21st Infrastructure Technology Development Award 2019

Rapid Removal Technology for Replacing Reinforced Concrete Decks of Composite Girder Bridges . 2

Introduction of Fukabari-Method 5
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.

As more incentives should be provided 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).

Seventeen technologies competed for the 21st Infrastructure Technology Development Award. In principle, the applicants’ technologies should have been developed within the past five years and applied to the real sites already.

As a result of examination, institutes and researchers with the following technologies were awarded 21st prizes.

The grand prize is “Practical use of monitoring technology in track maintenance and its application to maintenance management”.

And the two excellence prizes are “The Automatic Placement System of Dam Concrete”, and “Rapid Removal Technology for Replacing Reinforced Concrete Decks of Composite Girder Bridges”.

The one of the two excellence prizes is introduced below.

Any inquiries/ comments please contact to JICE:
Homepage: http://www.jice.or.jp/ (Japanese version only)
E-Mail: webmaster@jice.or.jp
1. Background and reason for development of this technology

Many expressway bridges built during Japan’s period of rapid economic growth are now suffering from remarkable aging and deterioration. Their renewal is one of the country’s key social infrastructure tasks. In the case of the Hanshin Expressway, more than 50 years have passed since it was opened in 1964, and its aging structures are deteriorating. Large-scale renewal and repair project, which began in 2015, covered 62km of the total length of 250.4km. Reducing adverse effects on the traffic by shortening the process has been an important issue in this work, along with reducing costs by utilizing improved construction methods. We have developed a rapid removal technology while focusing on replacing reinforced concrete decks of composite girder bridges.

2. Technical details

Replacing the decks of composite girder bridges includes the problem of dense configuration of studs on the steel girders which makes it difficult to remove joints between steel girders and concrete decks. To deal with this, water jets (WJ) are used to remove concrete from joints. Namely, WJ are used for the bottom side of decks of bridges open for traffic, to chip the joints (Photo-1) and to expose studs for lengths of about 50 mm over the entire length (Photo-2).
reinforcements (Figure-2) and temporary reinforcements made from special mortar are fixed to the exposed studs to maintain the design performance of the composite girder bridge and to ensure the availability of bridge for traffic. With the traffic being regulated, the temporary reinforcements are removed, and the studs are cut (Photo-3), for rapid separation and removal of the concrete decks and steel girders.

3. Scope of use of this technology
The technology is used for the renewal of reinforced concrete decks of composite girder bridges, while reusing steel girders. Currently the studs are limited to headed studs.

4. Effect of technology
- By exposing the studs on steel girders over the entire length, decks can be removed rapidly and simply by cutting the studs after closing the bridge to traffic (Photo-4). The decks can be cut without regard to the location of the steel girders (Photo-5), which means that the number of blocks to be removed can be minimized. In consequence, the period of closing the bridge to traffic during the removal of the decks of composite girder bridges can be reduced to half of the usual time, or even to one-third as far as the process of removing deck blocks is concerned.
- The conventional method requires manual chipping of concrete on the girders, and the estimated period required for deck removal on a bridge with two main girders, one span, and a span length of 20 meters is 18 days; the bridge will be closed for that length of time. The period when the bridge must be closed can be reduced
Table 1  Estimated shortening of the process

<table>
<thead>
<tr>
<th></th>
<th>Type of work</th>
<th>No. of days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work before closing</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Deck cutting</td>
<td>About 6 days</td>
<td></td>
</tr>
<tr>
<td>Removing deck block</td>
<td>About 6 days</td>
<td></td>
</tr>
<tr>
<td>Blasting above the girder</td>
<td>About 4 days</td>
<td></td>
</tr>
<tr>
<td>Stud removal</td>
<td>About 2 days</td>
<td></td>
</tr>
<tr>
<td>Total days closed</td>
<td>18 days</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Type of work</th>
<th>No. of days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipping with WJ, temporary reinforcement</td>
<td>None</td>
<td>About 17 days</td>
</tr>
<tr>
<td>Removal of temporary reinforcement, deck cutting</td>
<td>None</td>
<td>About 6 days</td>
</tr>
<tr>
<td>Deck block removal</td>
<td>None</td>
<td>About 3 days</td>
</tr>
<tr>
<td>Blasting above the girder</td>
<td>Included in previous work</td>
<td></td>
</tr>
<tr>
<td>Stud removal</td>
<td>Included in previous work</td>
<td></td>
</tr>
<tr>
<td>Total days closed</td>
<td>9 days</td>
<td></td>
</tr>
</tbody>
</table>

- Normal reinforced-concrete deck removal process
- Deck removal using preliminary treatment with WJ

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5. Social significance and further development of technology

The period of closing expressway bridges can be shortened, and the social burden reduced. In the future, reviewing the overall process of renewal projects, including deck installation, will enable meeting the need to keep bridges open to traffic during daytime, by closing one lane for traffic regulation, and by partial reconstruction, etc. The Large-scale renewal and repair project we currently are engaged in, is a pioneering challenge for us as well as neighboring countries. The technological achievements and improvements will be propagated to these countries.

