A Study on Measuring of Reinforced-Concrete Structure by 3D Laser Scanner and Making Design of Pre-Cut Interior Finishing Components with Polygon Model

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ABSTRACT

To achieve renovation work without noise, the authors developed techniques of manufacturing pre-cut interior finishing components for renovation work.

In this paper, to achieve the system of pre-cut interior finishing components, the authors describe a measuring method of reinforced-concrete structure by 3D laser scanner and then describe a method of making a design of pre-cut interior finishing components with the polygon model.

Using these two methods, the steps of manufacturing pre-cut interior finishing components consist of the following four steps: First, measure the building shape using a 3D laser scanner. Secondly, integrate a point cloud data and retrieve the markings on the floor. Then, create a polygon model of the building based on the point cloud data. Lastly, make a drywall design using a polygon model.

To evaluate the technique feasibility of manufacturing pre-cut interior finishing components, the authors have conducted an experiment of the finishing interior work of the drywall.

Using pre-cut interior finishing components, the authors have been able to achieve interior finishing work without noise.

KEYWORDS

3D laser scanner, Point clouds, Pre-cut, 3D CAD, Reinforced-Concrete Building

1. Introduction

Repair and renovation work in the building is required to work material processing at the construction site. However, because the processing materials by saws cause much noise, it is difficult to process material for renovation work in the building located in the city. To achieve renovation work without noise, the authors have to develop techniques of the pre-cut interior finishing components for renovation work. But, to achieve pre-cut interior finishing components is required to precisely measure the three-dimensional shape of the existing building.

There have been many studies of 3D scanner in mechanical engineering and civil engineering. In recent years, there have also been similar studies in building engineering [1].In construction engineering, many researchers have adapted 3D scanner to create 3D building models and have developed the method of the shape recognition of 3D point clouds.

In this paper, to achieve the system of pre-cut interior finishing components, the authors describe a measuring method of reinforced-concrete structure by 3D laser scanner and then describe a design method of making pre-cut components with the polygon model.

Using the two methods, the steps of manufacturing pre-cut interior finishing components consists of the following four steps:

(a) Measure the building shape using a 3D laser scanner
(b) Integrate a point cloud data and retrieve the markings on the floor
(c) Create a polygon model of the building based on the point cloud data
(d) Make a drywall design using a polygon model

To achieve the technique of manufacturing pre-cut materials, the authors have developed the following two methods.

Firstly, the authors developed the benchmark system for matching three coordinate systems: existing building, point clouds and 3D CAD.

Secondly, the authors developed the method of making a design for drywall using polygon model representing the building surface.

2. The method of manufacturing pre-cut materials in finishing the interior work by 3D laser scanner

2.1. Measuring the building by 3D laser scanner and planning the drywall based on polygon model of the building

In order to create a polygon models from point cloud data of the structure, a room of office building is measured from several locations. An allowance between the shape of the building and pre-cut materials in interior finishing must be less than 2 mm. Therefore, accuracy of polygon model for production design of drywall must be equally less than 2mm. In order to create polygon models whose accuracy is less than 2mm, the point cloud data of building has to be measured more accurately. Individual points have errors of about a few millimeters, these errors are able to be corrected by mathematical methods such as the least squares method. To correct these errors are necessary to acquire high density of point cloud data of the structure. In addition, point cloud data is necessary to record the plane of horizontal. Moreover, measurement by 3D laser scanner in our technique is necessary to use the benchmark for matching three coordinate systems among existing building, point clouds and 3D CAD.

2.2. The benchmark for matching three coordinate system — real existing building, point clouds and 3D CAD

Point cloud data obtained by the three-dimensional laser scanner consists of coordinate system(XYZ) and reflective luminance of the irradiation point. In addition, the 3D laser scanner built into camera is also possible to obtain the RGB color information of the laser irradiation points. However, the luminance varies with the distance from the 3D laser scanner to the interior finishing surface, and varies with angle of incidence of the laser beam on the building surface. Moreover, point clouds of RGB color are affected by the measuring environment. Therefore, the luminance and RGB color are not suitable for quantitative analysis by computer. Because the color of marking, which shows the installation position of the drywall is black, the point cloud data does not represent the marking position from the luminance and the RGB color of the point clouds.

