Abstract. This research uses a 3D scanner to scan the construction process at a building construction site in order to produce point-cloud information to compare with the 3D-computer model from a shop drawing. In the check process, we can find construction inaccuracy, and measure the value of the inaccuracy. This will help us determine the precision of the construction methods.

1. Introduction

In the general building construction process, they prevent operation inaccuracy through construction machines or other external force factors. The scanner usually needs to set up a control point on the building itself or on the periphery of building to monitor construction. However, it produces to change shape or location as structural components or structure body. Although, measurement equipment and instruments are used to observe
changes in shape or location, it is unable to be used directly to control operation status quickly by the construction manager on site. Therefore, it must rely measurements to control the whole change location status during building construction (Alfeld, 1988; Oberlender, 1993, Dakhil and Henderson 1998).

In the construction process, it controls effectively construction inaccuracies and changes in location. For on site management control and time efficiency, it will make the construction process go smoothly. For bigger construction projects, load and degree of difficulty of measurement is higher.

For example, because of limited construction height and spatial relation during the steel construction fabricated process measurement equipment, it will affect result of to set up and measurements. Their numerous components prevent step-by-step inspections of every construction component with precision. At most, it only can control the gist of the whole building structure precision in accordance with every datum control point.

Therefore, if constructor/client/designer can use the 3D scanner (Cyrax 2500) to scan the structural body, it will help with control of the construction schedule (Shih, 2003), it can use point cloud information and a three-dimensional computer structural model to inspect the operation. Since the computer model is built with structural shop drawings and steel structure production shop drawings, its sizes and location are matched with the building construction needs. However, in the building construction site, there are construction limits due to external terms and construction inaccuracy that can produce unanticipated construction inaccuracy. Some inaccuracy though cannot go so far as to influence structural safety; the inaccuracy could be so great as to produce construction components problems in the future. In seriousness, it even affects the safety of the building body (Vähä 1997).

This research combines the 3D scanner and computer structure model to measure precision in the building construction process. The computer model, in accordance with shop drawings and steel structure produce shop drawings, conforms to fabrication size of structure components and matches the construction schedule used with the same schedule computer model. They both display three-dimensional information, so they can quickly inspect on computer screen to find out possible inaccuracy from the fabrication process on the construction site. This allows the construction manager find repeated problems so that they can be eliminated. It can inspect the scanning information to find differences before and after construction (Shih, 2002).
2. 3D scanner and scanning shape

A long-range 3D laser scanner can retrieve the shape geometries of remote objects as point clouds. 3D scanning of small objects at short range has been widely applied to industry design in the process of reverse engineering. Previous industrial applications were not suitable for data retrieval of large objects such as buildings until the recent development of a long-range laser scanner. This study applied Cyrax 2500 to scan a building site as a way to record construction status. As-built construction used to be recorded using text, photos, and videos and was generally a tedious process. The application of 3D scanning data could be used as a supplementary record in the analysis and evaluation of a work schedule.

Chronological scans represent on-going records which include the configuration of objects that are visible to the scanner. These records are useful for checking work progress. Since the clouds are made up of points with x-, y-, and z-coordinates, as-built geometric information can be compared with 3D design models. Both types of 3D data can be brought up on a computer screen for the purpose of verifying any differences between them (Shih and Wang 2002). This manner of comparison can also be used with clouds made in different time periods.

The suitable range for the scanner is between 50 and 100 meters. The site we worked on was about 90 meters in width and in length. Scans were made from the top floors of two buildings located nearby. By differentiating the time lapse of laser points, the distance between a point on an object’s surface and the center of the scanner was calculated. A matrix of 999 points in width and 999 points in length was used to figure the shapes of the surfaces of the objects that were exposed to the scanner. This system allows modifications of scan density and the juxtaposing of multiple scans in one scanworld. Scans can be registered using reference points that exist on all scans. The size and boundary of the scanworld is virtually unlimited.
Scanned data are stored in the .imp format of Cyclone, which translates it into .xyz or .dxf files for other application uses such as with AutoCAD and MicroStation. CloudWorx and MicroStation Triforma were used in this study (see Figure 1).

3. Develop building structure model from construction need

In the past, building 3D drawing operations were used to present design results. They also presented a combination result of the structure components with 3D drawing tools to insure structure safety in the construction period. If it can monitor construction precision and location using different tools during the structure construction process, it can help to decrease inaccurate construction and ensure construction quality afterward.

This research scanned a steel building in the process of being built and used its shop drawings and steel structure's drawings to develop a computer structure model. This building is a steel building with twelve floors above ground and three floors beneath the ground. The goal of the project is to inspect the construction of the above ground steel structure. The computer model is built up from this. Unnecessary and dispensable components are ignored in order to decrease model and point cloud inspecting conveniently.

The study inspection schedule was from 2003/04/07 to 2003/05/27 during the steel construction hoisting operation above ground, and in accordance with the construction schedule, one scan per week of the building exterior and some interior construction was done to receive steel fabricate and slab grouting real point cloud information throughout the construction process. For convenient inspection with point cloud, the computer model created major use main columns and beams from the steel structure producing drawings.

As expected with the exterior steel structure, we tried to scan some finished construction like the fireproofed steel beams, and to inspect the point cloud with the fireproofing and computer beam model, to find some difference.

4. Inspect precision with 3D point cloud and computer structure model

This research scanned the building eight times in order to receive eight building exterior sharp point cloud information. To get higher inspection precision, we placed point cloud in 2003/04/07 with computer model, to base location of columns and beams to match the 3D computer structure model (see Figure 2). It can clearly display the correct location of columns and
beams with the computer model. This means that the computer model is accurate.

