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CASE REPORT

ENGINEERING SCIENCES

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Application of 3D Laser Scanner to Forensic Engineering

ABSTRACT: In the case of building collapses and overturned structures, a three-dimensional (3D) collapse or overturn model is required to reconstruct the accident. As construction sites become increasingly complex and large, 3D laser scanning is sometimes the best tool to accurately document and store the site conditions. This case report presents one case of a structure collapse and one case of an overturned crane reconstructed by a 3D laser scanner. In the case of structural collapse of a prefabricated shoring system, a 3D model reconstructed all the members successfully, a task that is nearly impossible using a scale such as a tape measure. The reconstructed prefabricated shoring system was verified through a structural analysis through comparison with the construction drawings to investigate faults in construction. In the case of the overturned crane, the jib angle and other major dimensions were successfully acquired through 3D laser scanning and used to estimate the working radius. As a result, the propriety of the working radius with the given lifting load was successfully determined.

KEYWORDS: forensic science, building collapse, structure overturn, 3D laser scanner, shoring system, crane

Scanners have been widely used in the field of reverse engineering, and their application has been expanded to the field of forensic science. In general, two types of scanners have been applied in forensic science, short-range high-resolution scanners and long-range scanners. Short-range high-resolution scanners are used in the analysis of trace evidence within the microscopic range. Joong et al. (1) performed a seal impression analysis using a high-resolution 3D scanner and suggested a technique that can successfully identify seal impressions with an error rate of <1%. The repeatability, probability, and precision of scanned data have been studied for commonly encountered forensic evidence, such as bite marks and crania (2–4). These studies suggested a framework for empirically estimating the probability and necessity of a reporting protocol for scanning. Studies on repeatability comparing well-established commercial scanners, including Faro, Trimble, and Minolta, have also been carried out (5,6). They suggested a technique that produces results that are independent of a specific laser scanner. The particular application of a scanner for estimating suspect height and the documentation of physical evidence has been studied, and it was reported that the height estimated from surveillance video was not significantly different from that estimated by the scanner regardless of whether the person in an image was wearing a head covering (7,8). The application of long-range scanners for building collapse and blood pattern analysis also has been studied. Dominica et al. suggested that a scanned 3D collapsed building model could be very useful in identifying the cause of collapse (9). Nashad et al. calculated the point of origin of blood spatter using a laser scanner and suggested a technique that produces results within the range of accepted accuracy and reproducibility (10).

On the other hand, 3D laser scanning for forensic investigation of construction sites is uncommon despite its ability to accurately document the conditions of a large and complex site. In the case reports discussed herein, applications of laser scanners are presented focusing on a building collapse and an overturned structure. The cases were investigated using a Leica P40 laser scanner in conjunction with Leica Cyclone & Reshaper software obtained from the National Forensic Service Korea (11).

Case 1 with Discussion

On February 11, 2015, at about 4.52 p.m., the top slab of a gymnasium under construction collapsed, while the concrete was being cast. Eleven workers were injured as a result of falling from the top slab. The top slab was supported by prefabricated temporary shores. The prefabricated shore system consisted of vertical, horizontal, and diagonal members. In the case of a structure collapse investigation, it is necessary to check whether all the members were installed according to the construction drawings. In this case, it was nearly impossible to check all the collapsed members because they were covered with hardened concrete that had undergone severe deformation. Fortunately, half of the whole prefabricated shore system remained undamaged because, in that area, concrete had not been cast yet. Figure 1 shows the top slab of the gymnasium structure. Half of the top slab collapsed while the concrete was being cast, and the other half of the top slab, not cast, did not experience severe damage. Figure 2 shows the collapsed area, and Fig. 3 shows the remaining undamaged prefabricated shore system. As seen in Fig. 3, it is nearly impossible to accurately document every structural member of the shoring lattice work by hand using a

