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Application of 3D Bridge Information Modeling to Design and Construction of Bridges

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Abstract

Building information modeling (BIM) is a new technology in bridge construction industry. 3D models can provide perfect numerical expression of drawings from design results. 3D information models for bridge structures improve design quality in terms of accurate drawings, constructability and collaboration. However, there are lots of obstacles to apply these techniques to actual bridge projects. In this paper, extensible information schema for bridges is proposed to enable interoperability between different design and construction processes. From the planning stage of a bridge construction project to the construction stage, the proposed bridge information models were applied to enhance current practices. Digital mock-up, parametric modeling, 4D and 5D simulation were conducted. From several applications for four years, a design guideline of 3D information models was suggested. It is essential to change current processes for the effective use of BIM techniques in bridge construction industry.

KEYWORDS: building information modeling; 3D model; bridge structure; interoperability; information schema.

1. INTRODUCTION

Fragmented information transfer during the bridge lifecycle causes additional cost and time for locating and validating information. Object-based 3D models with metadata can be a shared information model for the effective collaborative design, construction and maintenance. Well-organized data architecture for the infrastructures is essential for the effective cooperation between engineers.

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A construction project life-cycle management system was proposed for the enhancement of productivity in construction industry. Architectures of geometry and information for several bridge types were built and utilized for collaborative works. Each information layer includes necessary metadata for the data sharing and knowledge accumulation during construction project processes. This information has its own data architecture which is derived from similar concept of product breakdown structure (PBS) and work breakdown structure (WBS). The integrated information model realized a virtual construction system for bridges and dramatically increased the productivity of the whole management process. Prototypes for the bridge information model were suggested and pilot tests were conducted to evaluate their effectiveness and to derive the guidelines for the future 3D models. The applications were mainly for international bridge construction projects and for domestic bridges. Because of obstacles in practices, 3D models were utilized for specific processes in the project. Evaluated effects of the applications were summarized and a guideline of 3D model based design was proposed.

2. 3D BRIDGE INFORMATION MODEL

For the effective collaboration of bridge construction projects, it is essential to define architectures of the information models and information delivery manuals. WBS and OBS (organization breakdown structure) need to be connected to PBS in the construction project lifecycle management (CPLM) system. Each participant has predefined tasks and outcomes from the tasks to share essential information.

2.1. Architecture of 3D Bridge Information Model

The architecture of the geometry and the information for bridges was built as shown in Figure 1. Geometry models are connected to the information database by defining the code numbers which are defined before modeling. Well organized libraries for 3D information models can be used. The design information layer has metadata on requirements, design codes, geometry, construction data and so on. The construction layer has data on drawings, real data for material and products, schedules and so on. The maintenance layer for the operation has the final geometry, material data, products and their suppliers and inspection/repair history. The integrated information model can realize virtual construction system for bridges and dramatically increase the productivity of the whole management process (Shim et al. 2008, 2009).

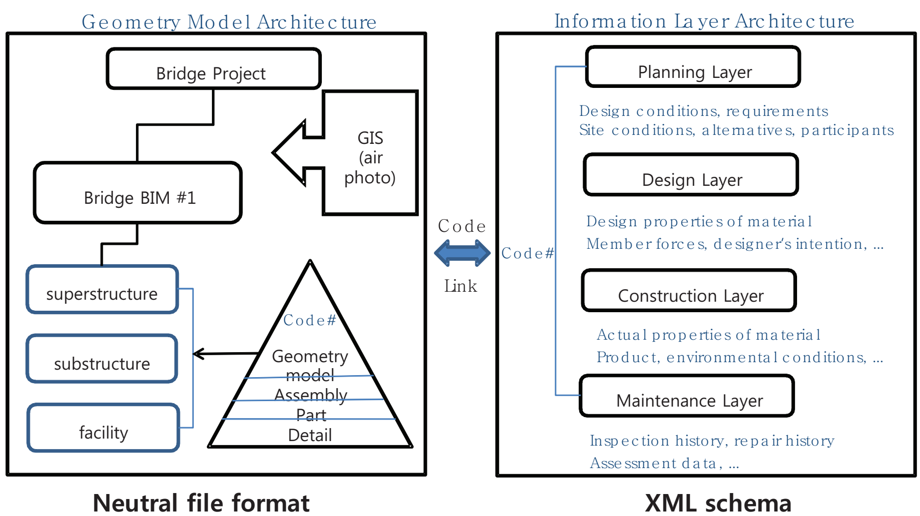

Figure 1: Architecture of 3D Bridge Information Model.

