Investigating Safety Passage Planning for System Shoring Supports with BIM

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Abstract –

All temporary structures at the construction stage are collectively called falsework. As part of the falsework, the importance of system shoring support (SSS) is often overlooked in construction projects, thus causing increasing accidents from SSS collapse. The 2014 occupational accident statistics of the Council of Labor Affairs show that most occupational accidents occurred in the construction industry, and fall and collapse were the most common accidents in the construction industry in Taiwan. Although the SSS is commonly used in construction, no well-defined instruction for the installation and required safety facilities for SSS have been established to provide a dependable guide. The status of SSS used in falsework of construction projects and the types of potential accidents and relevant examples will be investigated. With building information modeling (BIM), this study defined the relevant SSS facilities with the 3D modeling of BIM. This research drew the actual status of the erection of SSS on the construction site with the Revit from Autodesk to provide a communication platform for engineers, SSS contractors, and labor safety and health personnel. The corresponding preventive measures in terms of safety passages and stairs have been proposed for the reference of engineering personnel in construction site. Through the help of this study, the construction falsework safety can be enhanced and the accidents of SSS can be minimized.

Keywords –

System Shoring Support, Safety Passage, Building Information Modelling.

1 Introduction

1.1 Stages of Construction Projects

In terms of the life of buildings or civil structures, a construction project falls into two main stages: construction and use stages. At the “use stage,” main concerns are load factors including seismology, wind resistance, live load, and dead load. At the “construction stage,” they are new concrete placing, steel, formwork, workers, and machinery vibration. Nonetheless, the external load pattern of both stages is different [1]. Given that the safety at the “use stage” is the main concern of engineering professionals, the safety requirements of structures at the use stage are the focus of all existing structure design specifications, particularly seismic performance and wind resistance of structures. All temporary structures at the “construction stage” are collectively called “falsework.” Its importance is often overlooked as it is demolished after project completion. Kwak and Kim have analyzed shoring systems installed to support applied loads during construction [2]. Currently, there are very few specifications for the reference of falsework design. Most constructors simply calculate the structural strength of falsework based on the design specifications of structures at the “use stage”, the accuracy remains inconclusive. Reinfurt et al. have described the design, construction, and monitoring of a temporary shoring support system which permitted the construction of two urban stations for the Metro Link St. Louis Light Rail System [3]. As part of the falsework, the importance of SSS is often overlooked in construction projects, thus causing increasing accidents from SSS collapse. Stauffer et al. have presented the design and construction of an innovative shoring system in Seattle, Washington [4]. As concrete placing for large-area and atrium structures requires many workers working together at the same time, when SSS collapses, this usually causes mass injuries and deaths of workers and massive personal and property damages. Figure 1 shows the formwork SSS collapse occurred at the Beiling Boost Station Service Reservoir Project in Gangshan, Kaohsiung, on December 13, 1997, where seven workers were killed and twelve injured on-site [5]. Figure 2 shows the formwork SSS collapse occurred at the Beishan Interchange Bridge Project of Highway 6 in Nantou on September 30, 2010, where seven were killed and three injured on-site [6].

Figure 1. Formwork SSS collapse at the Beiling Boost Station Service Reservoir Project in Gangshan, Kaohsiung [5]

Figure 2. Formwork SSS collapse at the Beishan Interchange Bridge Project of Highway 6 in Nantou [6]

1.2 Introduction to BIM

Building information modeling (BIM) has become an undeniable trend across the world. As its ability to link 3D models with various analysis tools can improve accuracy, reduce errors, synchronize design, enhance energy efficiency rate, and promote sustainable development, it has been widely applied to architecture, engineering, and construction (AEC) industries and building life-cycle project design and engineering integration [7]. BIM is a 3D building software integration concept and a practical solution. It enables complete linking between fundamental module technology and architectural design databases and allows digital information interchange in the construction process. It also establishes mutually coordinated and consistent computable information for construction projects under design and construction. According to the engineering characteristics and needs to select the appropriate software in BIM products will be save a lot of manpower and resources in construction projects [8]. A BIM system generally refers to a system enabling the establishment, integration, and reuse of construction information and professional knowledge during the life-cycle of buildings [9].

