SIMULATION FOR STEEL BRIDGE ERECTION BY USING BIM TOOLS

Chui-Te Chiu[1]*, Tseng-Hsing Hsu[2], Ming-Teh Wang[1], and Hsien-Yen Chiu[2]

[1] *Department of Construction Management, Chung Hua University, Hsinchu, Taiwan*
[2] *Department of Civil Engineering, Chung Hua University, Hsinchu, Taiwan*
* *Corresponding author (ctc@chu.edu.tw)*

ABSTRACT: Steel bridge erection requires a series of processes in the construction site including shipping, sequentially lifting, and installing bridge components that are fabricated in the factory. Each process is critical and the risks are high due to the fact that conditions in the field are far more complex than in the factory. A detailed lifting plan is important to ensure the successful completion of steel bridge erection. In this particular study, Building Information Modeling (BIM) tools were used to precisely establish the 3D model of a π shape steel arch bridge following 2D detailed design drawings. Combined with the lifting and installation sequences described in the original lifting plan which were prepared by using 2D drawings and explanations, a 4D simulation for the steel bridge erection was produced and used to review and improve the lifting plan. A spatial conflict of steel component and concrete abutment was detected and corrected in time by postponing pouring of a part of the concrete. Three out of the four issues raised by using the 4D lifting plan were verified and the effectiveness of simulation was confirmed in the construction site.

Keywords: *Building Information Modeling, Steel Bridge Erection, Virtual Design and Construction*

1. INTRODUCTION

Conceptually, Building Information Modeling (BIM) is the collection of activities of using mature information technology (IT) to virtually build buildings on computers prior to physically building them in the real world in order to solve all kind of problems and inefficiencies in the construction industry [1, 2, 3]. The BIM processes of "Modeling Separately, Designing Cooperatively, and Analyzing Integratedly" could cause a series of revolutionary changes to accommodate varieties of expertise involved in the construction industry. To break the wicked cycle of market demand, software support and measured benefits [4], this particular study tries to use BIM tools to simulate the bridge erection of a steel bridge for obtaining convincing evidences of BIM benefits.

The new Su Le Bridge [5], which is a substitute for the old bridge destroyed by typhoon triggered landslides, is a π shape steel arch bridge on the northern cross-island mountain highway of Taiwan (Provincial Highway No. 7). The five main items of the 188 million (NTD) construction project are (1) a π shape steel arch bridge with a total span of 175 (50 + 75 + 50) meters and a width of 10 meters, (2) two 4-meter-diameter pit bases with a depth of 10 meters, (3) two 4-meter-diameter pit abutment foundation with a depth of 20 meters, (4) approach road retaining wall with a total length of 37.5 meters, and (5) rock anchored frame beam slopes. The construction work for the project started in December 2008 and was completed in August 2010. Steel bridge erection requires a series of processes in the construction site including shipping, sequentially lifting and installing bridge components that are fabricated in the factory. Each process is critical and the risks are high due to the fact that conditions in the field are far more complex than in the factory. A detailed lifting plan is important to ensure the success and complete the erection within a tight schedule before the flood season.

2. RESEARCH METHOD

Fig. 1 show the methodology used in this study for verifying the effectiveness of a 4D simulation in the Su Le Bridge project. The 2D detailed design drawings are all collected and used to convert into the 3D model by using

Revit Architecture software. All the conflicts and misunderstandings while converting were consulted with the structure engineer, (SE) who is in charge of the design, to confirm the accuracy of the model.

