PARAMETRIC MODELLING FOR MODULAR PREFABRICATED BRIDGES

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ABSTRACT

Standardized modular bridges improve the productivity of automation in design and fabrication in response to the variety of influence factors. In this study, optimized design models through the development process of a new structural system were constructed using Building Information Modeling (BIM) technologies. The models consider design specifications, constructability and optimized detailing. Parametric modeling was conducted to accommodate variation of each design values of the modular bridge structures such as bridge width, girder spacing and height of the pier. Each module by parametric modeling has fixed values, variables considering product specification and relationship between objects. For the connections between members, engineering knowledge is embedded in the 3D information models as parameter range of supper and lower limit and recommended default values. Using the parametric models, design productivity can be enhanced significantly in term of analysis, estimation and construction management.

Keywords: Modular bridge, building information modeling, parametric model, connection, knowledge

1. INTRODUCTION

Building information modeling (BIM) deals with product, process and resources (AIA 2008). Virtual manufacturing based on 3D information models is a new attempt in construction industry. Information delivery between designer, fabricator and contractor is the most important for the

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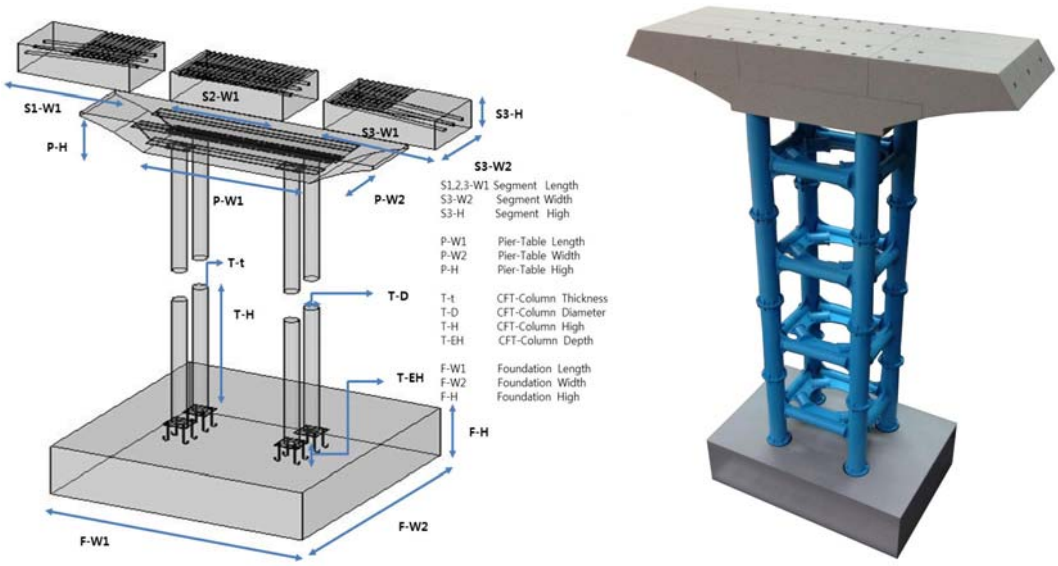
productivity of the new technology. 3D information models for bridge structures were suggested by Lee et al. (2012) and Shim et al. (2012).

Infrastructures have wide range of objects with different definitions and information requirements. This variety limits the application of BIM technology to infrastructures while building industry actively adopt BIM and enhance its information flow through life-cycle of a structure. Precast members have standard sections for certain range of design parameters. Therefore, information delivery manual (IDM) and model view definition (MVD) were developed and proposed (Sacks et al. 2005; Eastman et al. 2010).

For accelerated bridge construction, there have been many attempts to develop prefabricated bridge elements (Shim et al. 2008, 2010, 2011, 2012). Among the precast element, a modular bridge substructure was selected and 3D parametric modeling of the bridge pier was developed by Kim et al. (2012). In this paper, parametric model definitions for a modular bridge were developed and their MVD and level of detail (LOD) were proposed to enhance design productivity.

2. MODULAR SUBSTRUCURE

Integrated three-dimensional modeling is being adopted as the base construction information by major engineering firms. Common information has to be defined in advance for cooperation in 3D modeling of modular bridge structures. Engineering knowledge during development process of a new structural system is the most important information for the models. Collaboration needs prior definitions of terminology, classification, information delivery, level of detail, model view definition and embedded knowledge for the models.



a) 3D Modeling Definition. **b) Modular bridge by 3D Print**

Figure 1: 3D Modeling Definition of Modular substructure.

A modular bridge substructure using concrete filled steel tubes (CFT) and precast pier cap elements was proposed for fast construction as presented in Figure 1. LOD of the model was decided by considering the most detailed information. Work breakdown structure (WBS) and product breakdown structure (PBS) were constructed and each design parameter was defined as shown in Figure 1. Initial models of modular substructure were fabricated using a 3D printer as shown in Figure 1 (b).

