ISSN 2616-5767 Vol.4, Issue 1: 70-75, DOI: 10.25236/AJETS.2021.040107

An Analysis on the Thermal Expansion Displacement of Concrete Bridge by 3D Laser Scanning Technology

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Abstract: *Bridges are one of the most critical transportation structures related to a country's national life, and usually main arteries of national economic development. In the past, the bridge construction only pursues the speed, along with the time passage, the bridge collapse accident often can causes the human life casualties. The concrete bridge materials behavior and the thermal expansion can cause the deformation. Therefore, in this paper, as temperature differences, analysis of the concrete bridge deformation by the 3D laser scanning Technology.*

Keywords: *concrete bridge, 3D laser scanning, safety inspection, deformation, thermal expansion*

1. Introduction

Bridges are one of the most critical transportation structures related to a country's national life, and usually main arteries of national economic development. Countries lose that these structures of economic development, end up with disastrous results.

Therefore, overall inspections and evaluations are essential to give a complete picture of a bridge current condition, Inspectors must to evaluate structures to carry out maintenance or repairs to any damaged structural components to ensure the safety of the bridge.1)

Along with economical rapid development, transport facilities are more and more consummates, in 2000year compared with 1970 year, the numble of bridge had been increase from the 9,000 to 15,000. Entering the 21st century, the number of bridge has increased dramatically, up to 26,920.

In the past, bridges were expected to last about 60 years, However current technology and design allow bridges that are built today to last longer. High traffic volume, heavy trucks, and freeze/thaw cycles along with exposure to salt used for winter maintenance all reduce a bridge's lifespan. Regular maintenance, repair, and rehabilitation can largely offset the impact of these factors on bridge's

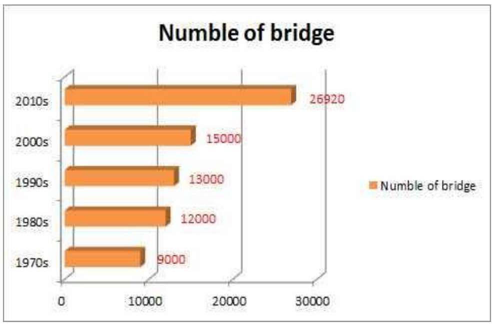

Fig. 1 The Numble of Bridge in Korea lifespan.

Regular maintenance, repair, and rehabilitation can largely offset the impact of these factors on bridge's lifespan. In addition, Bridges can have defects due to the development of various adverse effects, some of which are induced by external impacts, e.g., floods, chemical spills, and earthquakes, whereas other defects can result from improper design, construction, and maintenance, as well as fatigue and deterioration over time.2)

In this paper, we use of terrestrial laser scanning technologies for bridge safety inspection. Although terrestrial laser scanning technologies have evolved in a variety of industrial areas, 3D laser scanning application technologies for safety diagnosis and maintenance of real bridges have lagged

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behind. Until recently, bridge inspection and maintenance have been manually conducted by the trained inspection workers working outdoors3)4)

The terrestrial laser scanning technology is the science, which was developed in recent years, because it can provide a 3D coordinated figures including mountain surface, buildings, bridges, human body and human face. This technology has been applied the wildly in deformation monitoring of structural safety inspection due to the high spatial resolution of the acquired data. The inspection workers check the safety status beneath the bridge by counting the number of cracks, measuring the maximum widths and length of crack lines and taking pictures of them. Thus the accuracy and quality of diagnosis report becomes subjective and results differ according to the diligence of the inspection workers. Also, since the bridge inspection is performed outdoors, especially beneath the bridge, there may be the problem concerning the safety of inspection workers. Figure 2 shows the inspection workers standing on a temporary scaffolding in order to inspect the safety status of a real bridge.5)6)7)

Fig. 2 Inspection workers standing on temporary scaffolding

2. Experiment

2.1 Object

The survey presented in this paper was performed in the Amsogogae bridge, which is located in the Asan city, on the middle of the South Korea.

Figure 3 shows view of the Amsogogae bridge. The Amsogogae bridge is a concrete bridge, and the bridge total length is 53m, 12m in width. Design load is DB-24TON. Founded in 1996, completed in 1998, are estimated to 14 years old.

