INTERNATIONAL COLLABORATION FOR DEVELOPING THE BRIDGE PRODUCT MODEL "IFC-BRIDGE"

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ABSTRACT

IAI French Speaking Chapter developed a bridge product model called IFC-BRIDGE based on IFC of IAI and OA-EXPRESS of SETRA in 2002. Around the same, a Japanese research group at Muroran Institute of Technology developed a prestressed concrete bridge product model by expanding IFC in collaboration with Japan Prestressed Concrete Contractors Association. Both of the product models were verified by converting data among CAD systems, design and analysis programs. Both French and Japanese groups did not know their efforts in developing bridge product models each other, although their approaches were quite similar.

To make the product models internationally accepted in the future, both groups agreed that mutual collaboration would be necessary and both of the models should be carefully reviewed and merged into one and that the integrated product model should be verified internationally. Recently both French and Japanese groups have proposed a new modified IFC-BRIDGE by merging their product models.

In this paper, first, the previous French IFC-BRIDGE and the Japanese bridge product model are described. Then, how those two models were merged into one is presented. In the merging process, various modeling aspects, advantages and disadvantages of each approach were discussed. And finally, a new IFC-BRIDGE product model is described and future work is discussed.

KEY WORDS

product model, bridge, IFC, interoperability, CAD.

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INTRODUCTION

Much effort has been seen in developing product models for building design and construction in order to enable the interoperability among heterogeneous application systems such as CAD, analysis, conformance checking, cost estimation, construction scheduling, for more than two decades. Recently, Industry Foundation Classes (IFC) of International Alliance for Interoperability (IAI) seems to be considered as a de facto standard as a building product model. However, as for bridges, each CAD and design software company, nation, and organization has been developing its own product model such as Japan Highway Product Model (JHDM) (Hongo and Ishimura 2003), TransXML (Harrison 2005), and there is little interoperability among those models and application systems.

IAI French Speaking Chapter developed a bridge product model called IFC-BRIDGE based on the IFC and OA-EXPRESS, which is a bridge product model developed by SETRA, French governmental technical center for roads and highways, and it has been open to public since 2002 via the Internet web site (Lebegue 2002). Around the same, a Japanese research group at Muroran Institute of Technology developed a bridge product model named Yabuki Laboratory (YL) Prestressed Concrete (PC) Bridge (YLPC-BRIDGE) product model by expanding IFC in collaboration with Japan Prestressed Concrete Contractors Association. Both of the product models have been verified by converting data among CAD systems, design and analysis programs. Both French and Japanese groups did not know their efforts in developing bridge product models each other, although their approaches were quite similar.

To make the product model internationally accepted de facto standard in the future, both groups agreed that international collaboration would be needed and both of the models should be carefully reviewed and merged into one and that the integrated product model should be verified internationally. Recently both French and Japanese groups have proposed a new modified IFC-BRIDGE by merging their product models by the support of IAI.

In this paper, first, the Japanese YLPC-BRIDGE product model and the previous French IFC-BRIDGE are described. Then, how those two models were merged into one is presented. In the merging process, various modeling aspects, advantages and disadvantages of each approach were discussed. Finally, a new IFC-BRIDGE product model is described and future work is discussed.

YLBP-BRIDGE PRODUCT MODEL

CHARACTERISTICS OF THE PRODUCT MODEL

As there was no product model for PC bridges in the early 2000's, Yabuki and Shitani developed a PC bridge product model based on IFC2x (Yabuki and Shitani 2002). Figure 1 shows some classes of the develped product model. They analyzed the characteristics of PC bridges and defined new classes for slabs, prestressing strands, sheaths, voids, reinforcing bars (rebars), and anchoring devices. A feature of theia model is that it clearly represents the relationship that the concrete contains elements such as reinforcing bars, prestressing strands, and voids by representing the concrete as a spatial structure element by B-rep (Boundary representation). Then, they selected ifcXML for implementing the developed product model among several XML schemas, and implemented the schema of the product model and an instance of a PC bridge by using ifcXML. The basic characteristics of the product model for PC bridges are the following.