1.3 Research Motivation and Purpose

The visualized interface of BIM can effectively help engineers to convert what were originally 2D plans into 3D elevations. Except for well-trained senior engineers, it is difficult for ordinary people to capture all three-dimensional information from a 2D drawing, and not to mention detecting the conflicts and problems of work items from the drawing. As it is strenuous to erect the SSS, constructors are less likely to erect it again when errors are found after erection. When the problems of SSS were found, best way to solve these issues is to reconsider the whole design of SSS. As they simply strengthen the sections with probably lower strength, industrial safety accidents thus occur [10]. According to CLA’s 2011 analysis of major occupational accidents in the construction industry [11], most occupational accidents occurred in the construction industry, and fall and collapse were the most common and second most common occupational accidents among all major occupational accidents in the construction industry, as shown in Figure 3. Effective planning of safety passages and stairs thus become the key to the prevention of occupational accidents. By drawing detailed, actual on-site support conditions on the SSS in falsework of construction projects with BIM, engineers can visually examine the potential problems of SSS and adjust the method or position of erection from the computer to avoid disassembly and re-assembly of SSS when errors are found after erection. The purpose of this research includes:

1. To investigate the status of SSS uses in falsework of construction projects and the types of potential accidents and relevant examples.
2. To draw the actual status of erection of SSS and

relevant safety facilities on a construction site with BIM to provide engineers with a platform to discuss SSS suitability.

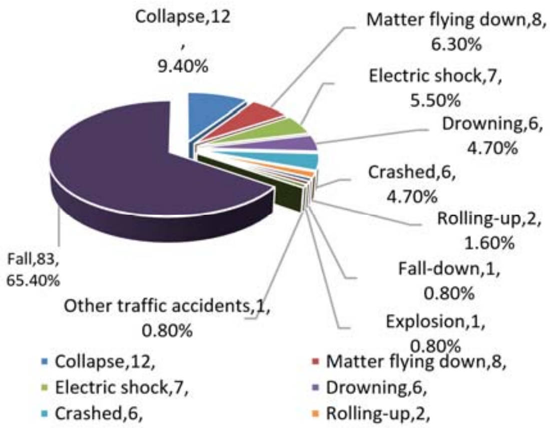

Figure 3. Occupational deaths by accident type in the construction industry [11]

2 Research Results

2.1 Current Status of SSS Safety Facilities

This research drew the status of on-site erection of SSS on the construction site with BIM software to assist in SSS safety passage design and investigated the current status of SSS safety passages by on-site interview and literature collection. Currently in Taiwan, falls likely occur when assembling SSS columns and beams and erecting safety nets due to safety feature inadequacy, personnel passage difficulty, and lack of appropriate stairs. When installing these safety facilities, as their reliability and security are often overlooked, collapse also likely occurs. In the absence of well-defined and dependable guidelines for the installation, choice, and layout of safety facilities for SSS using sites, even if industrial safety personnel are eager to install them, they can only bring a certain amount of safety, and unreliable safety protection cannot bring substantive protection, such as incomplete pavement of footsteps along passages or the absence of guardrails.

2.2 Investigating SSS with BIM

This research drew the `actual status of the erection of SSS on the construction site with the Revit from Autodesk to provide a communication platform for engineers, SSS contractors, and labor safety and health personnel. This research investigated the working space of workers in a construction project with the 3D display of BIM for SSS contractors to prepare adequate quantity of different kinds of elements and safety facilities and reviewed the safety considerations in construction and the conflicts of construction interface among different contractors for a comparatively reasonable and safer work environment.

Based on the current status of a bridge project, this research simulated the status of SSS uses on the construction site and drew up the 3D layout and planning of SSS with BIM software. Figure 4 shows the sectional view of the case. Figure 5 shows the side view of planning. Figure 6 shows the 3D perspective of the entire site.