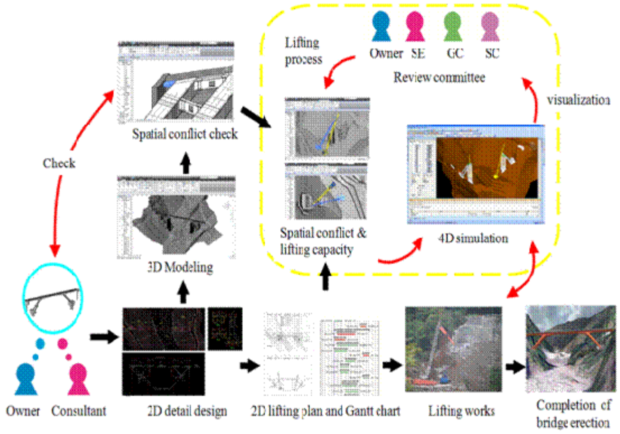


Fig. 1 Methodology for Verifying Effectiveness of 4D Simulation in the Su Le Bridge Project [5]

A 4D simulation is then produced by following the original lifting plan, which was comprised of eight sequential steps all expressed by 2D drawings of bridge components and Gantt charts. The characteristics of the proposed crane for lifting the bridge components are used to produce a 3D crane model. The 3D models and the topography under the bridge were all integrated into another tool (Navisworks) to produce an animation of 4D simulation for the bridge erection. Every steel bridge component was lifted in the virtual model on the computer by the proposed crane to check for spatial conflict visually and the capacity of lifting manually. A review committee composed of the highway agency (owner), the structure engineer (SE), the general contractor (GC), and the lifting subcontractor (SC) was organized to discuss the four issues proposed from the 4D simulation. The actual lifting works were photo recorded for comparison.

3. RESULTS

Table 1 shows that a total of six spatial conflicts were found by the automatic conflict check of Revit Architecture and analyzed by the authors. As shown in Table 1, the automatic conflict check is able to find both modeling error and design conflict. Modeling errors such as in Table 1 could be automatically ignored by adequate settings for the conflict check. The design conflict as shown in Table 1 is investigated further to avoid reworks and improve productivity. The No.6 conflict in Table 1 was reviewed carefully by the structure engineer. The concrete abutment was designed to form the super elevation for curvature of outer bridge lane, which is designed to be about 25 centimeter higher. However, the software used in this study is not capable of simulating physical properties of steel components. The elevations of the last two steel components were adjusted according to the super elevation design.

Table 1 Analysis of the Six Conflicts Found from Automatic Conflict Check

No	Conflict Parts	Reason of Conflict	Correction	Classification
1	The bottom of bracing column and the top of bracing column base, west, down stream side.	Accumulated error, overlapped less than 10 mm.	Ignored	Modeling error
2	The bottom of bracing column and the top of bracing column base, east, down stream side.	The same as above.	Ignored	Modeling error
3	The bottom of bracing column and the top of bracing column base, west, up stream side.	The same as above.	Ignored	Modeling error
4	The bottom of bracing column and the top of bracing column base, east, up stream side.	The same as above.	Ignored	Modeling error
5	The abutment cheek wall and the bridge end. (the cheek wall block the space from the component to fit in)	Concrete abutment design is not integrated well with the steel bridge design.	That cheek wall concrete was poured after erection of the component.	Design Conflict
6	The elevation of concrete abutment is about 25 centimeter higher to fit the bridge end at the outer curved side.	The concrete abutment was designed to form the super elevation for curve.	The model was adjusted to fit the abutment.	Physical properties of steel component were not modeled.

Fig. 2 shows the screen shot of the 4D animation of the bridge erection, which is a form of output from Navisworks. The animation was used effectively by the review committee for verifying the lifting processes.