- The basic structure of IFC2x has been retained and new classes of members for PC bridges have been defined as 3D models based on the object-oriented technology.
- New classes of property sets for a slab and contained members such as rebars, prestressing strands, voids, etc., have been defined.
- A modern model developing technique, i.e., separating property sets from object classes rather than representing all attributes in product classes, was employed, which makes the model more flexible.
- ifcXML has been selected for implementing the product model. ifcXML is compatible with the standardized modeling language, EXPRESS of International Organization for Standardization (ISO) – Standards for The Exchange of Product Model data (STEP).

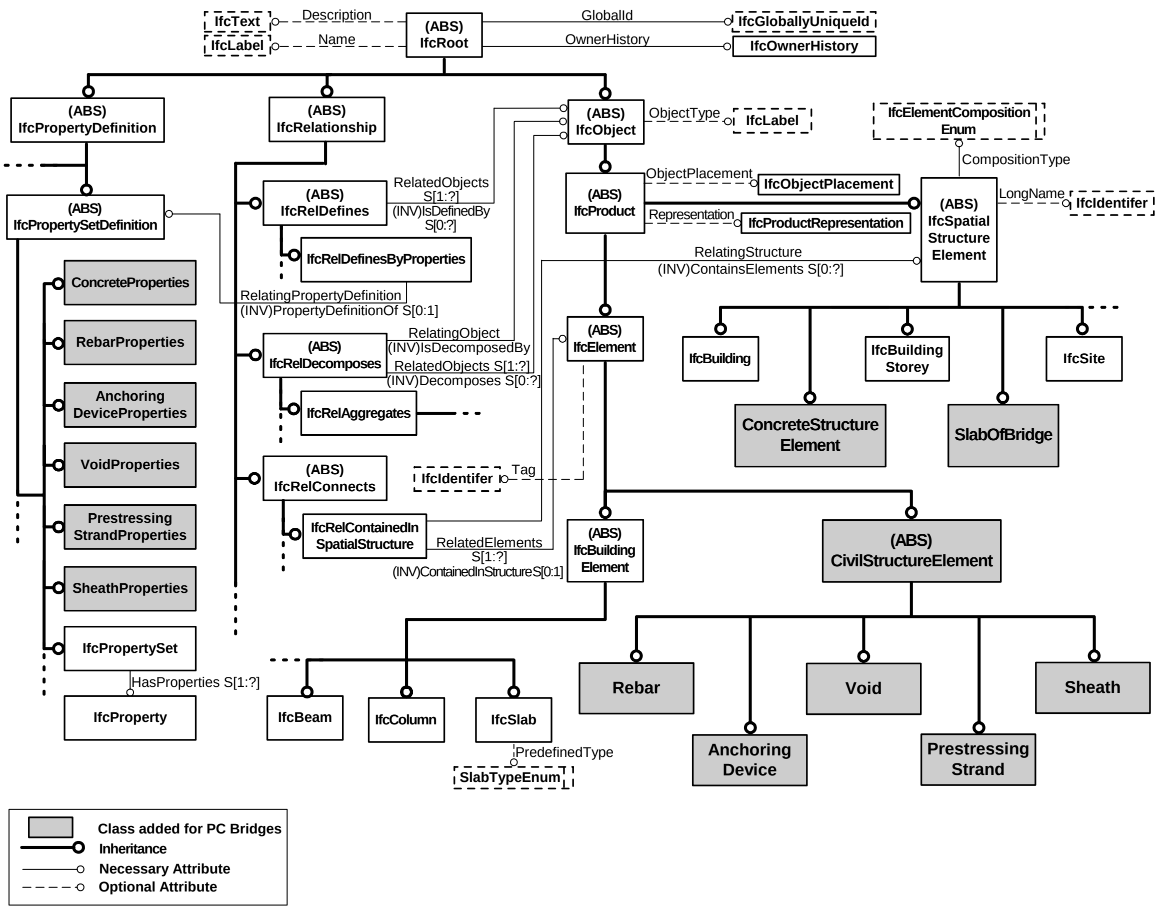

Figure 1: Product model classes for PC bridges in EXPRESS-G

INTEGRATION AND APPLICATION OF YLPC-BRIDGE PRODUCT MODEL

To check the validity and practicality of the model, they integrated the product model with three application systems, namely, 3D-CAD, a PC bridge structural design system, and Multi-Agent system by developing converter programs as shown in Figure 2. The converter program named CAD2PM (CAD to Product Model) can generate product model data of PC bridge objects as an ifcXML, and PM2CAD (Product Model to CAD) retrieves data from the instance file and renders the 3D model in AutoCAD automatically. The Multi-Agent consists of interference checking agent, reinforcing bar (rebar) cover checking agent and rebar space checking agent.

The application case of an interference checking agent is as the following. In this case, a user designed a prestressed concrete composite girder as shown in Figure 3, using CAD2PM and AotoCAD2002. When the design was done, the interference checking agent automatically read the instance file which was generated by CAD2PM, and checked whether interference existed or not in the file. In this case, interfered parts which consisted of re-bars, a prestressing strand and a sheath was found, and the interference checking agent generated 3D solids of the interfered objects as shown in Figure 3.

The application case of the rebar cover checking agent and the rebar space checking agent is the following. A user designed a 3D CAD model of a precast segment, using CAD2PM and AutoCAD2002. Since the instance file was generated by executing CAD2PM, the rebar cover checking agent and the rebar space checking agent worked autonomously and checked rebar cover and space, retrieving data from the instance file. In this case, the rebar space checking agent sent no message, but the rebar cover checking agent sent a message saying, "Some rebars violate the cover provision." And then, the rebar cover checking agent displayed the result of checking (Figure 4). At the same time, this system output this result into the instance file as a new property value. Then, the user executed PM2CAD, which constructed a 3D CAD model form the new instance file. Figure 4 shows that rebars which have yellow color, need to be modified. Then, the user modified the rebars and updated the product model data.

