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IDI QUARTERLY

Infrastructure Development Institute—JAPAN

Technology for increasing the safety and productivity of mountain tunneling works

Steel timbering erecting robot

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22nd Infrastructure Technology Development Award 2020

Japan Institute of Country-ology and Engineering (JICE) was established as a public interest corporation to promote construction engineering in Japan by conducting cutting-edge research and development activities.

To provide more incentives for construction technology researchers and research institutes to enhance the level of construction engineering more effectively, JICE commenced Infrastructure Technology Development Award with Coastal Development Institute of Technology (CDIT) under the auspices of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Forty technologies competed for the 22nd Infrastructure Technology Development Award. In principle, the applicants' technologies must have been developed within the past five years, already applied to real sites.

As a result of examination, institutes and researchers with the following technologies were awarded the 22nd prizes.

The grand prize was awarded to "Liquefaction Countermeasure for Existing Residential Areas", while the two excellence prizes were awarded to the "Educational System for Close Visual Inspection of Fatigue Failure in Steel Bridges" and the "Steel timbering erecting robot".

The two excellent prizes are introduced below.

For any inquiries/ comments please contact to JICE :
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Educational System for Close Visual Inspection of Fatigue Failure in Steel Bridges

Inspection training simulator system for effectively improving inspection skills

1. Background and opportunities for technological development

Fatigue failure is a type of deterioration on steel bridges caused by aging. Early detection via inspection is critical since the progression of fatigue failure may cause members to break. This makes improving inspection skills essential. Classroom lectures based on current textbooks can be carried out relatively easily to educate inspection engineers, but understanding the actual structure of a bridge in its entirety is difficult.

Furthermore, although the actual structure can be observed while conducting practice fieldwork on-site, a lot of effort is required to prepare and ensure safety at the site, and the number of students who can participate in fieldwork is limited. To supplement the advantages and disadvantages of classroom lectures and on-site practice, we developed a simulator that makes it possible to effectively learn about the areas where fatigue

failures occur and their causes in a virtual space. (Figure.1)

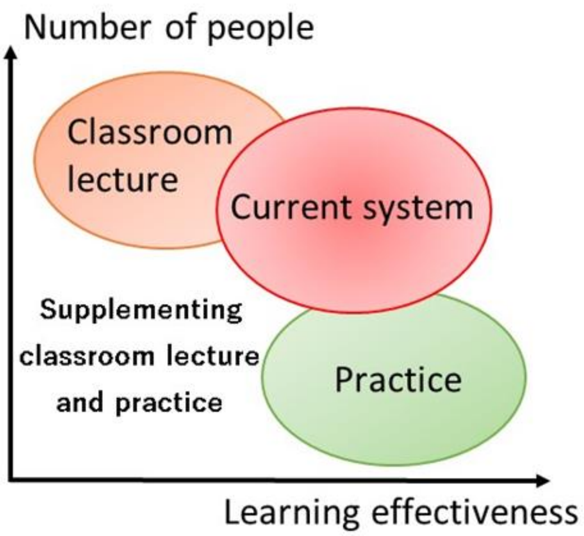


Figure-1 Purpose of the system

2. Details of the technology

The current simulator system uses the 3D game development software Unity as a development platform to create a 3D model of a bridge and to provide a virtual reality (VR) environment. This system allows the user to experience performing an inspection on a virtual bridge using a computer (Photo1) or head-mounted display (Photo 2), and has the advantage of not being limited by time or place.

The bridges that can be examined and studied within this system are simply-supported I-girder bridges with a reinforced concrete deck slab and box-girder bridges. (Figure.2)

The proposed system makes it possible to acquire basic knowledge of bridges and constituent members for inspection, learn how to assess and rank actual damage through plenty of case examples of damage, become proficient in identifying where dangerous crack failures occur and their causes, and undergo continuous training by identifying randomly occurring damaged areas.