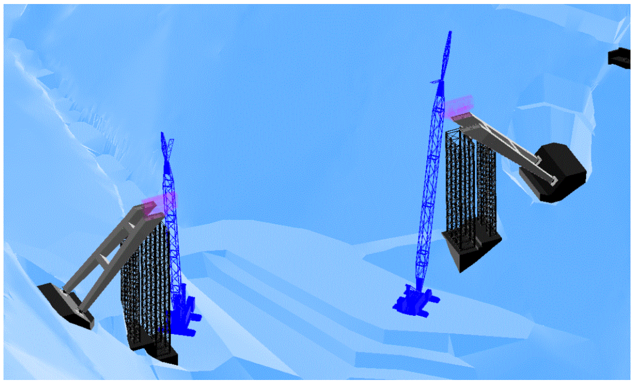
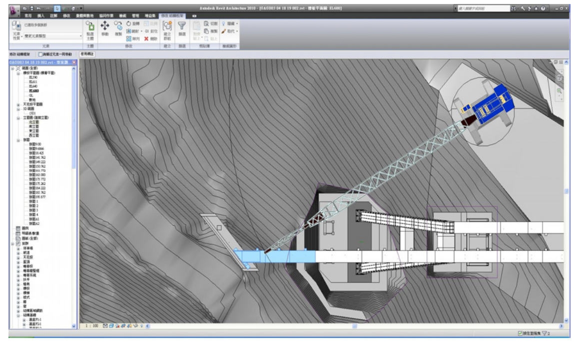
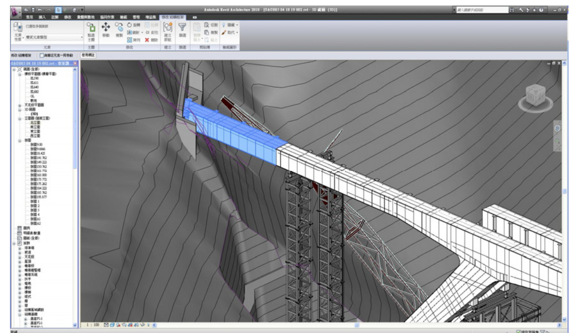


Fig. 2 A Screen Shot of the 4D Simulation of Bridge Erection in Su Le Steel Bridge Project

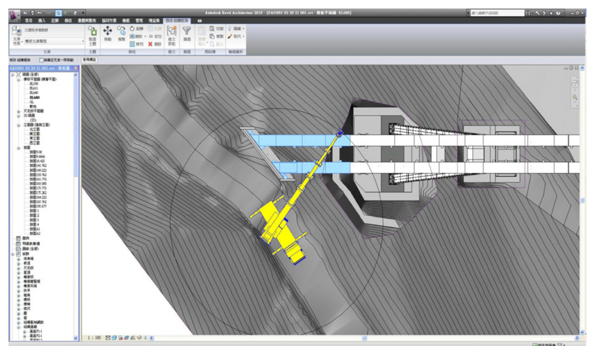
The erection procedures were checked in the virtual 4D models and verified with subsequent works in the real field. The original lifting plan was organized by an experienced engineer. After consulting with the original planner, a 4D simulation was produced by a civil engineering graduate student with little practical experience. Four lifting issues were proposed by the 4D simulation and reviewed by the Su Le Bridge project team. Three out of the four issues were verified by the committee. The other one is a misunderstanding of the original lifting plan. Fig. 3 shows one of the three issues which visually show shortage of the lifting arm. The alternative for this issue was also proposed in Fig. 3 to ask for a control on current traffic. The original planners admitted that he was unaware of these issues until he saw the 4D simulation.

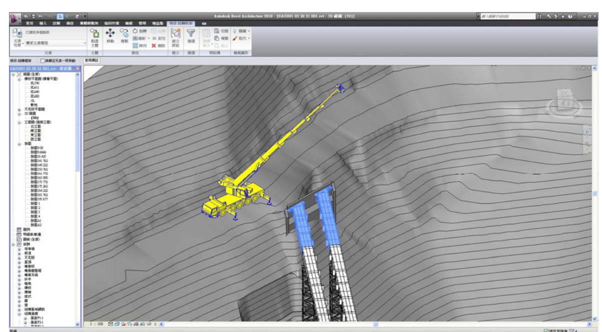
The conventional 2D lifting plan was compared with the proposed 4D simulation as shown in Table 2. For the conventional lifting plan, an experienced planner fully controls the lifting plan and visualizes the lifting procedures in his mind. Alternatively, with BIM tools all information could be integrated objectively in the simulation software and repeatedly reviewed either visually or automatically. It is clear that the 4D simulation is capable of improving inefficiencies of conventional lifting plan.





Crane SCX 2800, the total length of lifting arm 67.05+12.2 meter, working radius 48meter, lifting capacity 11.6 ton. The weight of component 11 ton. The lifting arm could be found visually too short to successfully lift the component in the virtual model.





