the input variables necessary for performing code checking for each item and the output variables required to represent the results.

KDS items were categorized as: 1) quantitative items requiring formula-based calculations and 2) qualitative items requiring engineering decisions (Table 3). Ultimately, only the quantitative items suitable for digitalization were selected, resulting in 1,437 KDS items being utilized.

Table 3. Examples of quantitative/qualitative classification items

Category	Contents of KDS
Quantitative	KDS 11 50 15_4.1.1.1 (2) [Allowable axial displacement of pile foundation] : The allowable axial displacement of the pile foundation shall be within the allowable displacement of the superstructure.
Qualitative	KDS 11 50 15_4.2.3.4 (4) [Consolidation settlement] : Other consolidation settlement can be calculated through appropriate numerical analysis methods such as finite element analysis.

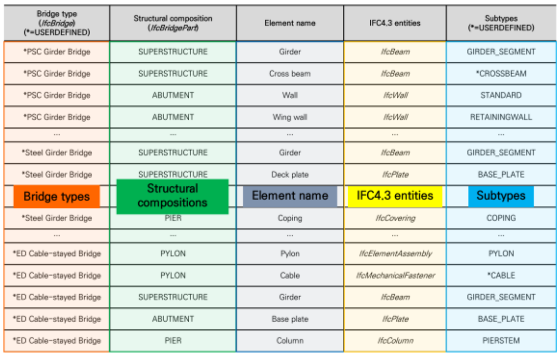
4.3 Detailed Schema of IFC-KR

The IFC-KR schema, designed to incorporate the newly defined items, was developed with a three-tier structure comprising 'Object taxonomy, KDS mapping, and Psets'. The schema was further divided into separate sub-schemas to align specifically with KDS requirements.

1) Object taxonomy tier

The object taxonomy tier defines the IFC entities required to represent the different types of bridge, structural composition, and element. It specifies the structures and elements associated with each bridge type. Specifically, it consists of (1) bridge type (*IfcBridge*), (2) structural composition (*IfcBridgePart*), (3) element name, (4) IFC4.3 entity (*IfcElement*), and (5) subtypes of each element (*IfcElementType*).

The taxonomy was developed to include the three bridge types and nine element types defined in Section 4.2.1. An excerpt of the KDS object taxonomy tier is provided in Figure 2. For example, 'PSC Girder Bridge' is defined using the *IfcBridge* entity, while one of its sub-elements 'ABUTMENT' is defined using the *IfcBridgePart* entity. The specific element 'Wall' is assigned using IFC4.3 entity *IfcWall*, while its subtypes such as the 'STANDARD' and 'RETAININGWALL' are defined using the enumeration type of the *IfcElementType* entity.

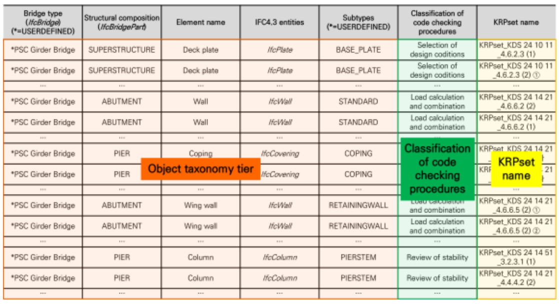


Bridge type (*IfcBridge*) (*=USERDEFINED)	Structural composition (*IfcBridgePart*)	Element name	IFC4.3 entities	Subtypes (*=USERDEFINED)
*PSC Girder Bridge	SUPERSTRUCTURE	Girder	*IfcBeam*	GIRDER_SEGMENT
*PSC Girder Bridge	SUPERSTRUCTURE	Cross beam	*IfcBeam*	*CROSSBEAM
*PSC Girder Bridge	ABUTMENT	Wall	*IfcWall*	STANDARD
*PSC Girder Bridge	ABUTMENT	Wing wall	*IfcWall*	RETAININGWALL
...	...	...	...	...
*Steel Girder Bridge	SUPERSTRUCTURE	Girder	*IfcBeam*	GIRDER_SEGMENT
*Steel Girder Bridge	SUPERSTRUCTURE	Deck plate	*IfcPlate*	BASE_PLATE
*Steel Girder Bridge	PIER	Coping	*IfcCovering*	COPING
...	...	...	...	...
*ED Cable-stayed Bridge	PYLON	Pylon	*IfcElementAssembly*	PYLON
*ED Cable-stayed Bridge	PYLON	Cable	*IfcMechanicalFastener*	*CABLE
*ED Cable-stayed Bridge	SUPERSTRUCTURE	Girder	*IfcBeam*	GIRDER_SEGMENT
*ED Cable-stayed Bridge	ABUTMENT	Base plate	*IfcPlate*	BASE_PLATE
*ED Cable-stayed Bridge	PIER	Column	*IfcColumn*	PIERSTEM

Figure 2. Example of object taxonomy tier (KDS)

2) KDS mapping tier

The KDS mapping tier defines the KDS items that need to be checked for individual elements previously specified through the object taxonomy tier. For example, the Abutment wall needs to be checked for its load calculation and combinations. These correspond to 'KDS 24 14 21_4.6.6.2 (1)' and 'KDS 24 14 21_4.6.6.2 (2)'. A sample of the KDS mapping tier is shown in Figure 3.