Photo-1 Computer version

Photo-2 Head-mounted display version

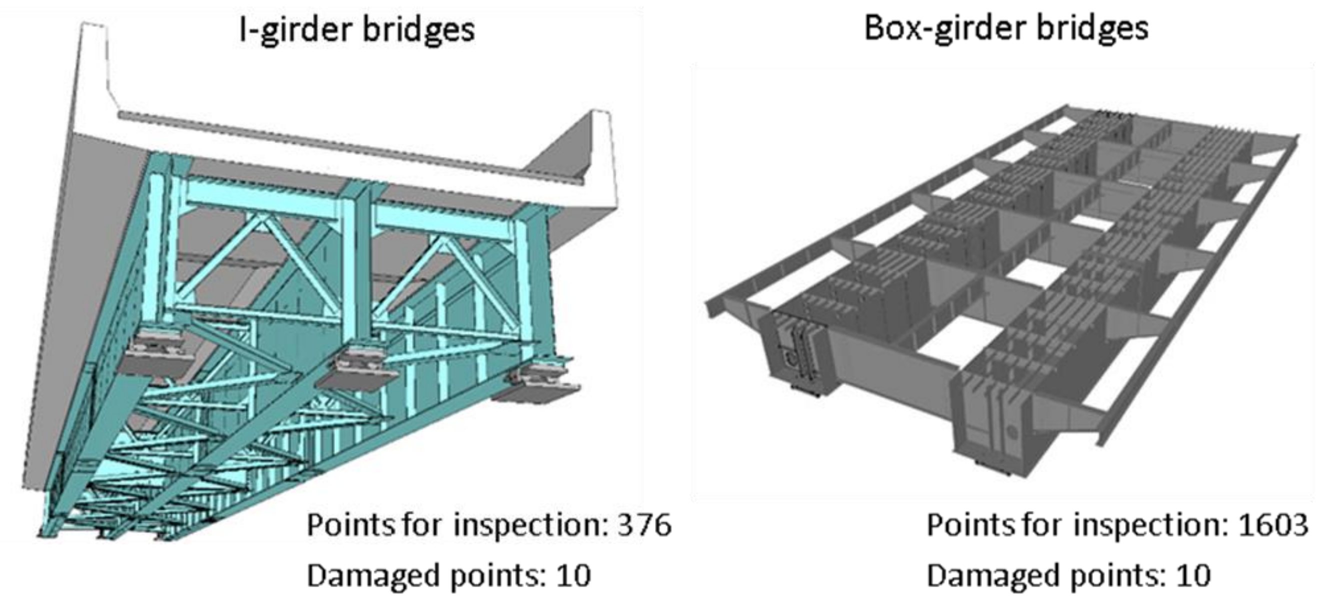


Figure-2 Composition of IMS3

Beginners can acquire the basic knowledge of fatigue failure and inspection, while experienced inspectors can improve their knowledge and skills in order to reliably perform inspections.(Figure 3)

3. Range of application of the technology

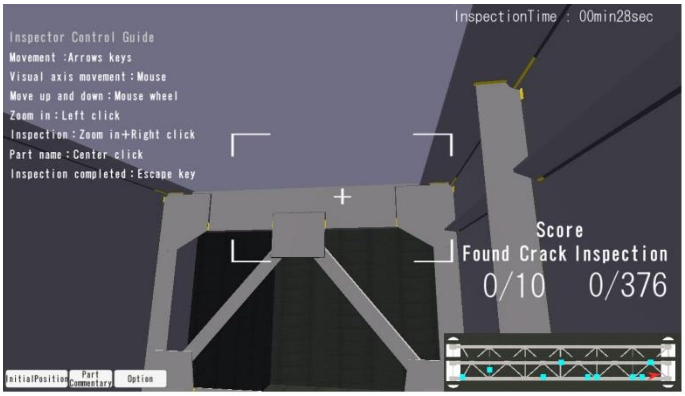
This system can be used for inspection training for all kinds of bridges.