3. DEFINITION OF DESIGN PARAMETERS

For the hierarchical structure of 3D information models, design parameters of modular substructures were defined as fixed variable (constant), variables and relationship constraints as presented in Table 1. Modular structures need to use standard product and design parameters for the product are fixed variables. Design parameters considering main design changes in actual design practices are variables. Connection details and relative position or geometry can be relationship constraints.

In the design of the modular bridge pier, steel tubes are standard product and have constant diameter and thickness of the tube. Precast segments normally require minimum amount of reinforcements from current design specifications and certain number of prestressing tendons and their duct to control tensile stress of the joints. These design parameters are also fixed values. Embedded steel members in the pier table mitigate stress concentration at the connection. The H-shape steel member can be a fixed design parameter.

Design parameters for design changes are height and width of the bridge substructure. According to these main variables, dimensions of pier table and precast segments should be changed. Therefore, relationship constraints between these design parameters need to be defined properly. Minimum gaps of the joints can be knowledge embedded parameters in the 3D models. Upper and lower bound of the gap and spacings between components can be included in the model definitions. Parametric modeling techniques are useful for this definition.

Table 1: Definition of Variables.

Case	*Fixed variables (constant)*	*Relationship constraints*	*Variables*
Pier - Segment	S3 – W2, S3 - H	Amount of form	
	Diameter of Reinforcement	Spacing of Reinforcement	
		Eccentric distance	S1,2,3 – W1
	Prestress	Shape of end anchorage	S3 – W2
		Jacking Force	S3 - H
	Cover Depth	Interior and Exterior Cover	
	Diameter of Duct	Number and Diameter of Duct	
Pier - Table	P-W2,P-H	Amount of form	
	Diameter of Reinforcement	Spacing of Reinforcement	P – W1
	Diameter of Duct	Number and Diameter	P – W2
	Cover Depth	Interior and Exterior Cover	P - H
	Property of H-beam	Welded, Detail of end-plate	

3.1. MODEL VIEW DEFINITION

Based on the IDM specifications, the Model View Definitions (MVD) are defined for the significant communication and data exchanges associated with all use cases associated with precast concrete. MVD also prescribes implementation bindings using the industry Foundation Classes (IFC) model schema (Eastman et al. 2010).

According to design phases in the life-cycle of construction, MVD needs to be defined considering different level of detail for each component of the modular pier cap. Figure 2 shows the MVD for a precast element. Precast elements have to include various information for fabrication. Defined information describes a flow of interrelation and classification according to the LOD. Pier cap's segment of the modular substructure can be classified as precast and non-precast, and should be defined with MVD. First of all, precast elements are manufactured with information such as shape, property and eccentric distance. Secondly, requirements of non-precast elements for 3D BIM are information for fabrication such as connection details and bonding conditions.

