3D digital fabrication and erection technologies for prefabricated bridges

S. Lee, S. Park, N. S. Dang & C. Shim
Department of Civil Engineering, Chung-Ang University, Korea

Abstract

Creative design of bridge structures requires new approaches for digital fabrication and accurate geometry control during construction. This paper deals with prefabricated bridge piers which have unique creative shapes. 3D design models were created to realize irregular column shapes. Economic formwork for the precast column segments was provided by 3D printing technology. Panelized formworks were created from the 3D design models and were attached to common steel formworks. During fabrication of precast segments, key values of geometry were controlled by laser scanning. The design models were revised by the scanned data. Before assembly of the segments in construction site, instructions for geometry control were provided to ensure final target geometry of the bridge piers. Information delivery from design to maintenance can be achieved by 3D information models and new format of drawings including QR codes and 3D models.
Keywords: digital fabrication, geometry control, prefabricated bridge pier, 3D design model, 3D printing.

1 Introduction

In construction industry, 3D engineering is a new paradigm to improve creativity and productivity. IT-tools for construction projects emerge by combining 3D CAD models and shared information with metadata, scheduling and cost analysis. Building information modelling (BIM) showed the potential for engineers to enhance current practices in terms of cost and time. Digital models of structures for multiple purposes through the entire life cycle provide significant efficiency in design, construction and management [1]. 3D scanning and 3D printing

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technologies have been fast adopting in 3D CAD based integrated design and fabrication processes [2].

Design of a bridge needs systematic approach requiring complex knowledge and collaboration between engineers from different disciplines. Life-cycle management of bridge structures from design to maintenance needs information feedback between participants who involve in the bridge project. Digital models of the bridge provide common data for information delivery. Applications of BIM to bridge practices have been reported in design, fabrication and construction [3–6]. Current BIM practices for bridges have narrow scopes for specific phase of the project such as digital mock-up, interference check, simulation, analysis and estimation.

3D engineering combined with prefabrication and preconstruction significantly improves efficiency of construction industry in terms of cost and time. For precast concrete structures, there were important efforts in parametric modelling [7] and model view definition [8]. Standard precast members are commonly used in bridge construction. Therefore, 3D parametric modelling can enhance current practices by providing information exchange between designers, fabricators, contractors and owners.

In this paper, a process of design, fabrication, construction, and maintenance of precast pier was proposed by utilizing 3D model and printing technologies. Well organized parametric modelling provides efficient communication between participants in different construction stages.

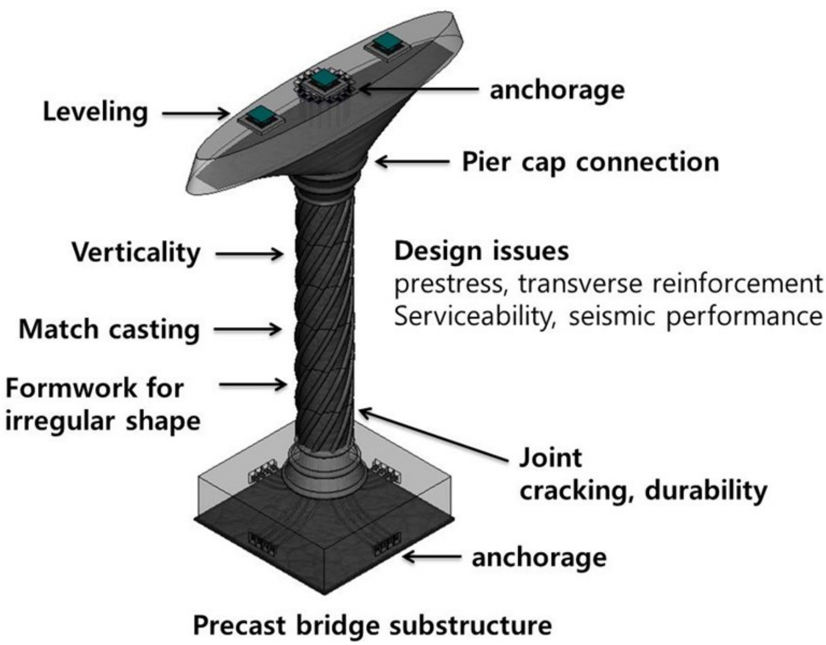

Figure 1: Prefabricated bridge pier details and 3D model [2].