In order to obtain the position of the mark from point clouds data, the authors have developed a new benchmark system to record the position of the mark in coordinate system of point clouds. Conventionally,a circular target is used to measure a particular point by 3D laser scanner. The center of the circular target is able to be measured correctly in case of the circular target facing the front and being the same height as the 3D laser scanner. However, the circular target placed on the floor are not able to be measured correctly that center because the angle of incidence of the laser beam is too large. Therefore, in order to record the markings, which show the installation position of the drywall or the parallel line of a few tens centimeters away from the installation position of the drywall, the authors depeloped the new benchmark which is a sphere target.

The sphere target developed by the authors is shown in figure.2 and figure.3. This sphere target consists of a white sphere and a seat made of SUS430 which is stainless steel with a magnetic. The sphere target can be fixed firmly on the seat because the sphere target embeds the neodymium magnet. The seat has a circular hole, plastic plate is attached to the bottom surface of the hole. The plastic plate is writen the center of the circular hole. Therefore, the center of the sphere, the center of the base and the mark are laid almost a straight line in the horizontal direction. In addition, the upper surface of the seat is set horizontally using with the a circular bubble(bull's eye spirit level).

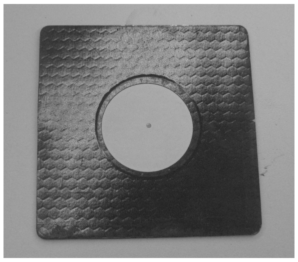

Figure.1 A circular target

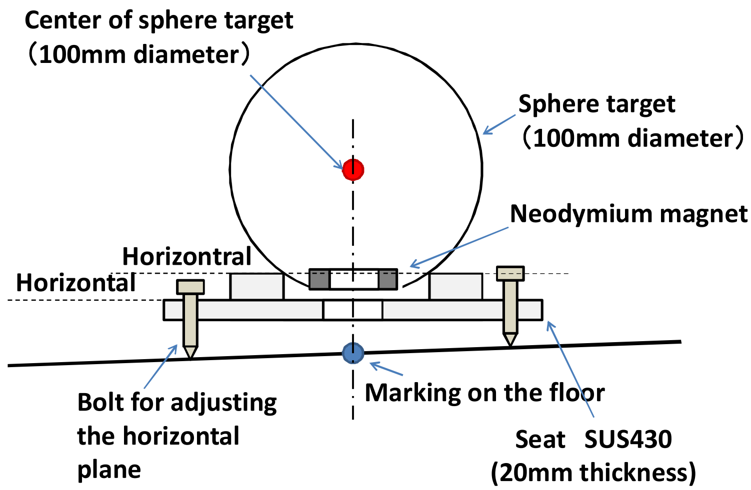

Figure.3 The basic design of sphere target developed by the authors

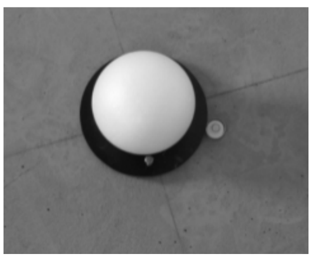

Figure.2 The sphere target developed by the authors

Table.1 The displacement between the center of the target sphere and the mark on the floor in the horizontal plane

Angle (in degrees)		0.020	0.100	0.200	0.500	0.800	1.000
Height from the floor to the center of the sphere	70mm	0.024	0.122	0.244	0.611	0.977	1.222
	80mm	0.028	0.140	0.279	0.698	1.117	1.396
	100mm	0.035	0.175	0.349	0.873	1.396	1.746

The angle refers to the angle between the horizontal level and the top surface of the seat.

2.3. The design method for drywall by polygon model of the building

Three-dimensional shape of the surface of the building interior is able to be recorded in the point cloud data, three-dimensional shape of the surface of the interior is also recorded in the polygon model. The authors have developed the production design method for drywall by polygon model of the building. The production design method for drywall consist the following two steps.

(1) Create a design cross-sectional of interior surface by thinly sliced polygon along the direction of the position of the drywall.
(2) Make a production design of the pre-cut materials for the drywall along the thinly sliced polygon in the design cross-sectional.

To make a production design of the pre-cut plasterboard is along the thinly sliced polygon in the two-dimensional design cross-sectional. On the other hand, the pre-cut stud have to be designed a little shorter length from the floor to the ceiling. The reason is that the runner of the light-gauge steel isn't able to follow the shape of the reinforced concrete structure. The clearance in inserting a stud is X [mm], the gap between the stud and the reinforced concrete structure is Y [mm]. A stud has to be cut a little shorter than the length that is the sum of the X and Y.