Fig. 3 View of the Amsogogae Bridge

2.2 Equipment

The point clouds acquisition was performed with a long range time of flight TLS TRIMBLE GX. This scanner measures distances in a range of 350 meters. In addition, the equipment include sphere ball, target, and emergency batteries.

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Table 1 Trimble GX Performance Specifications

Trimle GX	
Scanning Speed	Standard : 200m Extended : 350m
Single Point Accuracy	Position = 12mm@100m ; distance = 7mm@100m
Scan Resolution	Spot size : 3mm@50m
Laser	Type: pulsed 532nm. green Class : IEC 60825-1 - class 3R
Field of View	360˚ × 60˚ continuous single scan

In addition, The Trimble GX 3D Scanner includes VISION technology for digital image streaming and capturing. The Figure 4 is shown the 3D scanner head and full picture.

Fig. 4 3D Laser Scanner

2.3 Data Collection

In this paper, Measurements were performed under two different temperature conditions as follows:

Winter Phase, Ambient Temperature: 3 ℃ ±1 ℃

Summer Phase, Ambient Temperature: 27 ℃ ± 2 ℃ The data acquisition planning required the previous planning of the following issues: location and number of scans, In order to obtain the geometry information of the whole bridge, several scan positions around the building were necessary. In total, 5 positions were finally necessary, and the point clouds acquired from each station were then aligned thanks Post-process software (realworks).

Figure 5 shows the 5 scan positions around whole bridge.

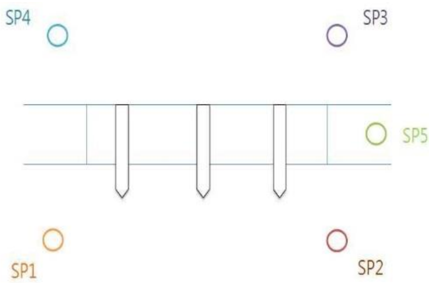

Fig. 5 Different scan positions and field of view from each station around the bridge.

Data acquisition was similar in both phases and the same technical principals were used in each case (summer and winter). The data collection process of this bridge is shown in Figure 6. Based on time of flight method, the scanner transmit the acquired data to the laptop by connect line, and displayed in point cloud data by Pointscape software.

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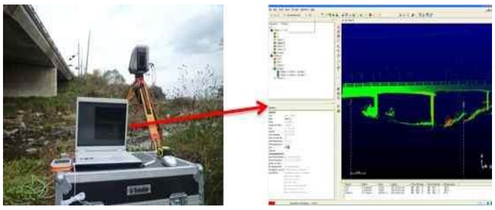

Fig. 6 Scanner Data Collect Process

2.4 Data Processing

After the field works finished, all the acquired information was processed in Realworks software. The first task was the registration (alignment) of the different point clouds, Realworks software by trimble company was used to register and process the point cloud, Figure 7 shows the registration process of various scan positions in this case study and based on the 3 points method. The 3 point method is that find same 3 positions points in red image and green image, this is how to complete the registration process. Then, the points cloud data that did not belong to the bridge surface were manually deleted. In addition to this method, there are have targets and sphere balls methods. In which, 3 points method is the fastest data collection in a field environment method. but it takes massive time in office work.

Table 2 shows the time required in two winter and summer phase.

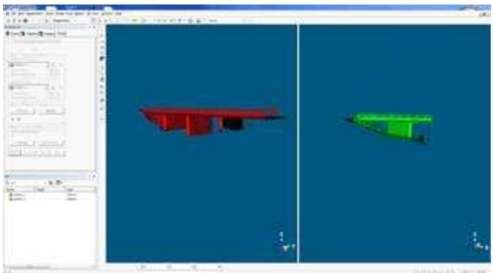

Fig. 7 Data Registration Process in Realworks

Table 2 Operation Time in Two Experiment

Operation	Winter phase	Summer phase
Bridge Survey	1 hours	1 hours
Field scanning	6 hours	4.5 hours
Office work	25 hours	22 hours
Total	32 hours	27.5hours

Finally, the complete bridge registration data in winter and summer are shown in Figure 8 and 9. The point cloud of the bridge in winter was composed of 1.618.871 points. And the point cloud of the bridge in summer was composed of 153,242 points. Because of rain, the amount of points cloud in summer was reduced.