4. Benefits of the technology

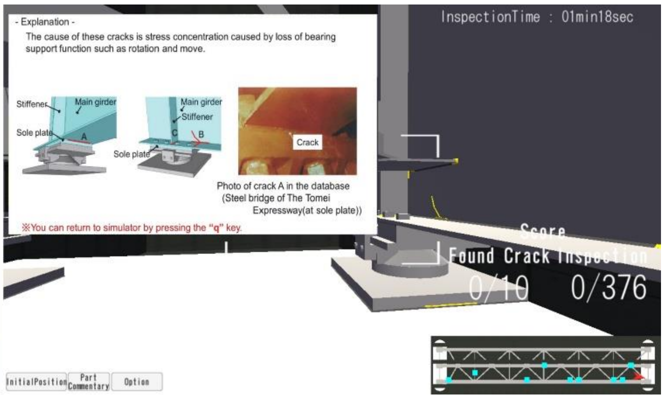
- Using 3D technology makes it possible to obtain a three-dimensional bird's-eye view of the bridge,thereby speeding up the learning process compared to using a textbook alone.
- Learning can be conducted at the user's pace without being restricted by place or time.
- The technology makes it possible to provide much greater efficiency, since practice inspections of actual bridges can be carried out indoors. Practical training can be acquired in a quarter of the time required for on-site inspections.

5. Social significance and potential of the technology

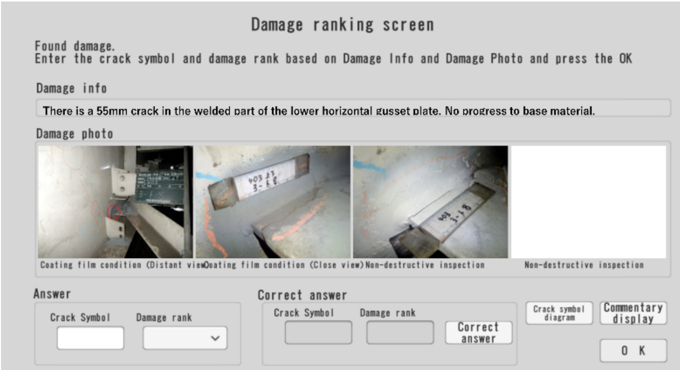
With the revision of the Regulation for Enforcement of the Road Act (issued in March 31, 2014, and enforced in July 1, 2014), regular road bridge inspections require a qualified person with the knowledge and skills to carry out close visual inspections once every five years. This led to a pressing social need for a more effective way to educate inspection engineers. The presently proposed system addresses these issues by making it possible to effectively learn through simulations of close visual inspection in a virtual space. Since this system can be easily used on a desktop computer, we anticipate its use at inspection workshops, study sessions and other training programs for bridge inspection engineers of highway administrators and local governments throughout Japan.



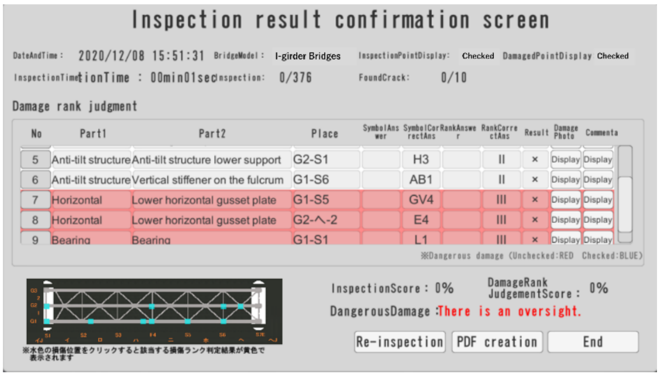
(a) Interior of a virtual bridge



(b) Explanation of the causes of damage



(c) Damage ranking screen



(d) Inspection result confirmation screen

Figure-3 Simulator screen

6. Adoption of the technology

FY 2019 Metropolitan Expressway Company Limited: Interim Review of Inspection Engineer Qualifications (Based on the Inspection Procedure for Structures, December 2019)

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Steel Timbering Erecting Robot

Technology for increasing the safety and productivity of mountain tunneling works

1. Background to and impetus for the development of the technology

Rockfall accidents on tunnel faces are specific to mountain tunnels, and human involvement in these accidents during steel timbering erection works represent the most common case of its consequences. As measures to prevent such accidents, efforts to reduce them have been made by taking measures to control the loosening of ground, predicting rockfalls, and providing protection in a complex manner. However, these measures tend to fall short in comparison to other extreme countermeasures.