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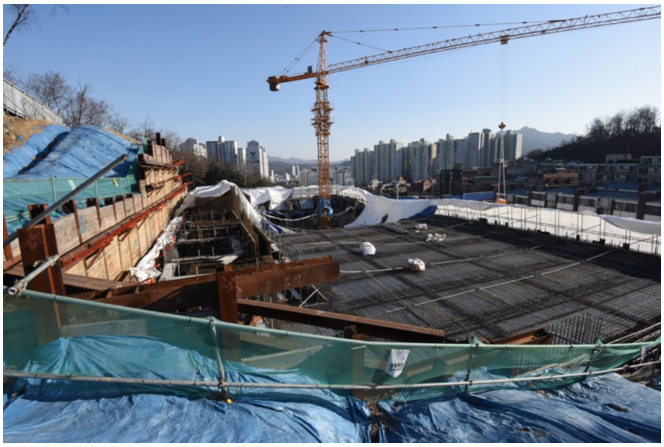

FIG. 1—*Top slab of a gymnasium structure. Half of the top slab collapsed while the concrete was being cast, and the other half of the top slab, not cast, did not experience severe damage.*

FIG. 2—*The collapsed area of the gymnasium.*

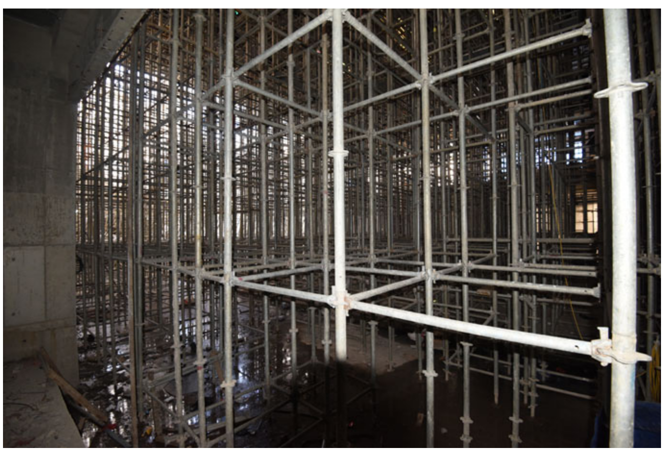

FIG. 3—*The remaining prefabricated shore system. It was nearly impossible to check the dimensions of all the remained members of the prefabricated shoring system through the use of a scale because of its complexity.*

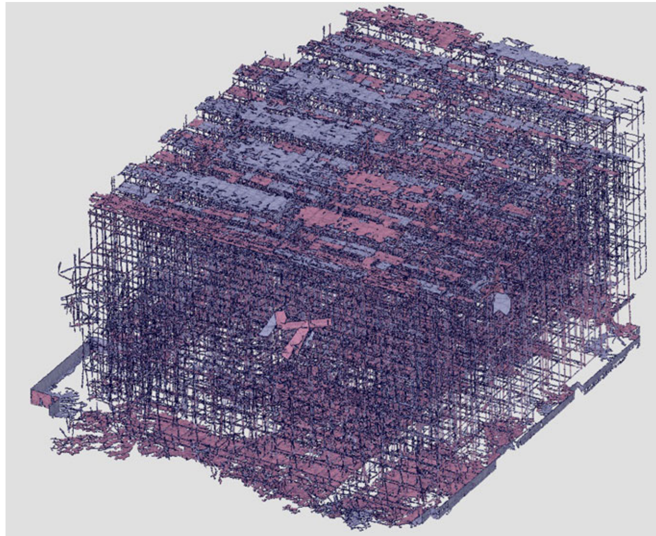

FIG. 4—*The Whole 3D scan image of the reconstructed shoring system. The reconstructed 3D shoring system was examined by making cross-section and floor plan drawings.*

