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VIRTUAL 3D MODELING FOR OPTIMIZED BRIDGE CONSTRUCTION PROCESS

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ABSTRACT

Over 50% of Korean government construction projects were reported to have been delayed over two years by frequent design changes. These problems are originated from the dynamic and uncertain characteristics of construction projects, such as unpredictable design changes. In particular, civil engineering facilities such as large-scale cable-stayed bridges are complex and require a thorough construction planning, because construction managers often find it difficult to have the construction processes under full control. For the purpose of comprehensive construction planning, virtual 3D process modelling can be utilized. Through the virtual process modelling, construction managers can forecast critical issues of the construction phase and prepare solutions for potential problems. In this research, a cable-stayed bridge construction is analyzed and modelled using the 3D graphic and simulation approach. This effort is expected to improve the construction processes and identify the limitations and capabilities of the 3D process modelling in bridge construction projects.

KEYWORDS

Cable-stayed Bridge, 4D CAD, Operation 4D, Process Optimization, 3D Model, Virtual Process Model

1. INTRODUCTION

The duration and cost of construction projects are increased by rework or inappropriate design. Over 50 percent of Korean government construction projects were reported to have been delayed over two years by frequent design changes [4]. These problems are originated from complexity of facility, poor design, and, above all, lack of communication between designers and contractors. In order to fill this gap between design and construction phases, an effective communication or process management tool is required. There are some computer based construction process planning tools such as Extend, Primavera, and MS Project. These tools are good at optimizing construction processes. However, the optimized processes are often hard to be understood because they tend to be shown in text formats. There are three dimensional visualization tools to show construction processes graphically, but these are not combined with the construction process analysis. In this research, the three dimensional process model of a cable-stayed bridge is developed to check the constructability. This research was motivated by the success of 4D CAD application in building and plant constructions. It is time to see the benefit of 3D/4D CAD even in traditional civil engineering projects such as cable-stayed bridges.

2. LITERATURE REVIEW

2.1. 4D CAD

4D CAD (Computer Aided Design) is technology that combined 3D graphic model and construction schedule. There are a number of efforts to use 4D CAD technology for architectural engineering. Koo and Fischer [5] developed a 3D model of commercial two-story building and connected it with the CPM (Critical Path Method) network. They studied the feasibility of 4D CAD in the building construction management. Kang et al. [3] tested effectiveness of web-based 4D visualization tool and Ma et al. [6] suggested an integrated site planning system for architectural engineering. In these efforts, 4D CAD were proven to provide high-quality construction process and constructability information.

2.2. Operation 4D

Operation 4D technology shows not only the activity level sequential information of the 3D model but also the visualization of equipment and construction operations. Al-Hussein et al. [1] showed the 3D model animation of tower crane operation based on the optimized simulation results. Kamat and Martinez [2] graphically simulated construction equipment operations in a 3D virtual construction site. Operation 4D offers the visualized process of construction equipment operations. As a result, construction manager can easily predict problems and other critical issues of the construction process.

3. 3D MODELLING PROCESS

3.1. Virtual Construction Activity Definition

Before making the 3D model, the activities of cable-stayed bridge construction should be defined. The activity definition determines how the various structural components can be grouped. Each 3D component, developed later, is linked with a construction activity.

3.2. 3D Component Modelling

The 3D structural component models of the bridge are developed in the AutoCad Revit Architecture Suite environment, using the 2D original design. Each part of the bridge model is stored at the bridge component library. Every time the virtual bridge is assembled, each part of the bridge is copied from the component library and adjusted by designer. Simplified processes of the bridge construction are developed in the virtual domain, based on the actual, planned construction procedures. The derrick crane which will be used in the construction of the main span is also three dimensionally modelled to simulate the equipment operations. These 3D components are used at the 3D process modelling phase which is explained in the following section.

3.3. 3D Process Modelling

Autodesk Inventor is typically used for mechanical engineering. However, this study uses the Inventor environment so that construction processes are simulated for component collision analyses and their three dimensional visualization. To operate the construction processes as efficiently as possible, optimized simulation results will also be obtained using specialized tools designed to simulate a range of construction scenarios. The process simulation results will be incorporated later into the Inventor platform to graphically display the optimized construction process. For the purpose of safety check, interference between the bridge structures and construction equipment is also investigated in the Inventor environment. Through these efforts, risks and uncertainties of construction processes are significantly reduced by the 3D process simulation.