Japanese Guidelines require a machinery-based measure be implemented to prevent such accidents, as human involvement in such accidents will not occur if workers do not enter the tunnel face in the first place.

This led to the development of a "Steel Timbering Erecting Robot," which is capable of installing steel timbering for mountain tunnels without requiring a worker to enter the tunnel face.

Photo-1 Steel Timbering Erecting Robot

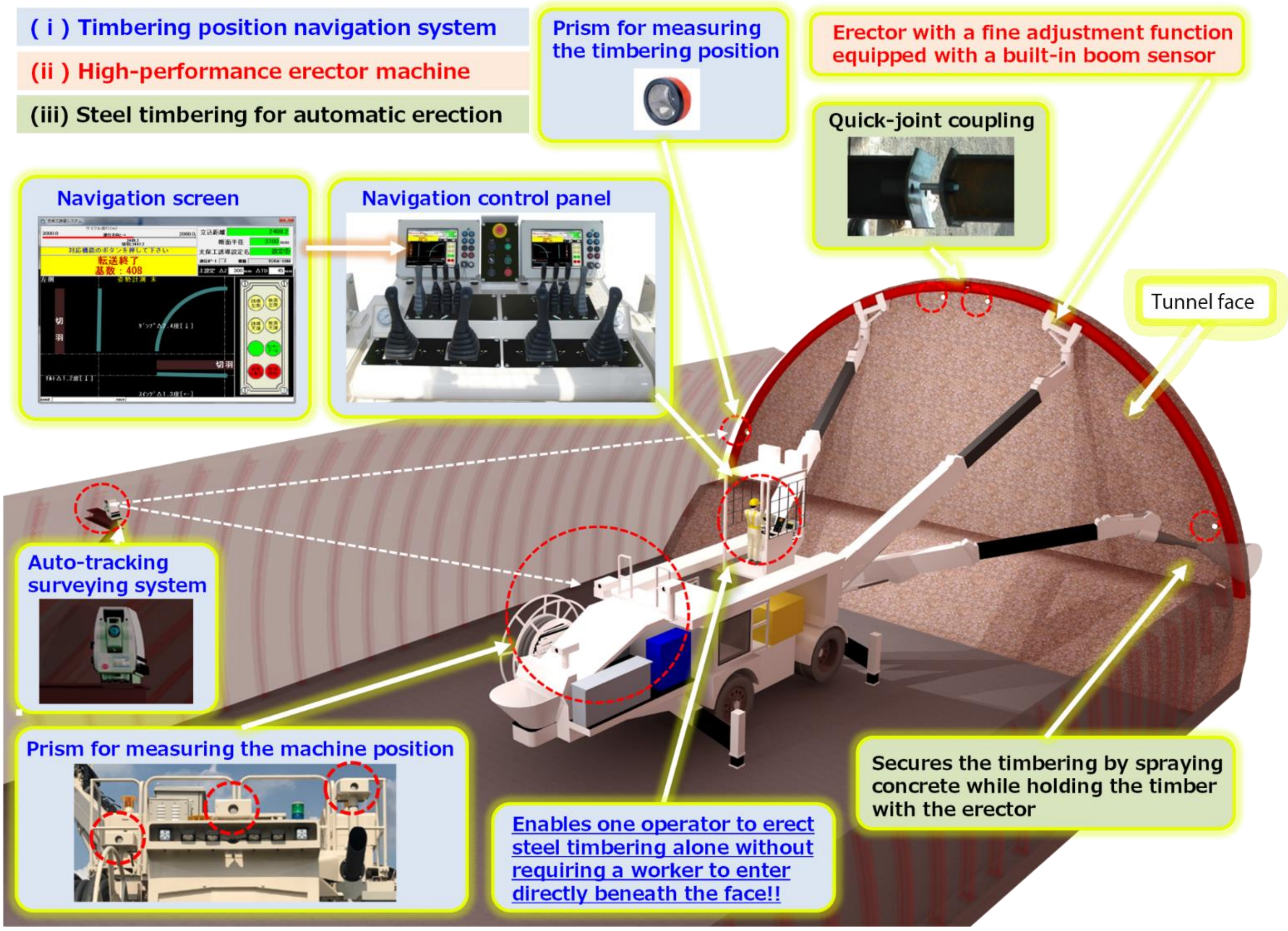

Fig. 1 Schematic drawing of the steel timbering erecting robot's system configuration

2. Content of the technology

This technology is intended to enable the operator to perform steel timbering erection work alone in a mountain tunnel. This high-accuracy timbering erection, solely performed through the operation of the robot from the cab seat, is achieved by combining a “timbering position navigation system,” which consists of devices such as a surveying prism magnetically mounted on steel timbering, a “high-performance erector,” an auto-tracking total station which is capable of holding steel timbering and fine-adjusting the installation position, and a “spraying arm,” capable of spraying concrete while the steel timbering is held. In addition, formerly required man-powered works are eliminated making it unnecessary for workers to enter the tunnel face, through the spraying of concrete and tightening of the crown joint using “steel timbering for automatic erection,” which is equipped with a quick joint, holding the timbering to secure the legs.

Photo-2 Positioning using the navigation system

Photo-3 Crown tightening, and positioning of the steel timbering

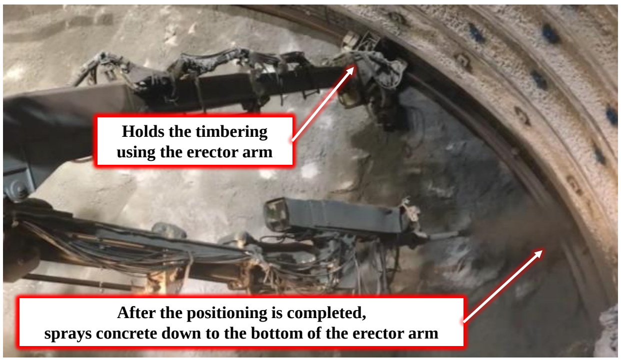

Photo 4: Securing the legs of the steel timbering

3. Scope of application of the technology

Steel timbering erection works in mountain tunneling.

4. Effects of the technology

- Achieving the elimination of works requiring human entry in tunnel faces for steel timbering erection work
- Manpower saving in steel timbering erection work