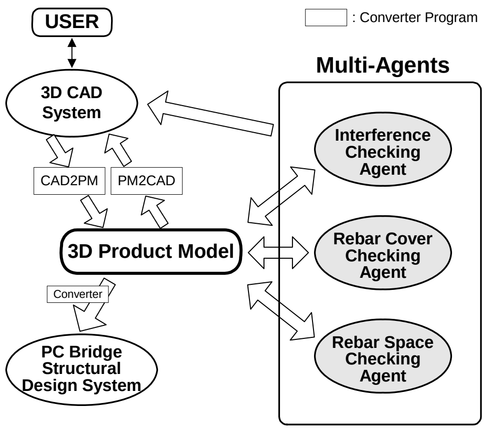

Figure 2: A Concrete Bridge Design System Using Multi-Agents

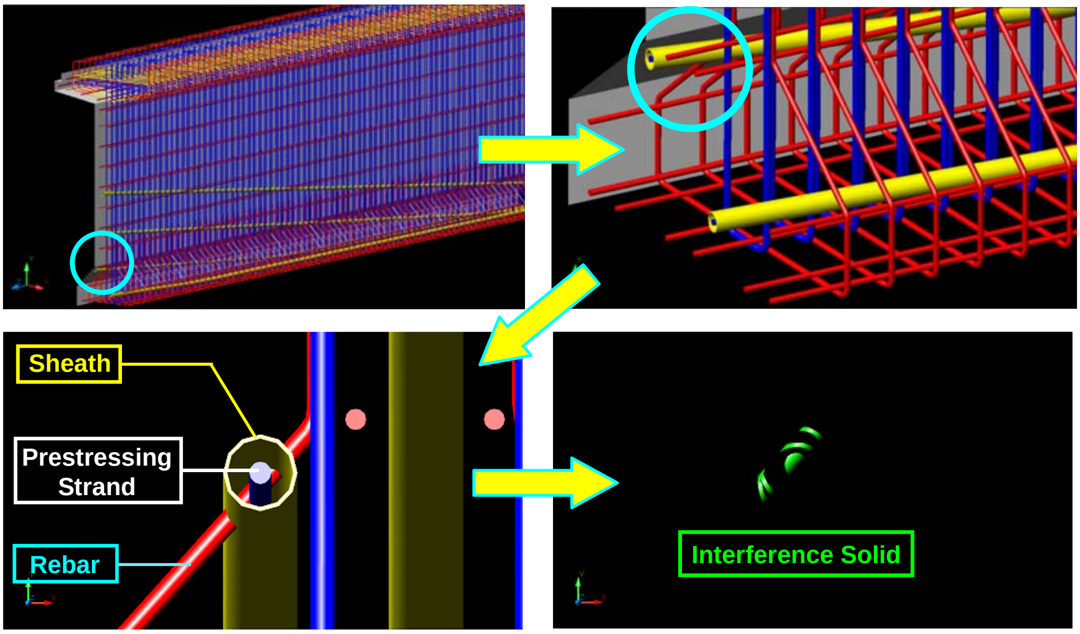

Figure 3: An interfering rebar and interference solid

IFC-BRIDGE DATA MODEL

THE DEVELOPMENT PROCESS OF IFC-BRIDGE DATA MODEL

In France, a study was conducted on bridge data model at French Civil Engineering Association (AFGC) in 1994. In 1998, a French bridge data model named OA_EXPRESS was developed by SETRA with building firms, design offices, etc. In 2000, they demonstrated that OA_EXPRESS could be used for exchanging data among a 3D-CAD software for bridges, called OPERA and a 3D structural analysis software for bridges, called PCP. Both OPERA and PCP were developed by SETRA (Figure 4).

In order to extend the audience of OA_EXPRESS, they looked at international standards based on Express technologies, and found IFC of IAI. They decided to translate OA_EXPRESS to IFC and developed IFC-BRIDGE Version 1.0 in 2002.

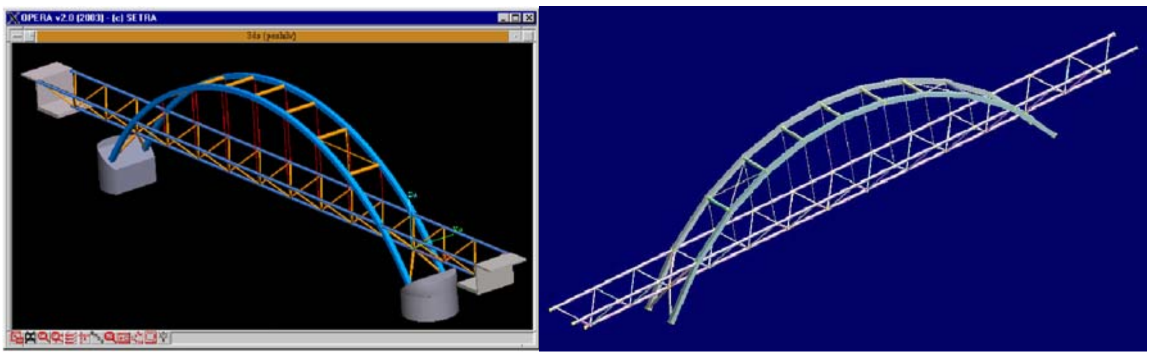

Figure 4: Screen shots of OPERA (left) and PCP (right)

MAIN CHARACTERISTICS OF IFC-BRIDGE DATA MODEL

In complement to standard IfcBuildingElement entity, an IfcBridgeElement entity was proposed for identifying bridge specific objects (Figure 5). For aggregating these bridge elements, two new entities, IfcBridge and IfcBridgeStructureElement, were proposed so tha typical bridge parts such as decks, cables, pylons, etc. can be identified. In IFC-BRIDGE, a transversal cut of a bridge element composed of several fibers and materials can be completely defined.