2 Parametric modelling of precast columns

2.1 Model authoring

Model authoring is a time-consuming work when there is a decorative irregular design. As illustrated in Figure 2, a flowchart for parametric modelling of a precast bridge pier was proposed. Precast models are divided into two parts including main design parameters and their properties. Information requirements for the parametric modelling were defined, and the proposed algorithm built the concrete objects and reinforcement objects. Concrete parts have several blocks with decorative design shapes and are assembled by defined assembly coordinate. A final design model is authored by combining the two parts using the predefined coordinates.

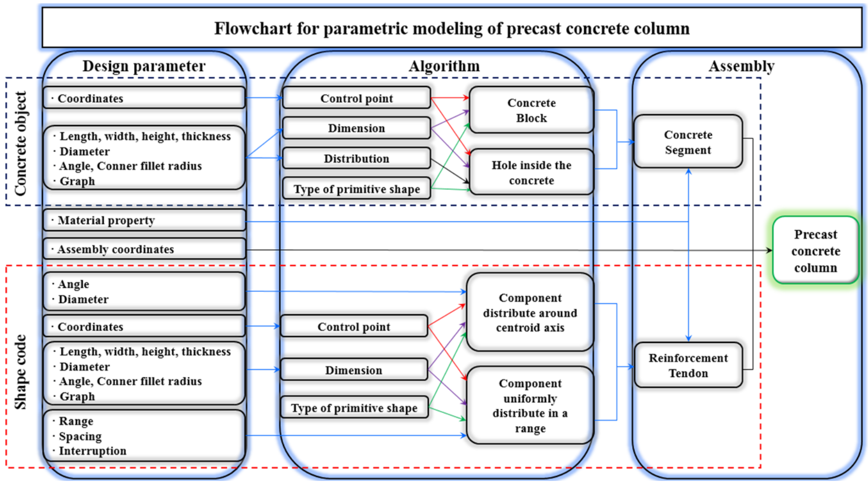

Figure 2: Test specimen details.

Figure 3 shows the realized example of the parametric model using an algorithmic modelling tool, grasshopper. The precast pier has a footing, precast column segments, and a pier cap. Reinforcements, prestressing tendons and their ducts are included in the model. Each part has its own design parameters, which have lower and upper bound from experiences. Decorative parts of the precast column segments were created from images or patterns. Various creative design can be utilized in the design. Irregular shape of the formwork was fabricated by 3D printing and panelizing inside of a common metal formwork.

3 Geometry control

In the process of assembly of precast concrete columns, it is necessary to use match-casting method in common practices. In this research, a new quality control process was suggested. Formworks of the segments and fabricated segments were

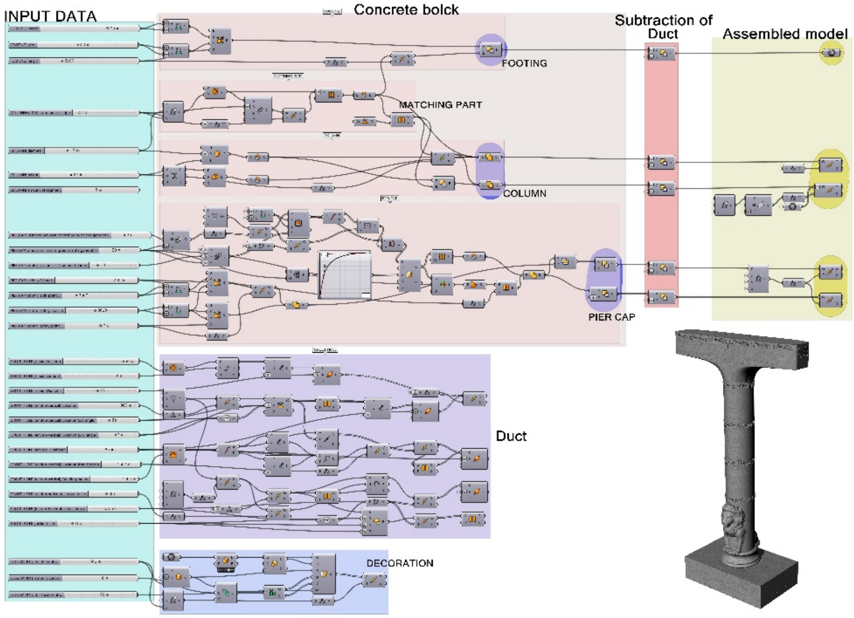

Figure 3: Parametric modelling of a designed pier.