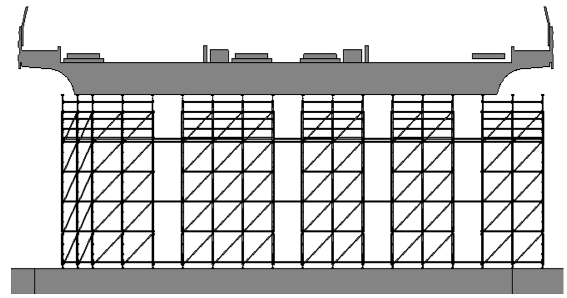

Figure 4. Sectional view of SSS erection

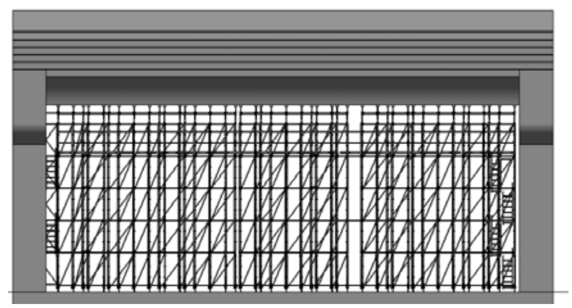

Figure 5. Elevation of SSS erection

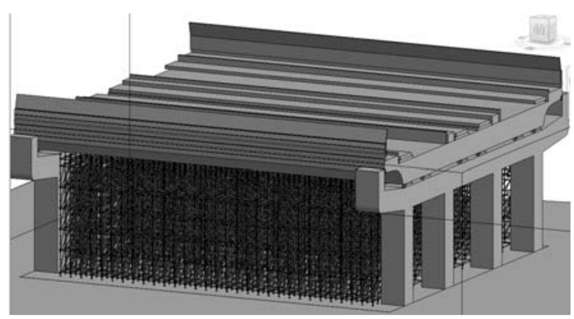

Figure 6. Perspective of SSS erection

2.3 Investigating Footsteps with BIM

This research constructed a 3D model to investigate the viability and safety of SSS safety passage planning. When laying out footsteps based on current practices, passage difficulty or fall often occurs. Although it is difficult to find passage difficulty in SSS from 2D layouts, the 3D drawing in Figure 7 clearly shows the problems in footstep layout on SSS and vertically deployed footsteps must be installed on the left for workers to pass through SSS. Figure 8 shows the need for an additional footstep to prevent any fall of workers, as the interval from the footstep on the right hand side becomes larger after moving the footstep to the left. In addition, as the connection point of the two vertically deployed footsteps is not aligned under this situation, workers may fall when they overlook this, and warning signs should be posted. Figure 9, the aerial view of the entire site, shows that the safety passages are too narrow and the interval between footsteps is too large, thus personnel or objects falling is very likely to occur. From the BIM, this research can adjust the footstep layout (as shown in Figure 10) to improve problems of narrow safety passages and too large intervals between footsteps, minimizing the possibility of personal falls.