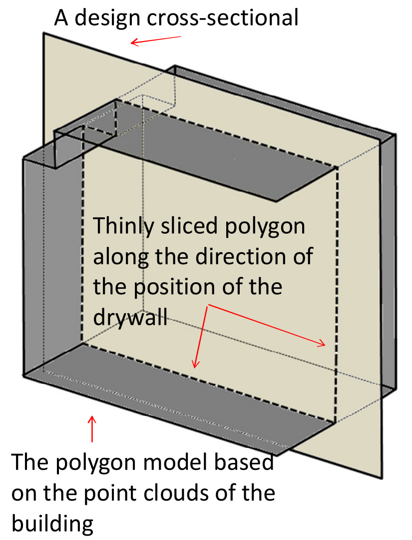

Figure.4 Create a design cross-sectional by thinly sliced polygon along the direction of the position of the drywall

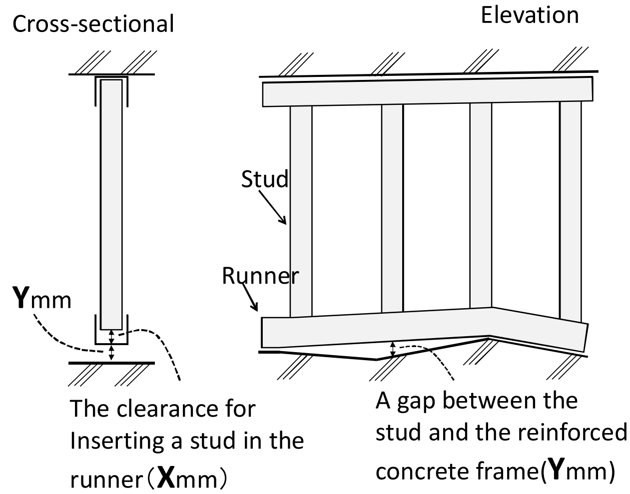

Figure.5 The clearance for inserting a stud in the runner

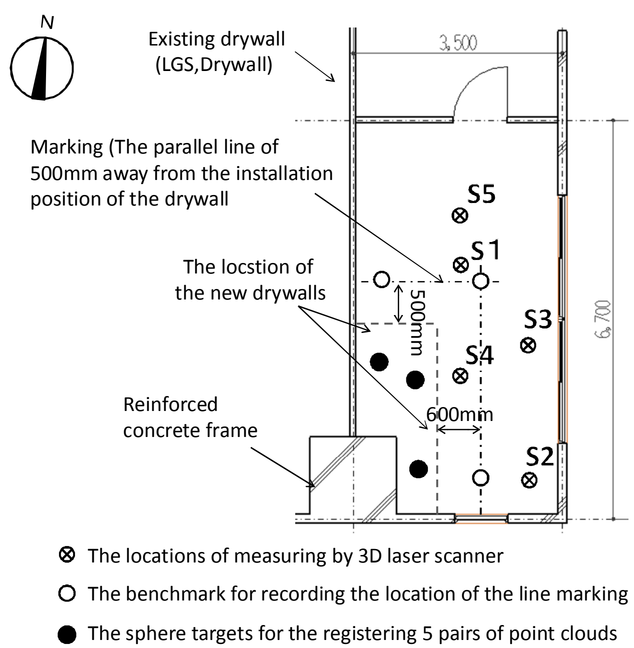

Figure.6 The locations of measuring by 3D laser scanner and the locations of the targets

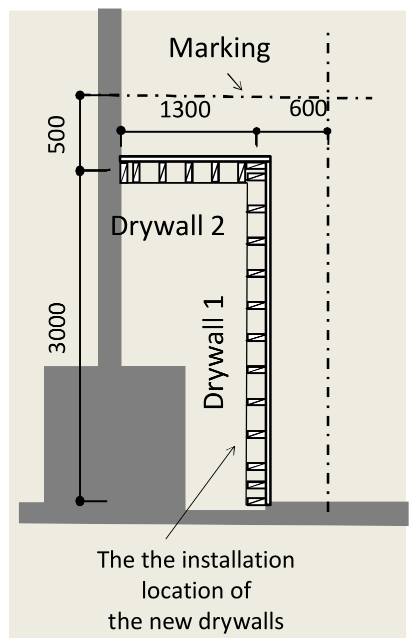

Figure.7 The installation location of new drywalls

3. The result of applying the system

3.1. Point clouds of existing building obtained by 3D laser scanning

To evaluate the technical feasibility of manufacturing pre-cut materials for interior finishing, the authors have conducted an experiment of the finishing interior work of the drywall. This drywall consists of studs, runners and plasterboards, and the drywall is in contact with the concrete wall, floor and ceiling surface (Figure.7). Therefore, the authors have scanned the concrete wall, floor and ceiling surface by 3D laser scanner, and then those point clouds has been converted into a polygon model. The authors have designed the working drawings of the drywall based on the polygon model.