Alternatively, Crane AC 395 could be used at the abutment edge to successfully lift the component. However the crane was blocking the current traffic.

Fig. 3 Models used to check the spatial conflict visually and lifting capacity manually

Table 2 Comparison of Conventional Lifting Plan with 4D Simulation Plan for Bridge Erection

Item	Conventional Lifting Plan	4D Simulation Plan
Communication media	2D drawings, tables	3D models, tables, 4D animation
Method and Cost	2D drawings, simple, low cost.	3D modeling, Software training, higher cost
Evaluation for spatial conflict, lifting capacity, and safety	Integrated in the planner's mind. The planner's experiences dominate.	Integrated in computer software, automatic, objective, and repeatable.

Two more cranes were used in the actual bridge erection, one of which was installed with a longer arm to make up for the issues raised from 4D simulation. Besides the use of different types of cranes, the simulation looks similar to the actual lifting as shown in Figure 4.

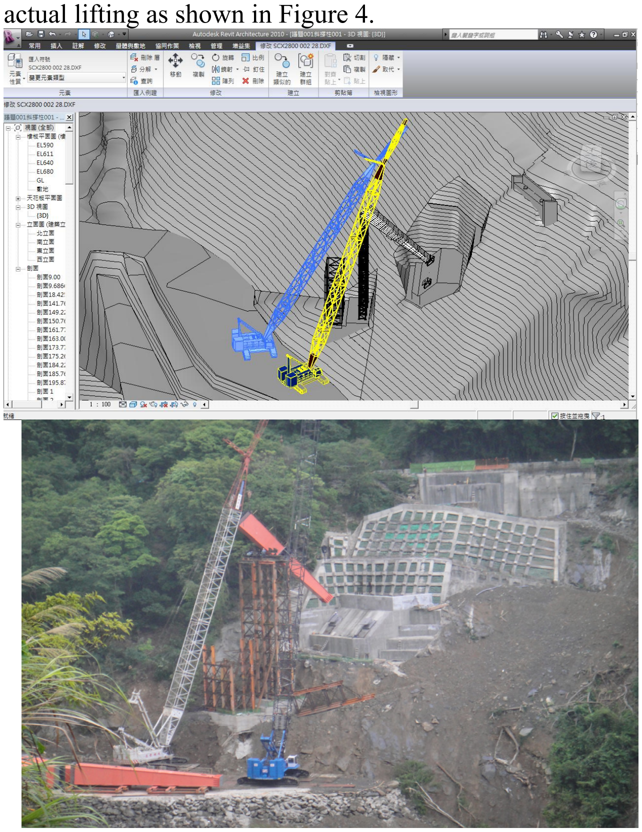


Fig. 4 Comparison of Computer Simulation and Actual Lifting Picture

CONCLUSIONS

The purpose of this study is to verify the effectiveness of using BIM tools by simulating the erection of a steel bridge. By converting the original 2D detailed drawings into 3D models and combining the erection plan (the Gantt chart), a 4D simulation of steel bridge erection is produced. The erection procedures were checked in the virtual 4D models and verified with subsequent works in the field. When the Su Le Bridge project team reviewed the erection plan, the results of the 4D simulation showed the different states of the steel bridge at different points in time, effectively pointing out collisions in space that would have been disastrous before any actual hoisting. Necessary adjustments to the construction site, equipment, and lifting steps were made in time, and the lifting was completed smoothly before the deadline. Utilizing BIM technology in the 3D modeling program, we found a particular spatial collision that cannot easily be spotted in a 2D drawing. To avoid this conflict, the placement of concrete was rescheduled to later time. Of the four communication and coordination issues raised from reviewing the 4D simulation, two are foreseeable by professional sub-contractors, but cannot be correctly expressed. The other two were not foreseen, but was corrected in time through our simulation. Applying existing BIM tools for reviewing the steel bridge erection plan as in this particular case, two trained graduate students, although without any on-site construction experience, completed the tasks in three months, proposed procedural recommendations for reliable hoisting. The benefits of using BIM tools for virtually check, review, and integrate detailed drawings and designs have been clearly demonstrated.

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