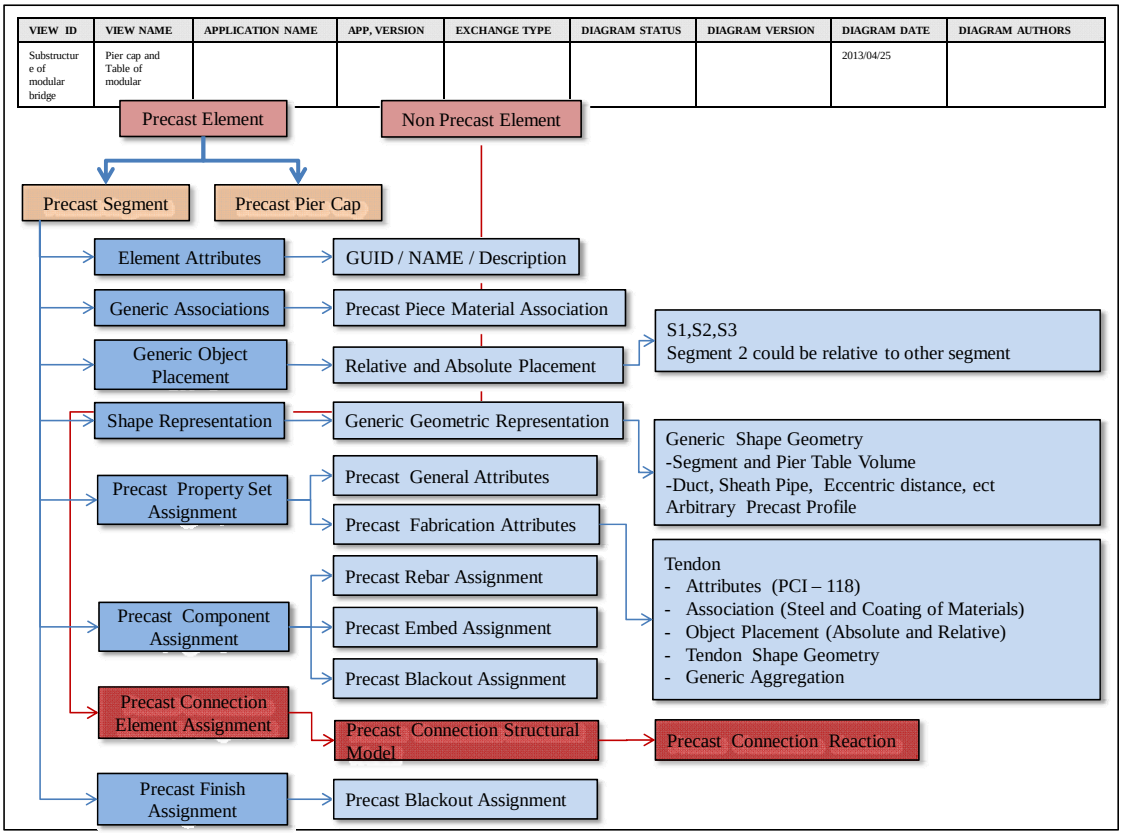


Figure 2: Model View Definition.

3.2. LEVEL OF DETAIL FOR MODULAR BRIDGE

Level of detail (LOD) of the 3D models can be defined according to two different approaches such as database and model capability. LOD identifies the specific content requirements for each model element at each phase of a project. There are five progressively detailed levels of completeness. Each subsequent level builds on the previous level (USC, 2012). Figure 3 shows 3D models according to different LOD considering the following recommendation.

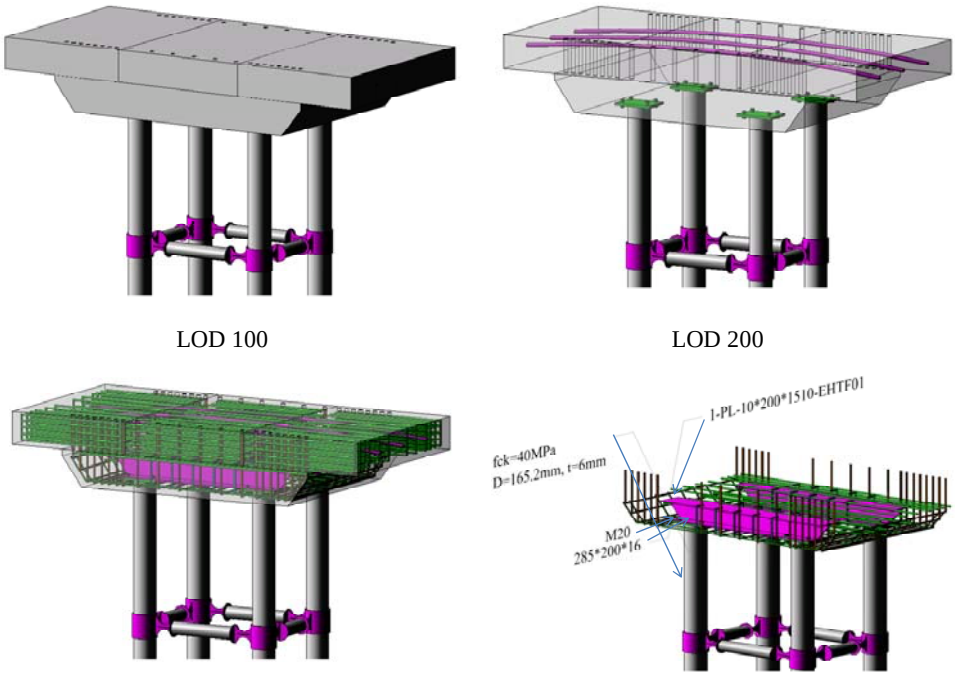
LOD 100: Overall building massing indicative of area, volume, location and orientation

LOD 200: Model elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location and orientation.

LOD 300: Model elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location and orientation.

LOD 400: Model elements are modeled as specific assemblies that are accurate in terms of size, shape, location, quantity and orientation with complete fabrication, assembly and detailing information.

LOD 500: Model elements are modeled as constructed assemblies that are actual and accurate in terms of size, shape location, quantity and orientation.



LOD 100 LOD 200

LOD 300 LOD 400

Figure 3: Level of Detail for Modular bridge substructures

4. CONCLUSIONS

Delivery of knowledge for the design of new structures can be successfully accomplished by parametric modeling techniques. Proper definitions of variables, LOD and information are essential

tasks. Practical adoption of parametric modeling for modular structures can provide better design productivity and reduce loss of information between each phase of construction cycles.

A new modular bridge substructure was proposed and developed by experiments. From the experience of the development, parametric models were defined and utilized for better and more accurate design of the structure. A matrix to define LODs and their components was proposed. Through these attempts, design intents and obtained knowledge from the development process can be delivered to practitioners without loss of essential information.

5. ACKNOWLEDGMENTS

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