2.2. Delivery and Share of Information Models

Interoperability is the crucial for the sharing and delivery of the information. Until now, the 3D CAD engines or solutions are not enough for the effective use of the system. Technical advancement is needed to accommodate the requirements from all the participants of a construction projects. Before any international or national standard of the information delivery manual (IDM), an information delivery system for a specific bridge construction project was constructed as shown in Figure 2.
For the sharing of the 3D information models in the different solutions, a neutral file format is needed and information database in the format of neutral file such as XML is also an essential part. By using these predefined formats, each task for the engineering process can be successfully executed for engineering applications.

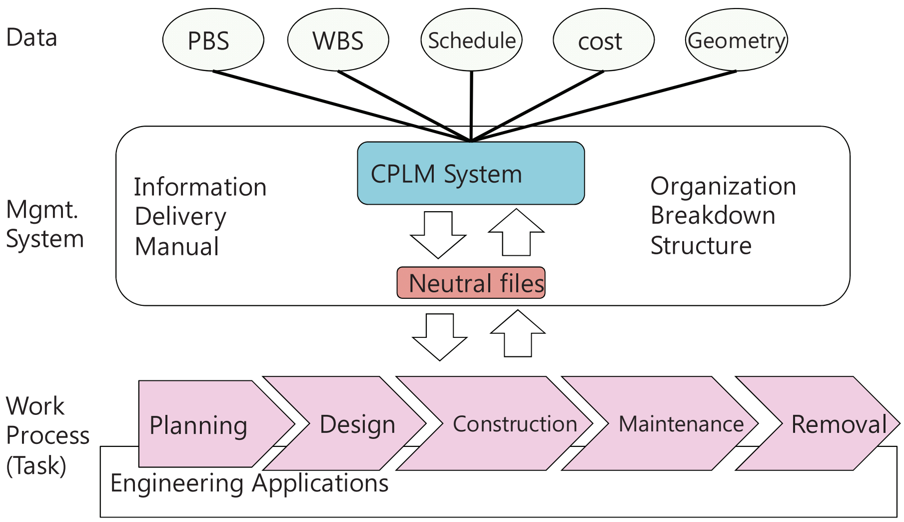

Figure 2: Information Delivery System.

3. APPLICATIONS AND 3D DESIGN GUIDELINE

Building information modeling (BIM) is a new technology in civil engineering industry. In order to reduce initial cost to adopt BIM for bridge construction, several pilot applications were conducted in Korea. From these applications and investigating the current technologies in ICT, a 3D design guideline for civil engineering industry was developed.

3.1. Applications to Bridges

Integrated design and construction of bridge structures can be accomplished by several principles such as parametric modeling, layered model architecture, interoperable schema for information. As shown in Figure 3, each component of a bridge is modeled with basic parameters and connected with other components by layered architecture of geometry models (Lee et al. 2010). Many engineers can cooperate in the design of a bridge and share the essential information.

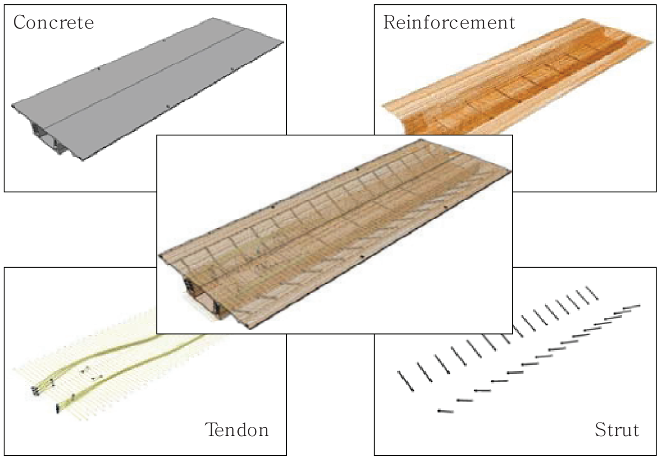

Figure 3: Layered concrete box girder bridge model.