For geometric definition of bridges, which can be associated to bridge elements, standard IFC2x geometric entities can be defined. However, in the scope of IFC-BRIDGE project, a new IfcBridgeSectionedSpine entity is proposed for defining specific bridge “prismatic element” geometry which can be defined by providing a set of IfcBridgeSection objects along a reference line. In addition, the Clothoidal curve was added to the geometric library since the original IFC did not have this curve.

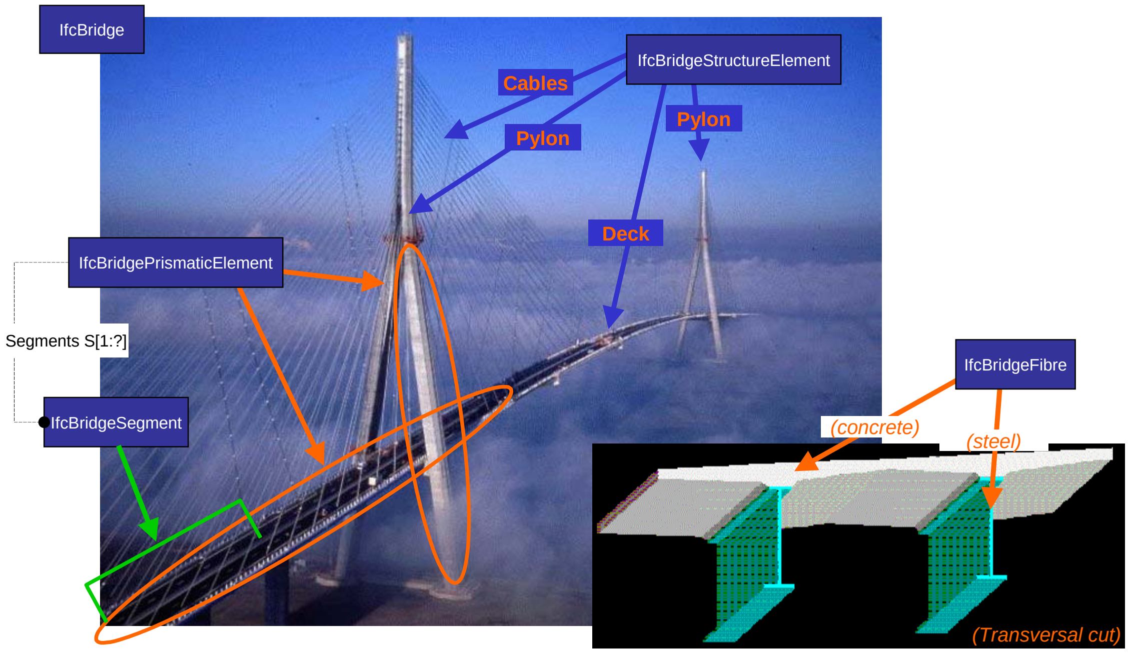

Figure 5: General structure of bridge and transversal cuts

INTEGRATION OF YLPC-BRIDGE AND IFC-BRIDGE PRODUCT MODELS

INTERNATIONAL COLLABORATION PROCESS

We held our first meeting at SETRA in April 2004 for searching ways for international collaboration and agreed to merge the two models into one, developing a new IFC-BRIDGE. After the meeting, the Civil Engineering Group was newly established in IAI Japan Chapter in November 2004 as a counterpart of the IFC-BRIDGE group of IAI French Speaking Chapter. In 2004, our proposal for a joint research project of Japan-France Integrated Action

Program (SAKURA) of Japan Society for the Promotion of Science (JSPS) and the Ministry of Foreign Affairs of France was accepted for 2005-2006.

