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LIDAR-BASED DEFORMATION MEASUREMENT METHOD OF BRIDGE STRUCTURES USING TLS

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ABSTRACT

Bridge over 30 years account for 35% of all Bridges, because of rapid economic development and urbanization. The structure can't maintain its original shape due to natural disasters and loads, and deformation occurs. The accidents caused by the deformation of the structure have become a common news in the surroundings.

In this study, vertical deflection deformation was measured using a terrestrial laser scanning equipment to measure deformation of the structure. The point cloud data was matched using the ICP algorithm and the vertical deflection value was estimated by the Hausdorff distance. Therefore, this study proposes a noncontact shape management monitoring method that can check structures and detect deformation.

Keywords: Deformation Measurement, Terrestrial Laser Scanning, Point Cloud, Shape Management Monitoring

1. INTRODUCTION

Most of the sensors used to measure the deformation of the structure are of the contact type with a narrow measurement range. Contact sensors are not easy to apply to places where high-rise buildings, hazardous facilities, etc. are not easily accessible. In addition, when an unexpected load occurs, local monitoring by a narrow measurement range limits the evaluation of the response to the structure. In order to acquire data from the sensors installed in the structure, a complicated wired network configuration is required. On the other hand, a laser scanner TLS (Terrestrial Laser Scanning) is a system that can acquire three-dimensional coordinate information of a target remotely using a laser.[1]

Since TLS can acquire shape information of a structure remotely, it can be applied to a place where access is not easy, and it is possible to reduce additional cost and hassle because a wired network for data acquisition is not required.

In this paper, we propose an inspection method that can acquire surface shape information and verify the deformation by using TLS.

2. Lidar based Laser Scanning System

The principle of position measurement of a three-dimensional scanner is to measure the distance by emitting a laser beam to a measurement object and calculating a pulse round trip time or phase shift measurement of the returning beam.

Then, the rotation angle by the rotation motor is applied to calculate the three-dimensional coordinates of X, Y and Z. The coordinate value calculation is as shown in equation (1).

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = r \begin{bmatrix} \cos\alpha\cos\beta \\ \sin\alpha\cos\beta \\ \sin\beta \end{bmatrix} \quad (1)$$

The measurement points calculated here are generally referred to as point cloud data in an amount of 10 million to 50 million points or more.

It is stored in a proprietary format according to the equipment manufacturer. In actual use, it is converted into three-dimensional coordinate data such as ASCII or BIN.

Also, non-target non-contact type laser measurement method is used compared with existing method of installing and measuring target at necessary point.

This can minimize the missing part when measuring the shape of the object and can acquire data quickly, so that it can respond in real time when there is a data submission request.

The scanner used in this experiment is (Scan Station C5) pulse laser scanning, and the equipment performance is shown in Table 1. This is a method of measuring the time that a laser is fired and reflected on a surface of a measurement object, reflected back, and multiplied by the speed of light to calculate the distance. Dd The principle of the distance measurement of

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the pulse scanner is shown in Figure 1 and the distance calculation formula is shown in Eq. (2). [2]

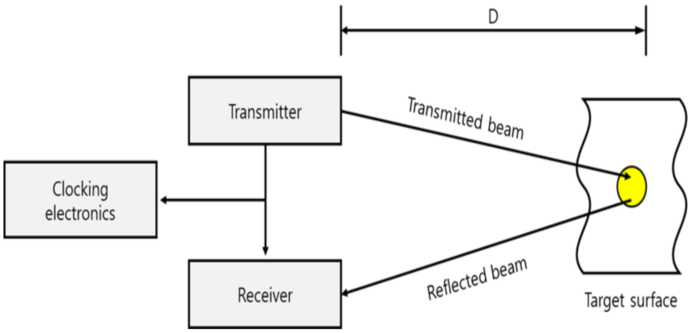

FIGURE 1: PRINCIPLE OF PULSE TYPE SCANNER

$$D = (ct) / 2 \tag{2}$$

Where C is the speed of light, T is the reflected time, and it is possible to scan an object at a relatively long distance (≒400 m).

Since the measurement is made in pulse unit, accuracy is lowered, and error is large at a close distance. Many of the equipment currently used for measurement in the market uses a pulse method, and the performance is determined by the precision of the beam launch angle.

TABLE 1: SPECIFICATION OF SCANSTATION C5

Model	Leica ScanStation C5
Measurement distance	300m
Spot size	From 0-50 m: 4.5 mm (FWHH-based), 7 mm (Gaussian-based)
Range accuracy	35m at 300m
Precision	2 mm
Speed	50,000 point/sec
Range	Horizontal 360˚(max) Vertical 270˚(max)
Laser Class	3R (IEC 60825-1)
Memory	80 GB

3. Scanning laser for bridge deformation measurements

The Hausdorff Distance technique was used to calculate the distance between the point clouds acquired by the scanning data.

Hausdorff Distance was used as the algorithm to find the closest distance between two points, and the value of the distance between all the points was obtained.

h (A, B) and (B, A) represent the Hausdorff distance between point set A and B and are expressed by equation (3) and (4).