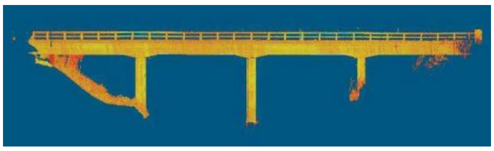

Fig. 8 Bridge points cloud registration data in winter

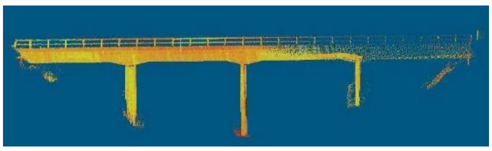

Fig. 9 Bridge points cloud registration data in summer

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3. Results

3.1 High Precision

After the five positions points cloud registration, insert the data which obtained by the realworks software measurement tool, the section created in CAD system. Figure 10 is shown a bridge 2D floor plan in AUTO-CAD software. Figure 10, the bridge length is 53680mm, By comparison with the real length of bridge, error is very small (impact on external factors such as weather)

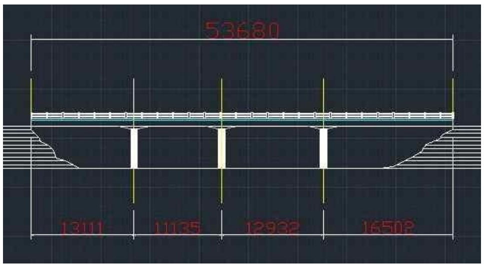

Fig. 10 Bridge 2D floor plan in AUTO-CAD

3.2 Displacement

Theoretical calculation indicate that the over thermal movement which should occur at bridge for a temperature variation of 30 ℃ is about 16mm assuming frictionless expansion bearings. From Figures 11 and 12, we can see parts of the bridge changes.

The coefficient of thermal expansion of concrete is

$$8 \sim 12 \times E - 6/°C$$

Determined by aggregate type, content and concrete mix, following the average coefficient of thermal expansion:

$$10 \times E - 6/°C$$

So, the 53m length of concrete expansion volume is 53,000mm x(50-20) °C x 0.00001/°C = 15.9 mm.

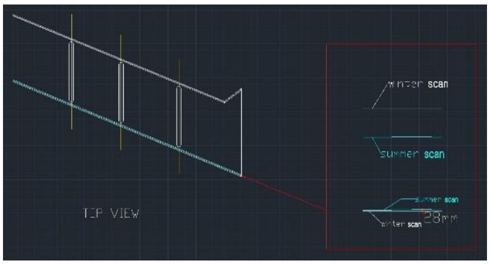

Fig. 11 The hydrostatic leveling of two survey comparison in AUTO-CAD

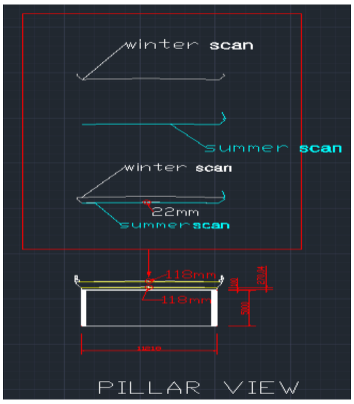

Fig. 12 The pillar of two survey comparison in AUTO-CAD

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Though the two pictures, we can see differences in winter phase and summer phase. Because of thermal expansion, the road surface error of two experiments is 28mm. and the pillar error is 22mm.

Table 3 Error of two experiments

Target location	Error
Road surface	28mm
Pillar	22mm

4. Conclusion and Discussion

In a complex geological environment, how to acquire the spatial deformation information of bridge transition section in an accurate and comprehensive way is the key to ensure the safe operation of bridges. It is also crucial to the implementation of pertinence bridge maintenance. In this paper, the terrestrial laser scanning technology has great development prospects in the bridge deformation field and survey. It has distinct and excellent characteristics and can be advanced in practice.

In the following research, we will be more efforts to explore 3-dimensional scanning technology in the health monitoring system of bridge, road, building, and so on. Make this technology widely used in public infrastructure8). As well as, Use as fundamental information for bridge safety evaluation.

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