Bridge type (*IfcBridge*) (*=USERDEFINED)	Structural composition (*IfcBridgePart*)	Element name	IFC4.3 entities	Subtypes (*=USERDEFINED)	Classification of code checking procedures	KRPset name
*PSC Girder Bridge	SUPERSTRUCTURE	Deck plate	*IfcPlate*	BASE_PLATE	Selection of design coditions	KRPset_KDS 24 10 11 _4.6.2.3 (1)
*PSC Girder Bridge	SUPERSTRUCTURE	Deck plate	*IfcPlate*	BASE_PLATE	Selection of design coditions	KRPset_KDS 24 10 11 _4.6.2.3 (2) ①
...	...	...	...	...	...	...
*PSC Girder Bridge	ABUTMENT	Wall	*IfcWall*	STANDARD	Load calculation and combination	KRPset_KDS 24 14 21 _4.6.6.2 (2)
*PSC Girder Bridge	ABUTMENT	Wall	*IfcWall*	STANDARD	Load calculation and combination	KRPset_KDS 24 14 21 _4.6.6.2 (1)
...	...	...	...	...		...
*PSC Girder Bridge	PIER	Coping	*IfcCovering*	COPING		
*PSC Girder Bridge	PIER		*IfcCovering*	COPING		
...	...	...	...	...		...
*PSC Girder Bridge	ABUTMENT	Wing wall	*IfcWall*	RETAININGWALL	and combination	KRPset_KDS 24 14 21 _4.6.6.5 (2) ①
*PSC Girder Bridge	ABUTMENT	Wing wall	*IfcWall*	RETAININGWALL	Load calculation and combination	KRPset_KDS 24 14 21 _4.6.6.5 (2) ②
...	...	...	...	...	...	...
*PSC Girder Bridge	PIER	Column	*IfcColumn*	PIERSTEM	Review of stability	KRPset_KDS 24 14 51 _3.2.3.1 (1)
*PSC Girder Bridge	PIER	Column	*IfcColumn*	PIERSTEM	Review of stability	KRPset_KDS 24 14 21 _4.4.4.2 (2)
...	...	...	...	...	...	...

Figure 3. Example of KDS mapping tier

3) Psets tier

The Psets tier define the data required for the quantitative code checking of the 1,437 KDS items. Each Pset contains the following items: (1) Pset name (KRPset Name), (2) KDS code, (3) BIM design values, and (4) Results. The detailed structure of the Pset tier for the 'Load calculation and combination' item (KDS 24 14 21_4.6.6.2 (2)) related to the wall element of a PSC girder bridge is given in Table 4, with an example input shown in Figure 4.

In Table 4, 'KRPset name' indicates the name of the design code associated with the element, while 'Property name' indicates the names of the input/output variables. 'Property value' represents the detailed values of these variables, and 'Property type' indicates the specific data type. Data types are expressed as *IfcLabel* for strings, *IfcReal* for real numbers, and *IfcBoolean* for boolean values. Finally, the 'Property unit' defines the unit of the detailed values.

KRPset name	KDS code	Property name	Property value	Property type	Property unit
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	KDS code	24 14 21_4.6.6.2 (1)	*IfcLabel*	
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Ruleset code	KDS241421_04060602_01	*IfcLabel*	
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Library code	Library code	*IfcLabel*	
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Total cross-sectional area of all reinforcing bars including reinforcing bars with lap joints		*IfcReal*	mm²
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	cross-sectional area of a column		*IfcReal*	mm²
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Cross-sectional area of prestressing steel		*IfcReal*	mm²
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Design tensile strength of prestressing steel		*IfcReal*	Mpa
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Design basis yield strength of axial reinforcing bar			
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Design standard compressive strength of concrete			
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Effective tension stress of prestressed steel		*IfcReal*	Mpa
KRPset_KDS 24 14 21_4.6.6.2 (1)	24 14 21_4.6.6.2 (1)	Results		*IfcBoolean*	
...	...	...	...	...	...
KRPset_KDS 24 14 21_4.6.6.4 (3)	24 14 21_4.6.6.4 (3)	Coarse aggregate maximum size		*IfcReal*	mm
KRPset_KDS 24 14 21_4.6.6.4 (3)	24 14 21_4.6.6.4 (3)	Spacing between centers of spiral bars		*IfcReal*	mm
KRPset_KDS 24 14 21_4.6.6.4 (3)	24 14 21_4.6.6.4 (3)	Axial bar diameter		*IfcReal*	mm
KRPset_KDS 24 14 21_4.6.6.4 (3)	24 14 21_4.6.6.4 (3)	Results		*IfcBoolean*	