A well-organized bridge information model can dramatically enhance the design revision process and communication with workers on the construction site. Currently, main applications of BIM technologies are digital mock-up (DMU), shop drawings, local analysis, estimation, 4D simulation, and 5D simulation. As shown in Figure 4, important bridge construction projects adopted BIM technologies mainly in the beginning stage of construction. By building 3D models for a bridge, engineers can check constructability by DMU and produce accurate shop drawings. In Korea, remarkable number of cable supported bridges used 3D models (Kim et al. 2009).
Even though the client does not require 3D models for the design, general contractors found the effectiveness of BIM technologies to reduce construction cost and risk. 4D simulations with detailed activities in 3D models enhanced engineer's knowledge of a bridge and resulted in effective usage of resources for the construction. Some contractors have started innovation of their processes by adopting BIM technologies.

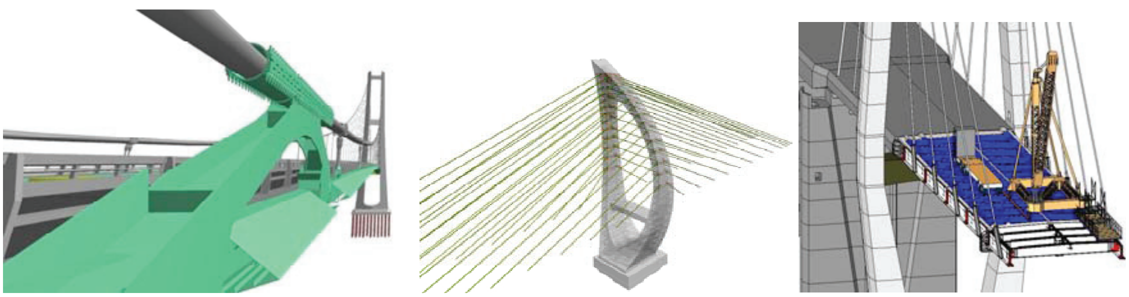

Figure 4: Typical applications of bridges.

3.2. 3D Design Guideline

There are many BIM guidelines for building structures but those guidelines are not sufficient for civil infrastructures. 3D information models have much dependency on a CAD engine. From the pilot applications, a 3D design guideline of civil infrastructures was proposed. Main contents of the guideline are as follows;

Part I: General principles (classification, 3D object model, information, process, management and security, collaboration)
Part II: Interoperability for design solutions (design solution, 2D drawings)
Part III: Interoperability for analysis (3D finite element model, 1D and 2D finite element model)
Part IV: Interoperability for estimation (classification, WBS, CBS, estimation)
Part V: Interoperability for virtual reality (active simulation, 4D, 5D)
Part VI: Interoperability and information system
In this guideline, significant suggestions to overcome obstacles to adopt BIM technologies in civil engineering industry are derived. Related unreasonable systems for designers and contractors are listed and improved systems are proposed and several pilot applications are also summarized.

4. CONCLUSIONS

Even though ICT can provide innovative way of engineering, the most important contents are engineer's knowledge and previous project experience. BIM technologies support engineers to improve productivity and to reduce risk. Collaboration is an essential part of the innovation and requires process innovation.
In this paper, extensible information schema for bridges is proposed to enable interoperability between different design and construction processes. From the planning stage of a bridge construction project to the construction stage, the proposed bridge information models were applied to enhance current practices. Digital mock-up, parametric modeling, 4D and 5D simulation were conducted. From several applications, a design guideline of 3D information models was suggested.

5. ACKNOWLEDGMENTS

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