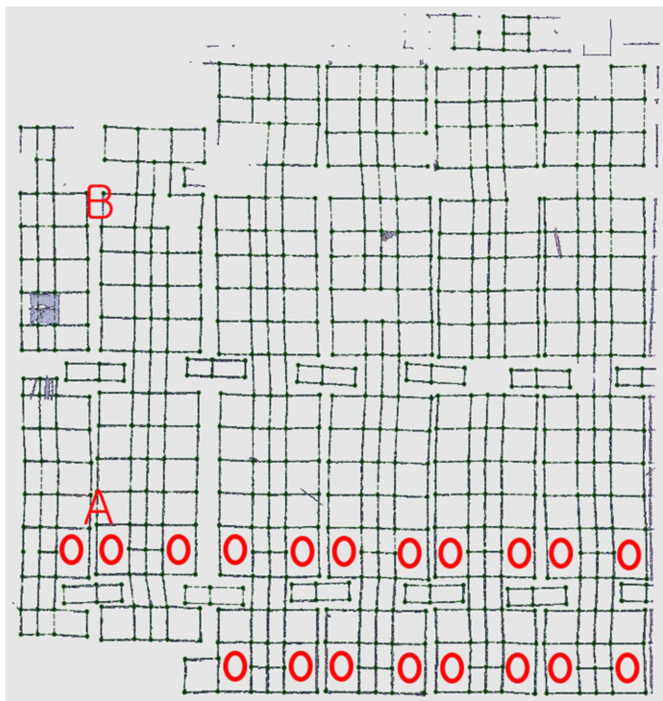

FIG. 5—*An example of a floor plan drawing of Fig. 4. The prefabricated shoring system was not installed along the beam so it was not parallel to each other; For example, points A and B and some members shown on the construction drawings were not installed, as indicated by red circles.*

tape measure or other type of scale. We used a laser scanner to reconstruct the remaining prefabricated shoring system. Because of its large size, the shoring system was scanned in at least 15 directions and each scanned file was merged using Cyclone software to represent the whole shoring system. As the metal surface of the shoring was covered with concrete dust, there was no difficulty in scanning. Figure 4 shows the whole 3D scan image of the reconstructed shoring system. The reconstructed 3D shoring system was examined by making cross-section and floor plan drawings. Figure 5 shows an example floor plan drawing of

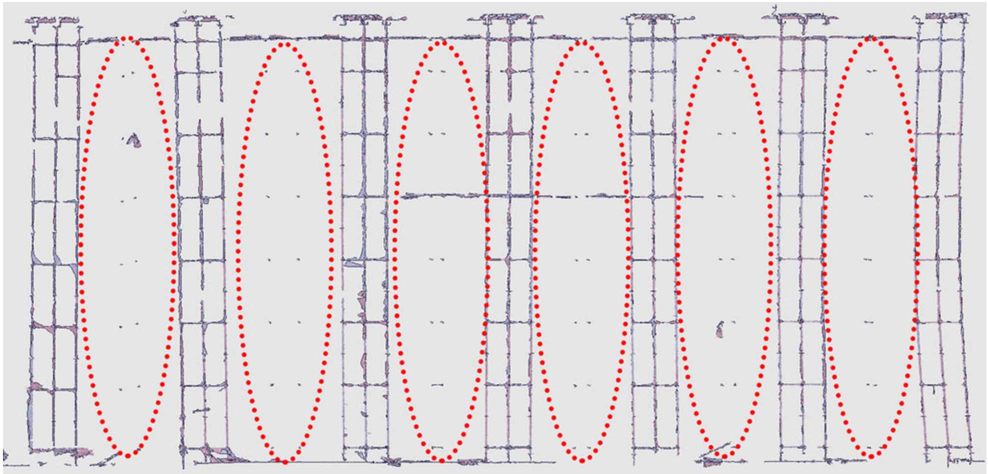

FIG. 6—*An example of a cross-sectional drawing of Fig. 4. The dashed circles represent positions where the members were not installed.*

TABLE 1—*Specifications of the crane. The boom and the jib length are the data at the time of accident.*

Manufacturer/Model	Kobelco/SL6000
Type	Hydraulic crawler crane
Boom length (m)	48
Jib length (m)	72
Max. boom lifting capacity	250 tons $\times$ 4.6 m

FIG. 7—*The crane just before the collapse recorded by CCTV.*

Fig. 4. As seen in Fig. 5, the prefabricated shoring system was not installed along the beams and hence its members were not parallel to each other. For example, points A and B and some members shown in the construction drawings were not installed, as indicated by red circles. Figure 6 shows an example cross-sectional drawing of Fig. 4. In Fig. 6, dashed circles represent positions where the members were not installed. In general, the construction drawings of the prefabricated shore system were made through a structural analysis. The prefabricated shore system reconstructed by the scanner was verified through the structural analysis. As a result, the cause of collapse of the prefabricated shore system was successfully established through the structural analysis using the reconstructed 3D shoring system. Thus, a laser scanner can enable inspection of the construction state of many complex structures and modeling of their construction state for a structural analysis.