scanned by a laser scanning device. Control geometry including member dimensions and centre coordinates of the duct holes was defined in the model authoring stage as illustrated in Figure 4. Scanned point cloud data was used to evaluate geometry error. Target geometry of the bridge pier is determined in the design stage, and the error is considered in the work order for assembly. An adjustment devices is utilized to compensate the error by changing the gap between segments.

4 Digital information delivery

One source multi-use strategy is a useful for digital fabrication and assembly. During the model authoring, design parameters were defined to generate 3D models. These input data are utilized to visualize the 3D model and its properties in mobile devices as shown in Figure 5. Only essential information should be included in the parameter data. Precast members include these digital information by attaching QR codes. Digital drawings including a 3D model was also used for better communication. Bridge owners can utilize the information for inspection and management.

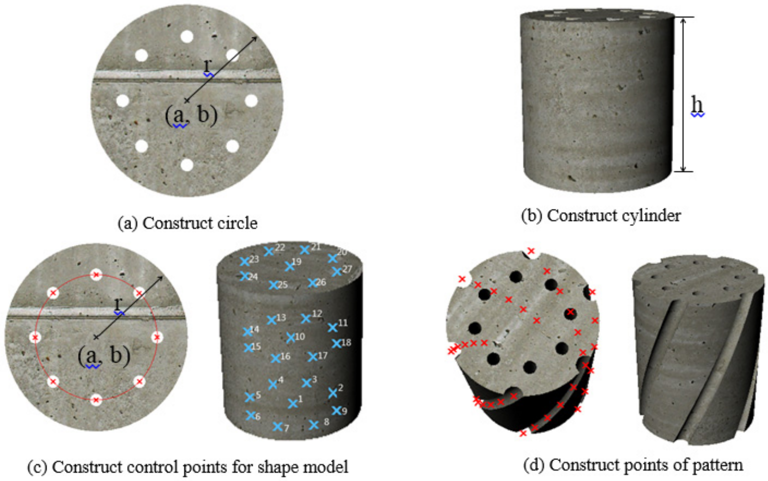

Figure 4: Geometry control of a precast segment.

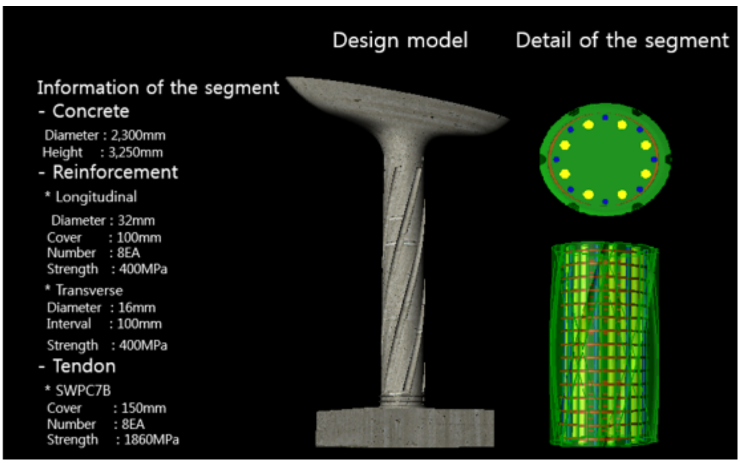

Figure 5: Visualized model and its information.

5 Conclusions

Modular structures designed by 3D modelling techniques were proposed. Parametric model authoring provides much better opportunity for engineers to reuse the data for fabrication, construction and maintenance. Creative design for infrastructures can be realized without increasing much cost. From this research, a new approach of digital manufacturing of precast members was successfully tested using digital devices including 3D printers, laser scanners, and mobiles.

Acknowledgement

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