Figure 4. Example of Psets tier (KDS)

Table 4. Example of Pset for ‘KDS 24 14 21_4.6.6.2 (2)’

KRPset name	Property name	Property value	Property type	Property unit
KRPset_ KDS 24 14 21_ 4.6.6.2 (2)	KDS code	24 14 21_ 4.6.6.2 (2)	*IfcLabel*	-
	Axial reinforcing bar cross-sectional area in normal section, not at lap joint		*IfcReal*	mm^2
	Cross-sectional area of a column		*IfcReal*	mm^2
	Cross-sectional area of prestressing steel		*IfcReal*	mm^2
	Design tensile strength of prestressing steel		*IfcReal*	Mpa
	Design basis yield strength of axial reinforcing bar		*IfcReal*	Mpa
	Specified compressive strength of concrete		*IfcReal*	Mpa
	Results		*IfcBoolean*	-

5 Development of Module for creating IFC-KR extensions

5.1 Process of creating IFC-KR extensions

A four-step process for inserting KDS data into individual elements within an IPF using the extended IFC structure, IFC-KR, is presented in Figure 5.

The first step involves specifying the bridge type and individual structure types for the IFC4.3 model extracted from a BIM authoring tool. The second step determines the appropriate entity and subtype according to the specified element type. The third step selects the design checking procedures applicable to the specified element type and displays the relevant KDS items. Finally, detailed data is displayed for each checking item, including ‘KDS code, BIM design values, and results’ with the option to manually enter detailed BIM design values if necessary.

5.2 IFC Schema Extension Module ‘IFC-KR Toolkit’

The process was implemented by developing the ‘IFC-KR Toolkit’. This module was integrated as an add-in within KBim Assess-Lite. The User Interface (UI) was designed to display appropriate KDS provisions for the selected element by allowing users to specify consecutively, the Object taxonomy, KDS mapping, and Psets tier of IFC-KR. The module operates on IPFs extracted from BIM authoring tools (e.g., Autodesk Revit) which need to be extracted using version IFC4.3 and Reference View. The module also allows for the modification of incorrectly entered element types and enables the selection of unmapped additional items from the complete KDS list.

6 Validation of Results

6.1 Validation of extension results

To verify the effectiveness of the developed module, the validation process was conducted in three stages: 1) data integration accuracy, 2) property set consistency, and 3) IFC standard compliance.

1) Data integration accuracy

The IFC-KR was applied to an ED cable-stayed bridge model, where five KDS items were mapped to three key elements (pylon, girder, and pier). The IFC-KR Toolkit was used to insert the required KDS properties into the IPF (.ifc). The extended IPF file was then inspected to confirm that the correct KDS properties were assigned to each corresponding element.

2) Property set consistency

To ensure the accuracy of the inserted data, the generated IFC file was loaded into KBim Assess-Lite, where the extended KDS properties were checked within the ‘Property Set’ tab. Each property was manually verified to confirm that its naming, data types (e.g., *IfcReal*, *IfcBoolean*), and data structure matched the intended KDS format (Figure 6).

3) IFC standard compliance

Finally, the extended IFC-KR model was exported and tested using BIMvision, a commercial IFC viewer supporting IFC4.3. This step ensured that the inserted KDS properties were correctly interpreted and displayed without loss of data or formatting inconsistencies. Additionally, interoperability with third-party IFC viewers was assessed by verifying that the modified IFC schema maintained compatibility with existing BIM workflows.

The results of this validation confirmed that all KDS data was successfully embedded into the IFC model and could be accurately visualized and interpreted in external IFC software (Figure 7).