Where h (A, B) represents the distance from one point a to the points of point set B and h (B, A) represents the distance from one point B to the points of point set A. [3]

The Hausdorff distance H (A, B) between the point cloud data sets A and B is calculated by equation (5).

$$\begin{aligned} h(A,B) &= \max_{a\in A} d(a,B) \\ &= \max_{a\in A}\min_{b\in B} d(a,b) \\ &= \max_{a\in A}\min_{b\in B} \|a-b\| \end{aligned} \tag{3}$$

$$\begin{aligned} h(B,A) &= \max_{b\in B} d(b,A) \\ &= \max_{b\in B}\min_{a\in A} d(b,a) \\ &= \max_{b\in B}\min_{a\in A} \|b-a\| \end{aligned} \tag{4}$$

$$H(A,B) = max\big(h(A,B), h(B,A)\big) \tag{5}$$

FIGURE 2: LASER SCANNING MEASUREMENT EXPERIMENTS FOR NOSEONG BRIDGE

In order to measure the static response of the actual bridge, the static load test was carried out for the Noseong Bridge. Figure 2 shows the laser scanning installation environment for Noseong Bridge. This Bridge carried out the experiment while controlling the vehicle for a short period of time considering the driving vehicle with the main bridge of buyeo - Daejeon. A total of 27.29tonf and 26.14tonf dump trucks were used for the load test. About 63.2% and 60.5% of the design load of each vehicle were measured and the displacement response was measured by static dump truck.

4. RESULTS

The variation of the structure shape change using laser scanning is calculated by applying TLS data matching algorithm and Hausdroff Distance. Figure 3 shows the unload case and load case 1 deformation.

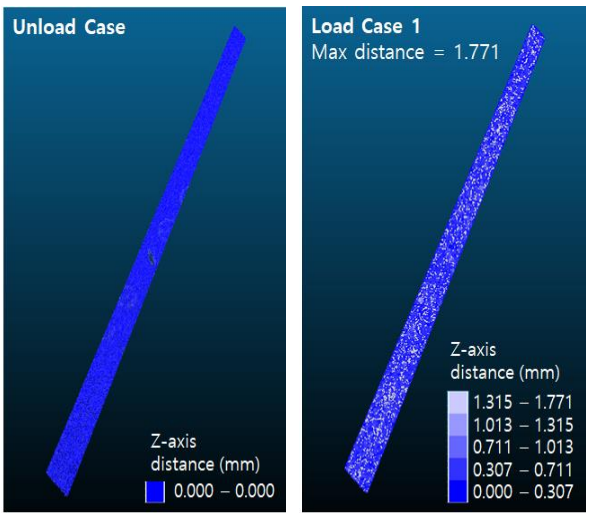

FIGURE 3: ESTIMATION RESULTS OF THE DISTANCE BETWEEN THE REFERENCE(UNLOAD CASE) SCANNING DATA AND LOAD CASE 1 SCANNING DATA

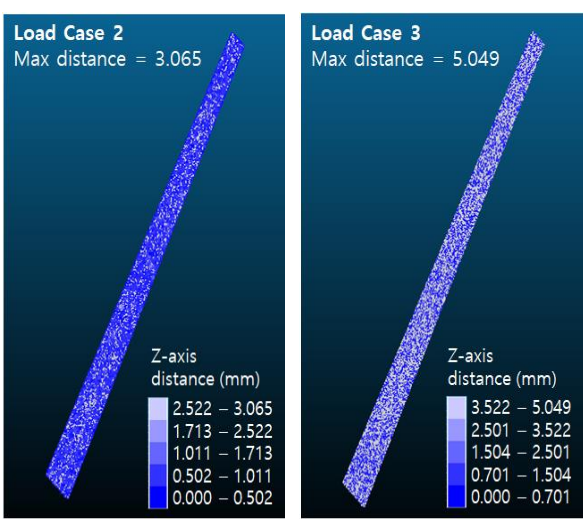

FIGURE 4: ESTIMATION RESULTS OF THE DISTANCE BETWEEN THE REFERENCE SCANNING DATA AND LOAD CASE 2, 3 SCANNING DATA

Figure 4 shows the result of calculating the deformation amount in Load Case 2 and 3, and compared with the LVDT value. The experimental results show that the LC3 has a maximum deflection value of -4.826mm and the 3D model shape estimation value is -5.049mm, which is 4.6%.

In the field test, it is difficult to measure the shape change of the 3D model within 1.711mm, and it is confirmed that there is an error of about 10% in the change of 2.7mm or more. In other words, it is confirmed that the error rate is reduced by about 5% compared with the conventional deformation estimation technique.

5. CONCLUSION

deformation estimation experiments were conducted on structures that are not easily accessible, such as bridges, high - rise buildings, and hazardous facilities, using laser scanning.

A three - dimensional model was created using a point cloud, and the deformation of the structure was measured using this model. As a result, it was confirmed that the strain of 4.8 mm or more can be measured within 5% of the error rate.

In domestic, deformation estimation using laser scanning is still in its infancy, and laboratory-scale studies are actively underway. This indicates that it is possible to manage the shape of the structure using the coordinate values of the laser scanning. Future research will be conducted to develop a monitoring system for shape deformation estimation of bridges and structures.

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