FIG. 8—*The crane just after the collapse recorded by CCTV.*

FIG. 9—*The collapsed boom, the ruffing jib, and the front and rear struts located on the roof being constructed. The jib angle with the struts remained undamaged.*

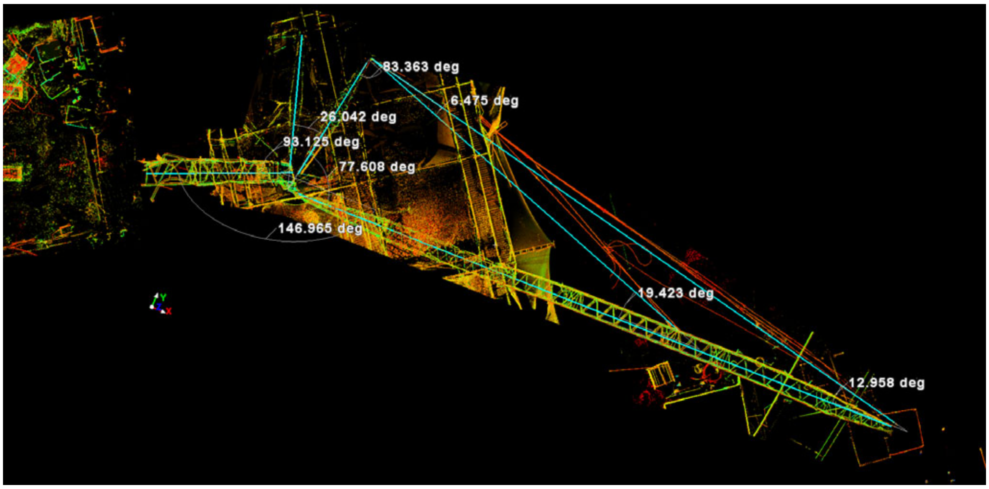

FIG. 10—*The reconstructed image of Fig. 9 by 3D scan data. The jib angle and other major dimensions were successfully acquired and used to estimate the working radius.*

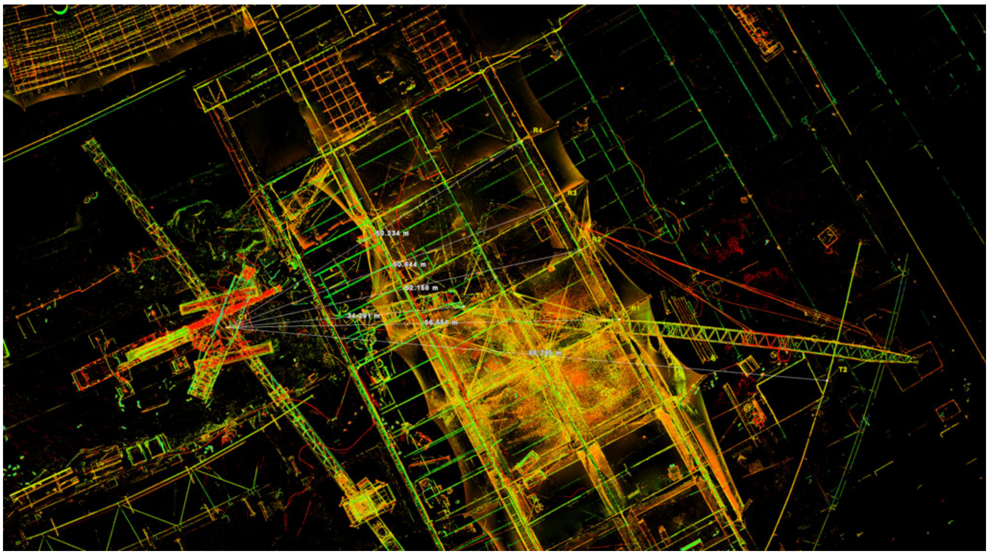

FIG. 11—*The reconstructed working radius. The lifting load was examined with the acquired working radius through a rating chart.*