In August 2005, the French group revised IFC-BRIDGE and proposed the Version 2.0. The Japanese group had reviewed the Version 1.0 and quickly reviewed the Version 2.0, and wrote up a proposal for modifying the IFC-BRIDGE Version 2.0 by merging the YLPC-BRIDGE. Three researchers of the Japanese group visited the Center for Science and Technique of Buildings (CSTB) at Sophia-Antipolis in France in September 2005 and discussed the integration of the two data models. They agreed the modification proposal of the Japanese group there. In November 2005, Four researchers of the French group visited Japan and discussed with many of Japanese researchers and engineers. And we held seminars on bridge product models and their impact on design and construction.

REVIEW RESULT OF IFC-BRIDGE BY THE JAPANESE GROUP

The following is a list of major issues pointed out by the Japanese group based on their review of IFC-BRIDGE.

- Since classes represening members of bridges such as void, sheath, etc., were not defined in the model (Figure 6), prestressed concrete (PC) or reinforced concrete (RC) bridges cannot be represented in detail.
- New classes, such as IfcBridgeSection, IfcBridgeProfileDef, IfcBridgeFibre, etc., were developed in this model, and a number of material attributes such as concrete and steel to a bridge section (IfcBridgeSection) can be added by using thes classes. However, a concrete or a steel part of the section cannot be treated as an independent object.

MODIFICATION PROPOSAL FROM THE JAPANESE GROUP ON IFC-BRIDGE

Main items of the proposal for modifying IFC-BRIDGE Version 2.0 (V2) from the Japanese group consist of the following:

- First, IfcBridgeElementComponent should be added to IFC-BRIDGE V2 as a subclass of IfcBridgeElement. Second, the subclasses of IfcBridgeElementComponent of YLPC-BRIDGE data model, such as Rebar, Void, Sheath, AnchoringDevice, PrestressingStrand, etc., should be added to IFC-BRIDGE V2.
- IfcBridgeSingularInternalPoint, which was newly developed in IFC-BRIDGE V2 as a required attribute should be added to IfcBridgeElementComponent as an optional attribute instead of required one. By doing so, we have two optional methods for describing the subclasses, e.g., Rebar, PrestressingStrand, of IfcBridgeElementComponent as in the following; 1) Using the classes developed in IFC-BRIDGE V1 and IFC-BRIDGE V2, such as IfcBridgeReferenceLine and IfcBridgeSingularInternalPoint. 2) Using the origin classes of IFC2x2, such as IfcExtrudedAreaSolid and IfcSectionedSpine.
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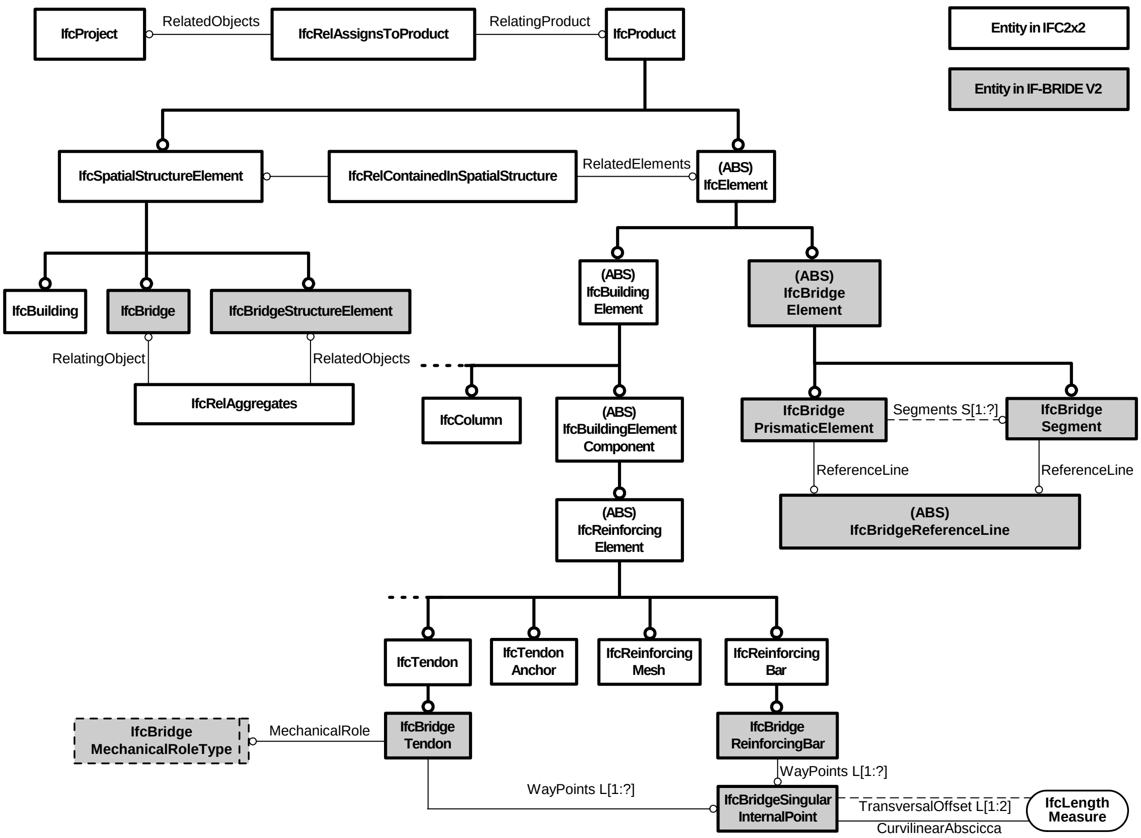