- Shortened work cycle
- Increased accuracy of steel timbering erection

5. Social significance and potential of the technology

This technology can eliminate all works involving human entry in tunnel faces for steel timbering erection, significantly increasing the safety against rockfall accidents on tunnel faces during erection. In addition, it saves manpower in steel timbering erection work, increasing productivity through the shortening of the work cycle, and achieving high-accuracy erection. This will contribute to the improvement of the safety and productivity techniques, which have long been a social challenge in mountain tunneling. The technology is expected to be adopted not only in construction sites in Japan and abroad, but also in the field of mining.

6.Track record of the adoption of technology

Adopted in Miyazaki No. 218 Hirasoko Tunnel Building Work, March 2018 to March 2019

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About IDI and IDI-quarterly

Infrastructure Development Institute-Japan (IDI) is a general incorporated association operating under the guidance of Ministry of Land, Infrastructure, Transport and Tourism of Japanese Government.
IDI provides consulting services to facilitate international assistance to developing countries, to promote international exchange of information and human resources, and to support globalization of project implementation systems targeting both developed and developing countries in the field of infrastructure.

IDI has been publishing the free quarterly journal called “IDI Quarterly” since 1996 to introduce information regarding public works and construction technologies developed in Japan, to foreign countries. We have distributed the journal to administration officials in more than 90 countries around the world via e-mail.

It will be highly appreciated if you could send us your opinions, impressions, etc. regarding the articles.
We also welcome your specific requests regarding technologies you would like to see on following Quarterly issues.