The authors scanned a room in an office building made of reinforced concrete. The size of this room is 3500mm×6700mm. The height between the floor and the ceiling is about 4000mm. The authors have scanned from five locations shown in figure.6. In scanning, the sphere targets were used to record the position of the marking on the floor in point clouds (figure.8).

3.2. Matching three coordinate system which are real existing building, point clouds and 3D CAD

The point clouds scanned from five locations have been merged into point cloud data sets which have same coordinate system. Then the point cloud has been converted to a polygon model. The number of all point cloud is the points of 18 million. The table.1 shows the number of points in each scanning. The figure.10 shows the point clouds of the whole room.

The authors have taken out a part of the point cloud around the installation position of the drywall (Figure.12). And then, the point cloud has been converted into a polygon model (Figure.13). The polygon model consists of about 100,000 triangles.

Figure.8 the measurement in this experiment

Figure.9 The sphere targets used in this experiment

Table.2 The number of point clouds

locations of measuring by 3D laser scanner	The number of point clouds
S1	2,645,938
S2	3,126,787
S3	4,499,767
S4	7,509,244
S5	725,492

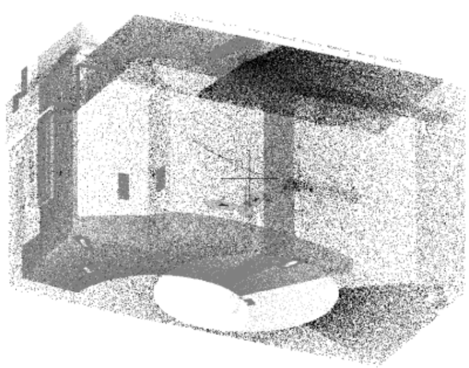

Figure.10 Point clouds of a room in an office building

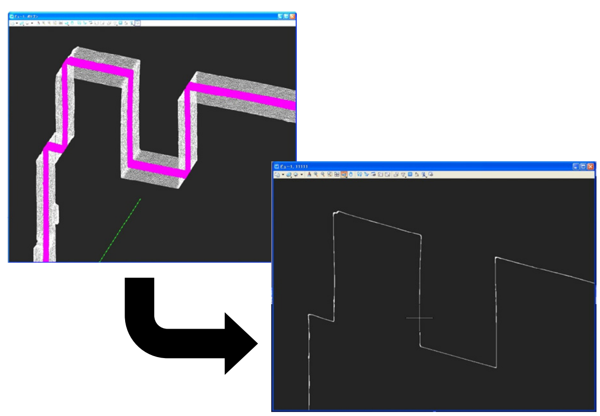

Figure.11 A design cross-sectional sliced the polygon thin

3.3. Making a production design of the drywall using polygon model

Using the polygon model, the authors have made the production design of the light-gauge steel (Figure.14) and of the plasterboard layout (Figure.15). Because the runner of the light-gauge steel is not able to follow the shape of the reinforced concrete structure, the stud has designed 5 mm shorter. After made the design of the plasterboard layout, the authors have made the cutting layout of standard plasterboard (Figure.16).