Figure 6: General structure of IFC-BRIDGE V2

- Both IfcBridgeTendon and IfcBridgeReinforcingBar were newly developed classes in IFC-BRIDGE V2, and are functionally similar to PrestressingStrand and Rebar of YLPC-BRIDGE, respectively. Therefore, if these classes are added to IFC-BRIDGE, IfcBridgeTendon and IfcBridgeReinforcingBar should be deleted from IFC-BRIDGE.
- In IFC-BRIDGE V1, IfcBridgeElement was the subclass of IfcElement. However, in IFC-BRIDGE V2, it became the subclass of IfcBuildingElement. So, IfcBridgeElement should be the subclass of IfcElement.

All the above proposal was accepted by the French group and was incorporated into the IFC-BRIDGE V2 Revision 2 (R2). Figure 7 shows a part of the schema of the new IFC-BRIDGE V2 R2 data mode.

On the other hand, the Japanese group also learned the following things from the IFC-BRIDGE.

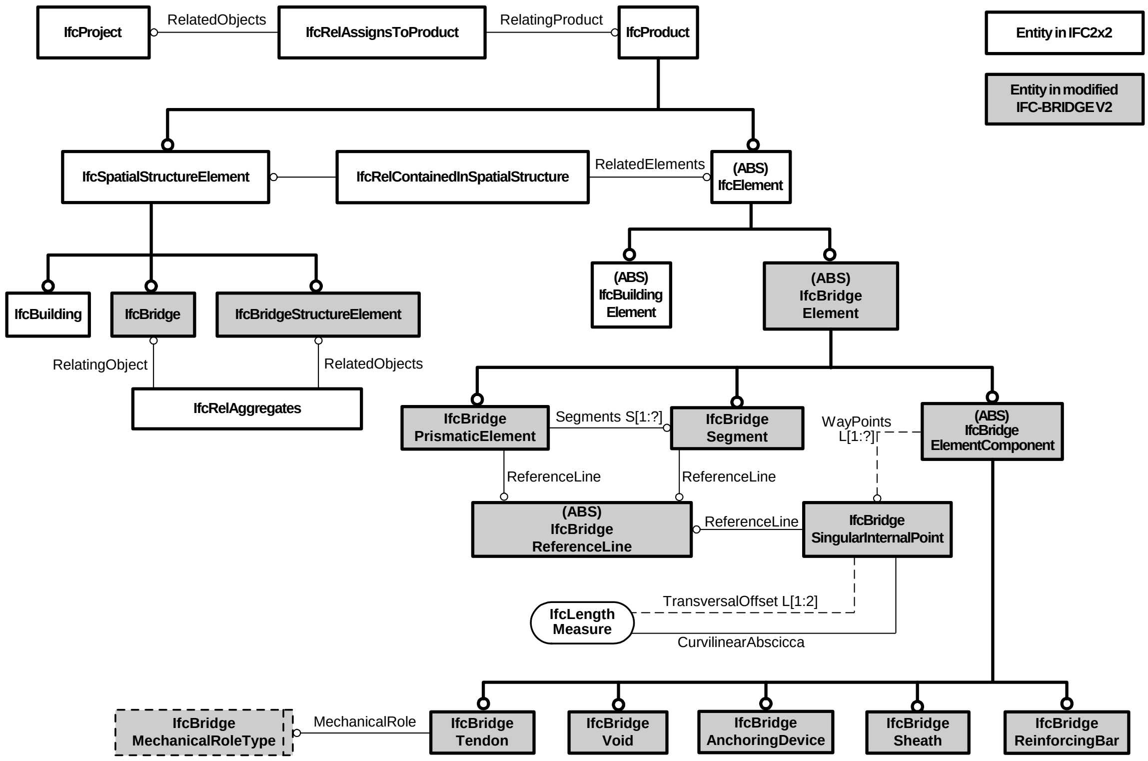

Figure 7: A new IFC-BRIDGE product model

- In YLPC-BRIDGE Data Model, there are also classes named SlabOfBridge and ConcreteStructureElement as subclass of IfcSpatialStructureElement (Figure 1). These classes were functionally similar to the class IfcBridgeStructureElement in IFC-BRIDGE V2. Thus, using the IfcBridgeStructureElement class instead of SlabOfBridge, ConcreteStructureElement of YLPC-BRIDGE is more appropriate.
- Using IfcPropertySet class instead of adding property set classes such as ConcreteProperties, RebarProperties, is more appropriate to maintain the IFC whole structure and class representation.

The new IFC-BRIDGE data model will be thoroughly reviewed and implemented into IFC by an IFC expert in the near future.

CONCLUSION