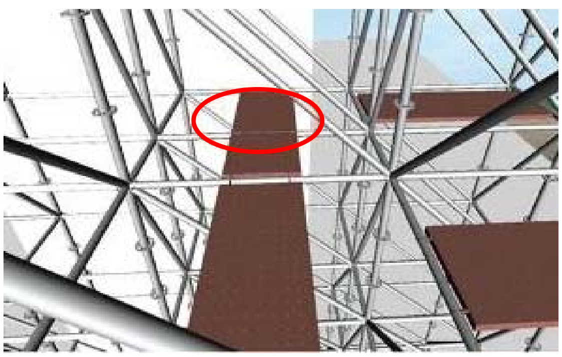

Figure 7. Passage difficulty caused by the present footstep layout

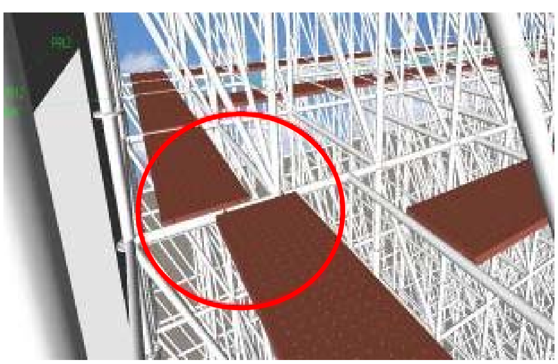

Figure 8. Footstep deployment after adjustment to the left

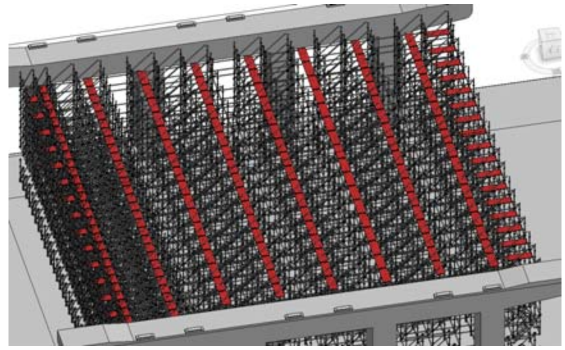

Figure 9. Footstep layout simulation with BIM

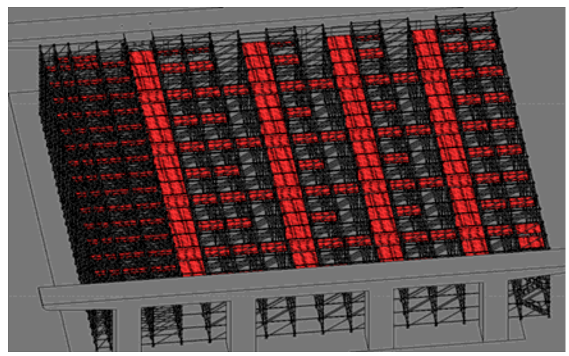

Figure 10. Simulation of footstep layout adjustment with BIM

2.4 Investigating Safety Stairs with BIM

The quantity and relevant requirements of SSS safety stairs are well-defined in relevant specifications [12]. In most cases, constructors only need to check the quantity, gradient, and width of safety stairs with reference to relevant standards. The layout of SSS safety stairs is shown in Figure 11 [13], and its BIM simulation is shown in Figure 12.

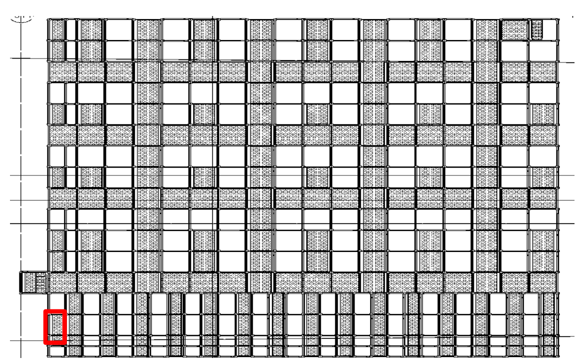

Figure 11. Location of SSS safety stairs [13]

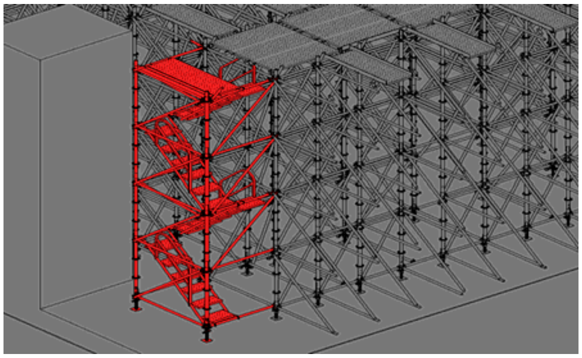

Figure 12. Simulation of SSS safety stairs on the lower left

3 Conclusions

The following conclusions are obtained from simulating SSS in 3D images with BIM.

1. In terms of safety passage, the work platform is the passage of the main work area at top of the SSS. BIM can help engineers to verify passage safety and compliance with the regulatory requirements of work platforms. Support formworks and safety nets should be installed on work platforms where footsteps are inadequate.
2. At the beginning of design, compared to traditional 2D drawings, BIM enables engineers to effectively plan the layout of safety passages, stairs, and safety facilities.
3. If budget allow, a fully paved work platform can always maintain personal safety and prevent personnel falls. This also provides a safer work environment for formwork workers afterwards.

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