![Construction status (top left), point cloud (top right), structure model (bottom).](image)

For every scan, we will set up some targets to control, if the targets are not subjected to factor in external force and artificial depredation. In theory, the point cloud locations are same for each scan. When we have these base fixed point cloud positions, we can receive scan point cloud that can be entered from the setting location every week. It can inspect differences with original computer structure model. It can effectively find the difference between the real construction status and the computer structure model. Inspection work uses slices of point cloud that can decrease unnecessary interference with the inspection result when the slice point cloud is inspected with the structure model (see Figure 3).

In the result, this research does not find any great mistake and inaccurate measurements from the point cloud and structure models by slice of columns and beams (see Figure 4, 5). This infers that it should not strike against, and not easily produce the location of major columns and beams that have been fabricated and fixed. The building was still being constructed at that time and did not load the whole edifice. Therefore, it did not notice settlement or location changes. However, if one considers the relation with the slab center level and around the beams, we find the second floor slab level has obvious differences between columns number H and I. There is a 1.7cm the
difference in distance (see Figure 6). In the shop drawings, it required slab with a thickness of 15cm, but the actual measurements by point cloud and the model is 11.8 to 13.5cm. This is very different from the shop drawing requirement.

Figure 3. Point cloud combine with structure model (03/04/07) of plan (left) and east-north elevation (right).

Figure 4. Slice of point cloud (03/04/15) of perspective (top left), plan (top right), and side view (bottom).

We believe that the reasons could be due to the thickness of the concrete slab not being enough, or that the beam produces a deflection. This needs to be checked further.
Figure 5. Inspect with point cloud and structure model (03/05/27), it didn’t find obvious inaccuracy, top is side view and bottom is detail.

Figure 6. The slab thickness of column number between H-I has little inaccuracy at second floor, top is location of slice and bottom is detail of measurement dimension of slab thickness.
We tried to measure the fireproofing thickness of the beams and found that some of the fireproofing thickness in the beams was different with others. In the first floor oration hall, the fireproofing thickness of the beams was thicker than other place by slice (see Figure 7). This thickness does not affect fire rate, but can prove that this method can efficiently measure finished or fireproofing thickness. It not only proceeds check and measure completely, but also finds the location quickly and efficiently. This can be an import reference for the construction check.

![Figure 7. Top is the slice of oration hall plan and bottom is section of point cloud and beams’ fireproofing inaccuracy.](image)

5. The effect of building construction precision

The research via 3D scanner obtained point cloud information and 3D structure models for inspection. We find that it can measure the inaccuracy of construction dimension. Let us not go into this area of how this inaccuracy can influence on building safety. The 3D scanner’s measurement can control spatial change.

In the past, the slab inspection used a reinforcing bar or steel column with distance from the slab to the make mark for slab grouting. But in the slab center one cannot have an objective standard to measure. It only uses the measurable bar to measure thickness when the concrete has not yet
congealed in the slab grouting process. However, when the slab congeals, construction inaccuracy is more difficult to control. This research uses the 3D scanner to record quickly for relative location information of construction and then inspect with the computer model. It can measure the inaccuracy value for a more objective standard. It is not only not easier to produce dispute, but also provide the construction manager with another precision control tool.

Since the point cloud information must rely on the location of the 3D scanner to scan the operation, the density and inaccuracy value and location of the 3D scanner must be close to the building. If the distance is too far, the interval will be larger between the dots causing the point cloud to become inaccurate. If the distance is too close, it can make a more accurate point cloud value measurement, but it cannot monitor the whole construction site. Since it must rely on targets to register, its inaccuracy of registration and the effect of the scan must be considered. If the construction site or construction interior does not have an appropriate higher control point or location for the scanner, it will produce many dead spaces thereby causing inspection mistakes.

In the interior construction scan operation, it limits the scan range and angle, so it must use multiple scans and allow interior space to register as a scanworld. It must consider the location and registration of the target as well as receive complete interior point cloud information. From the interior, spatial point cloud can inspect with original computer structure model. It is helpful for interior spatial construction dimension control and provides a method to inspect quickly and conveniently.

Therefore, if it can find a higher control point to set up scanner for scanning beside the construction site, we believe that it can use this method to inspect quickly with precision the finished part of construction interior site. It can control problems between point cloud and computer model. Clients and users can use this method to inspect construction quality.

6. Conclusion

This research uses a 3D scanner to scan the building structure and part of the building’s interior for a long time in order to produces point cloud with 3D computer structure model to inspect the building. It can find some information and data between point cloud and the computer model as well as demonstrate the differences between actual construction process and original shop drawings. It is different inspection method than the one currently used, but it provides a complete inspection method. It can use slices to develop an inaccuracy value, and quickly control construction data and information regarding the construction process.
Since the 3D scanner has a congenital limit based on distance, it cannot scan fully in one scan. It needs to consider targets locations to register and registration inaccuracy. Construction interior scans concern the work behavior effect. In order to avoid the influence of the workers on the construction site, the construction site must have many miscellaneous articles or objects piled that could influence scan quality removed. Another challenge is that the 3D scanner has a problem with vision dead space and cannot receive whole the building components information. It received point cloud through this study to provide the contractor with an inspection method that controls real construction relation dimension quickly. More importantly, it can use the scan results to understand construction site production.

References