In this paper, the Japanese YLPC-BRIDGE and the French IFC-BRIDGE product models were described. Then, we presented how those two models were merged into one by the international collaboration. In the merging process, various modeling aspects, advantages and disadvantages of each approach were discussed. And finally, a new IFC-BRIDGE product model was described and future work is discussed.

The conference organizers and proceedings editors will appreciate it if you would follow these guidelines.

ACKNOWLEDGMENTS

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REFERENCES

Harrison, F. (2005) "XML Schema for Transportation Data Exchange: Project Overview and Status." (available at http://www.transxml.org/Info/Project+Documents/543.aspx)

Hongo, T. and Ishimura H. (2003) "A Study on Development JHDM for the Superstructures in Metal Bridge." *Journal of Applied Computing in Civil Engineering*, JSCE, 12, 11-20, in Japanese.

Lebegue, E. (2002) "IFC-BRIDGE Introduction." (PowerPoint file available at http://www.iai-france.org/bridge/)

Lebegue, E. et al. (2005) "IFC-BRIDGE V2 Data Model Edition R2",

Yabuki, N. and Shitani, T. (2002) "Development of a 3 Dimensional Product Model for Prestressed Concrete Hollow Slab Bridges Based on Industry Foundation Classes (IFC)." *Journal of Civil Engineering Information Processing System*, JSCE, 11, 35-44, in Japanese.

Yabuki, N. and Shitani, T. (2003) "Development and Application of an IFC-based Bridge Product Model." *Proceedings of the Ninth International Conference on Civil and Structural Engineering Computing*, Egmond aan Zee, the Netherlands, Paper No.93, 14pp (CD-ROM).

Yabuki, N. and Shitani, T. (2004) "Development and Integration of an IFC-Based Product Model for Prestressed Concrete Bridges." *Proceedings of the fib Symposium*, Avignon, France, 6pp (CD-ROM).