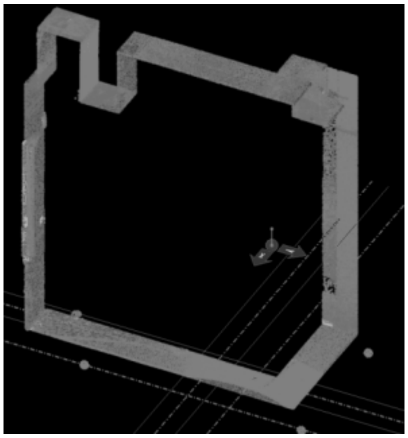

Figure.12 the point cloud of the building

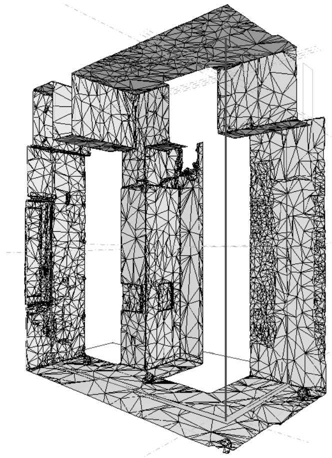

Figure.13 the polygon of the building

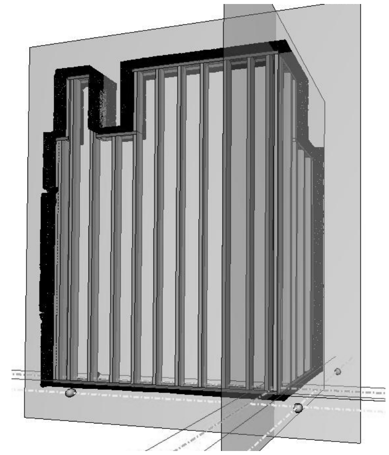

Figure.14 The production design of the new drywall in this experiment

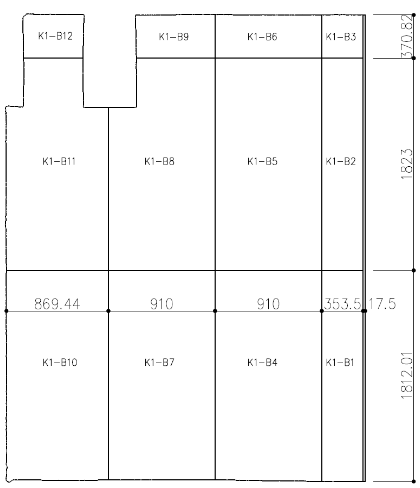

Figure.15 The plaster panel layout of the drywall 1

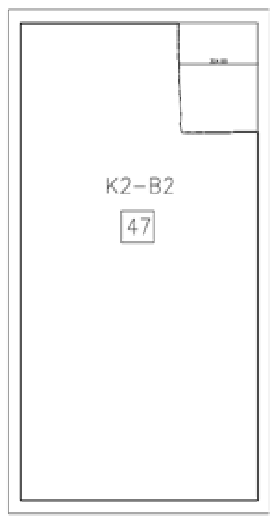

Figure.16 The processing plan of plaster panels.

Figure.17 The pre-cut material of plasterboard

3.4. Installation of pre-cut material for interior finish

Based on the production design, the authors have manufactured the pre-cut studs, runners, and the plasterboard. A pre-cut plasterboard is shown in figure.17. To build the drywall, the workers fixed runners on the floor and ceiling and installed studs into the runners. And then have attached the pre-cut plasterboard on the installed studs. The studs and plasterboard that are installed in the correct position are shown in figure.18 and figure.19.

Figure.18 The studs of the drywall

Figure.19 The plaster board of the drywall

Figure.20 No chink between the pre-cut plaster board and the reinforced concrete surface

4. Discussion of the method of the pre-cut material for interior finish

The pre-cut studs and plasterboard have been installed in the correct position. Because the production design of the pre-cut materials have been based on the polygon model, no chink between the pre-cut plasterboard and the reinforced concrete structure is shown in figure.20. Table.2 shows the distance of the chink between the stud and the reinforced concrete structure. The studs have been designed 5 mm shorter than the length between the floor and the ceiling surface. Because the distances of the gap between the stud and the reinforced concrete structure are within the range of 2.0mm ~ 7.5mm, our methods of manufacturing pre-cut materials were able to apply interior finish work in reinforced concrete buildings.

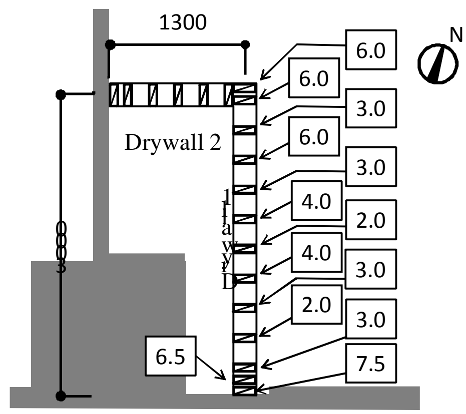

Figure.21 The distance of the gap between the stud and the reinforced concrete frame [mm]

5. Conclusion

To achieve renovation work without noise, the authors developed techniques of manufacturing pre-cut interior finishing components for renovation work. To achieve these techniques, the authors have developed the benchmark for matching three coordinate systems. The authors have also developed the design method for drywall by polygon model. And then, the authors have conducted an experiment of the finishing interior work of the drywall. Using pre-cut interior finishing components, the authors have been able to achieve interior finishing work without noise.

6. References

[1] Kano, N. Kawahara, Y. Kakizaki, H. Ishioka. (7/2009). Application of 3D Scanner in Building Construction. 26th Building Production Symposium, p187-p192