Case 2 with Discussion

On November 10, 2015, at about 10.15 a.m., a crawler crane collapsed while it was lifting a structure weighing about 40 tons. The specifications of the crane are shown in Table 1. The event of the collapse was recorded by CCTV. Figure 7 shows the crane just before the collapse, and Fig. 8 shows it just after the collapse recorded by CCTV. In this case, the core question regarding the accident was whether the crane was operated within its working radius or not. The working radius is the horizontal distance from the centerline of rotation to a vertical line through the center of gravity of the load, and it is determined by the lifting load, the boom angle with length, the jib angle with length, and the counterweight through the rating chart. The operation record of the crane could not be restored due to severe damage. As shown in Fig. 8, the crane and the related structure being built could not be reconstructed using a manual measuring device such as a tape measure or gauge because of its complexity and volume; therefore, the whole site was scanned to reconstruct the working radius. Figure 9 shows the collapsed boom, the ruffing jib, and the front and rear struts located on the roof being constructed. The jib angle with struts remained undamaged. Figure 10 is a reconstructed image of Fig. 9 based on 3D scan data. The jib angle and other major dimensions were successfully acquired and used to estimate the working radius. Figure 11 shows the reconstructed working radius. The lifting load was examined with the acquired working radius through a rating chart. As a result, the propriety of the working radius with the given lifting load was successfully determined. In this case, the laser scanner enabled inspection of the dimensions of the failed crane that were needed to estimate the working radius.

Conclusions

From the two cases reports, it was concluded that laser scanners can be very effective in the field of forensic engineering. In the case of a structure collapse, the laser scanner enabled the inspection of the construction state of many complex structures and aided in the modeling of their construction state for a structural analysis. In the case of an overturned crane, the jib angle and other major dimensions were successfully acquired through 3D laser scanning and used to estimate the working radius. As a result, the propriety of the working radius with the given lifting load was successfully determined.

Acknowledgments

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References

1. Joong L, Seong GK, Young-Soo L, Jun-Suk K, Nak-Eun J. Detection of transcribed seal impressions using 3-D pressure traces. J Forensic Sci 2012;57(6):1531–6.
2. Sabrina BS, Sebastian KTSW, Louise MF, Kevin WPM, Philip LW. Variation in the measurement of cranial volume and surface area using 3D laser scanning technology. J Forensic Sci 2010;55(4):871–6.
3. Mihran T, Fang L, Herbert LB, Edwin TP, Jeffrey AP. A framework for estimating probability of a match in forensic bite mark identification. J Forensic Sci 2011;56(S1):S83–9.
4. Ana M, Stella MH. Accuracy of 3D Scanner in tooth mark analysis. J Forensic Sci 2015;60(S1):S222–6.
5. Chiara V, Daniel G, Cristina C, Jo B, Andrew SW, Niels L. Surface curvature of pelvic joints from three laser scanners: separating anatomy from measurement error. J Forensic Sci 2015;60(2):374–81.
6. Higinio GJ, Sandra Z, Diego GA, Pedro A. Application of Kinect gaming sensor in forensic science. J Forensic Sci 2015;60(1):206–11.
7. Monique J, Eugene L. Suspect height estimation using the Faro Focus^{3d} laser scanner. J Forensic Sci 2015;60(6):1582–8.
8. Debra AK, Stephanie DJ, Summer JD. The use of a 3-D laser scanner to document ephemeral evidence at crime scenes and postmortem examinations. J Forensic Sci 2012;57(1):188–91.
9. Domenica C, Maria GA. Three-dimensional integrated survey for building investigations. J Forensic Sci 2015;60(6):1625–32.
10. Nashad H, Eugene L. Calculating point of origin of blood spatter using laser scanning technology. J Forensic Sci 2015;60(2):409–17.
11. Cyclone 9.0. Cyclone 9.0 for Windows. Heerbrugg, Switzerland: Leica Geosystems Inc, 2014.

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