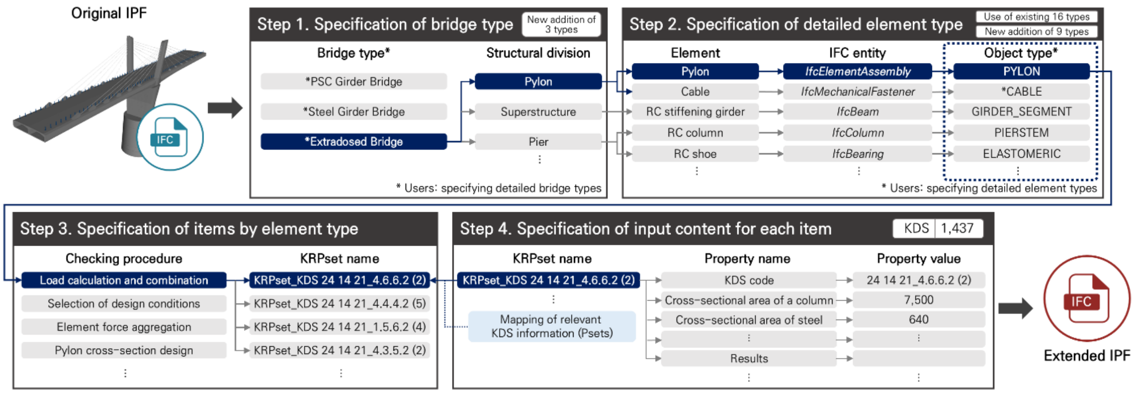


Figure 5. Process of extending KDS data using IFC-KR

This study primarily focused on the validation of an ED cable-stayed bridge as an example because ED bridges have a more complex structural configuration compared to PSC girder bridges and steel girder bridges. Given the higher complexity of ED bridges, it serves as a more rigorous test case for validating the IFC-KR schema. Additionally, the same validation process was applied to PSC girder bridges and steel girder bridges, and the results confirmed that the IFC-KR schema was equally effective for these bridge types as well.

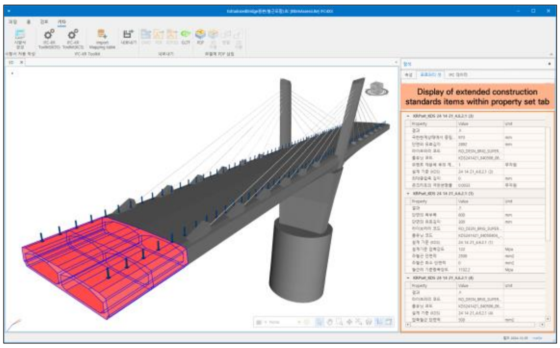


Figure 6. Extension results in IFC-KR Toolkit

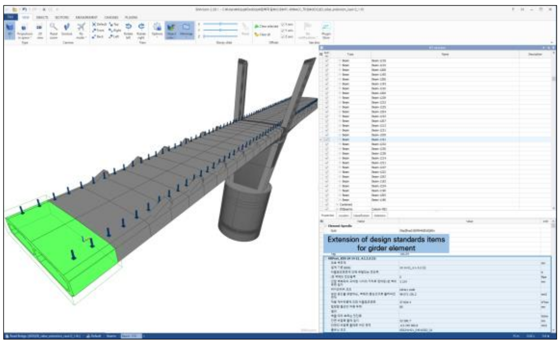


Figure 7. Validation of extension results in BIMvision

6.2 Computational Efficiency Considerations

The IFC model used in this validation had a file size of 80MB, and the extension process using the IFC-KR Toolkit took approximately 15 seconds. However, it is important to note that the validated IFC model contained only a limited number of reinforcing bars. For high-LOD models with a significant number of reinforcing bars, the processing time may increase substantially. As such, further research will focus on evaluating computational efficiency under different model complexities and exploring potential optimization strategies to enhance performance.

7 Conclusion

This study introduced the extended IFC schema, ‘IFC-KR’, and ‘IFC-KR Toolkit’, a module dedicated to creating IFC-KR extensions, to support BIM-based ACC for Korean design standards.

IFC-KR was built on the IFC4.3 standard, with three bridge types and nine detailed element types newly defined as USERDEFINED types. Additionally, 1,437 KDS items were mapped, and the required data for each item, including input/output variables and BIM design values, was extended in the form of Psets.

The IFC-KR Toolkit was developed as a tool that enables the creation of IFC-KR compliant IPF’s. The module allows the input and display of KDS items and Pset data for each element during the extension process.

To validate the module, KDS items were extended for the pylon, girder, and pier elements of an ED cable-stayed bridge model. The results confirmed that all KDS data was successfully populated, which was further verified by inspecting the data exported to a commercial IFC viewer, BIMvision.

This study formalized a framework for incorporating KDS data into IFC, and thereby enabled extended BIM-based ACC to include engineering specification checking for the infrastructure domain. This work is regarded as an important step in establishing a foundational framework for future BIM-based ACC implementation.

The stability of the IFC-KR schema in relation to future IFC standard updates was also considered during development. Since IFC-KR does not directly modify the core IFC schema but extends it through additional property sets, it remains stable within the same IFC version (IFC4.3). Significant changes within the same version are unlikely, ensuring that the proposed extensions remain functional in the foreseeable future. However, future iterations of the IFC standard may introduce updates to infrastructure-related entities, which could affect certain extensions. Therefore, continuous monitoring and adaptation will be necessary to ensure long-term compatibility and maintain interoperability across evolving BIM standards.

8 Acknowledgement

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