3.4. Construction Processes Refined

The operational problems and constructability issues are carefully investigated at the 3D process modelling phase. Based on the resultant analysis, the original construction processes are revised. Finally, construction project manager can deduce the optimized construction process that can be followed in the real construction phase.

4. CASE STUDY

4.1. The bridge construction description

Cheongpung grand bridge was selected for case study. The bird eye view of Cheongpung grand bridge is presented at Fig. 1. This bridge is located at Chungcheong-bukdo, Korea. The total length of this two lane cable-stayed bridge is 442 m, and the length of the main span is 327 m. The height of each concrete pylon is 103 m.

4.2. 3D component modelling

Based on original design, the 3D models of cable-stayed bridge and derrick crane were developed in the Revit environment (Fig. 2). The bridge structure and the derrick crane were independently modelled. The detail level of each 3D model is as high as the original 2D design. Every reinforcing bar or precast concrete block is modelled as a 3D component.

Figure 1. Cheongpung Grand Bridge

4.3. 3D Process modelling

At this stage of the research, the cable-stayed bridge and two derrick crane are modelled with their real dimensions copied to the Inventor environment. In the future, construction operations of the two derrick cranes will be modelled in conjunction with the 3D structural components of the bridge. The movement of the derrick cranes and those construction objects to be handled will also be graphically modelled based on the process simulation results. As for now, such simulations tools as Extend and Crystal Ball are considered for producing the optimized process results. Then, the simulation results will be loaded into the Inventor platform, to three dimensionally represent the whole construction operations. With this approach, construction practitioners can ensure the successful operation of the cable-stayed bridge construction in the construction phase. Interferences and inappropriate designs can easily be identified. The most efficient operation of the derrick cranes can also be found. Through combining the two models (bridge and cranes), construction managers can understand where to locate the derrick cranes. Based on these efforts, construction manager can forecast the construction processes and design changes in advance.

4.4. 4D Technology for Civil Engineering

Compared to architectural engineering, there is generally less repetition of construction activities in civil engineering constructions. Activities of architectural facilities are organized in a simple pattern, so construction managers, foremen and even 3D modeller can easily understand the process of construction. However, in civil constructions, much more efforts are required to pre-assess the construction activities. There are a range of equipment, such as cranes, backhoes, and trucks, so management of construction equipment on the civil engineering construction sites is a critical issue. Huge and complex construction equipment are being used in construction site these days; sufficient work space should be secured for the proper operation of the equipment. Construction managers can forecast the required work space for diverse situations, such as prefabrication shops and warehouse for construction equipment and materials before starting the actual construction. Based on the 3D model information, construction managers can also improve safety of the construction site, by securing the paths for workers and construction equipment. In addition, hazardous areas can be determined. All of these potential benefits are expected to be realized by adopting the virtual 3d process modelling.

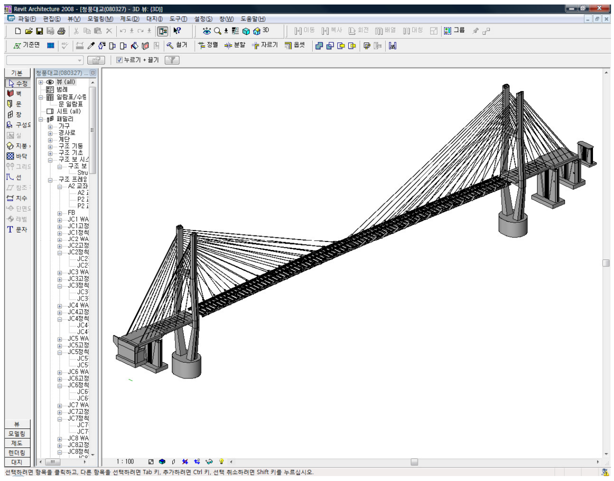

Figure 2. The 3D Model of the cable-stayed bridge

5. CONCLUSIONS

3D or 4D virtual models have mainly been developed in the area of architectural engineering. There have been few 3/4D modelling efforts for civil engineering facilities. In this research, a cable-stayed bridge and two derrick cranes were three dimensionally modelled in the AutoCad Revit Architecture Suite environment. The simulation of these models was implemented in the Autodesk Inventor environment. Although the research is in its preliminary stage, the 3D models and their link with process simulations results is expected to decrease design changes during construction processes, improve safety for construction workers, and reduce the total time duration.

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