6. Applicable record of technology

Study of cutting studs between steel girders and reinforced concrete decks (2) November 2017 to January 2019, 1 other case.

Technology Developer:
Hanshin Expressway Company Limited,
Tobishima Corporation

Joint Developer:
Dai-ichi Cutter Kogyo K.K.

Contact:
Daisuke Hashizume
Hanshin Expressway Company Limited
E-Mail: daisuke-hashizume@hanshin-exp.co.jp
TEL: +81-6-6232-6466
FAX: +81-6-6203-8322

Yasunobu Satake
Tobishima Corporation
E-Mail: yasunobu_satake@tobishima.co.jp
TEL: +81-3-6455-8324
FAX: +81-3-6455-8321
1. Introduction

Japan's social capital stock was intensively developed during the period of high economic growth from the 1950s to the 1970s, and there is serious concern that the number of aging facilities will increase rapidly in the near future, and it is required to strategically maintain, manage, reuse and renew infrastructure. In port berths, in addition to the aging of existing facilities, in recent years they have been required to adapt the increase of the size of ships (especially cruise ships) and to strengthen earthquake resistance in preparation for large-scale earthquakes. As a result, the number of cases where specified performance cannot be satisfied has increased, and reinforcement measures for existing berths have been required. According to a survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism, the ratio of key port berths exceeding 50 years of service will reach 35% in 2024 and reached 60% in 2044. Conventionally, measures such as the addition of piles have been taken in piled pier as a method of reinforcement, but large-scale construction such as the removal of superstructures (Fig. 1) is required. It causes a problem that the construction period of the site becomes long and the use of the pier is restricted. In order to solve these problems, “Fukabari-Method” which is a simple pier reinforcing method was developed. Fukabari-Method is a construction method for installing Fukabari (steel box beams) between existing piles. It is possible to make the maximum use of existing members such as piles and superstructures, and extend the life of the piers while adding functions to cope with the enlargement of ships and to strengthen the earthquake resistance. Furthermore, the construction period can be greatly shortened and the construction can be carried out while the pier is being operated. This paper introduces the outline of Fukabari-Method and its effects.

2. Summary of Fukabari- Method

As shown in Fig. 2, Fukabari-Method has a merit by installing Fukabari in the middle of existing piles. The pier becomes a multi-layer moment frame, which can distribute the bending moment generated in the pile head during the load action to the middle of the pile (Fukabari joint part). Thus, the pier can be reinforced while making maximum use of existing members such as superstructure.
As shown in Fig. 3, Fukabari is consisted of "steel box beam part" and "steel u-shaped connection part". Studs are placed on the inside of the u-shaped connection part and on the existing piles. Fukabari is installed in line with the existing piles, and a grout material is placed as a filler after closing the connection part.

3. Construction flow of Fukabari-Method

The construction flow of Fukabari-Method is shown in Fig. 4. In order to remove marine organisms adhered to existing piles, surface treatment is carried out. Then studs are placed in the sea (Flow ①). Rebar is wound around the stud (flow ②). By using a crane, Fukabari is immersed in the sea from the superstructure (flow ③). The diver places Fukabari at a predetermined position in the sea (flow ④). In order to integrate the existing pile and Fukabari, a grout is casted in the gap between Fukabari u-shaped connection part and the pile (flow ⑤), and the installation is completed (flow ⑥). In order to simplify the installation of Fukabari, the center part is made of a box beam, so that it is possible to transporte to a predetermined position as a floating body, and to sink in the sea by pouring the water into the box beam. In addition, since the U-shaped connection part is attached to both ends of the box beam via the opening/closing rotary hinges, it is easy to cover the piles with the connection part structure, and to integrate with the pile.

4. Effect of using Fukabari

Fig. 5 compares Fukabari-Method with the conventional additional piles method. Fukabari-Method can shorten the site
construction period by 60% and the shutdown period by 90%, and reduce the construction cost by 20%, compared to the additional piles method. In addition, a spillover effects, such as the reduction of economic loss by shortening the period of service shutdown and the reduction of environmental impact since a large heavy machinery is not required, can be expected.

<table>
<thead>
<tr>
<th>Conventional method</th>
<th>Fukabari-Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Superstructure Replacements</td>
<td></td>
</tr>
<tr>
<td>Additional piles</td>
<td>Fukabari Beam: 35</td>
</tr>
<tr>
<td>Pier length: L=350m</td>
<td>Pier length: L=350m</td>
</tr>
<tr>
<td>Construction time</td>
<td>Construction time</td>
</tr>
<tr>
<td>10 months</td>
<td>4 months ▲60%</td>
</tr>
<tr>
<td>Shutdown time</td>
<td>Shutdown time</td>
</tr>
<tr>
<td>9 months</td>
<td>1 month ▲90%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>Total Cost</td>
</tr>
<tr>
<td>1</td>
<td>0.8 ▲20%</td>
</tr>
<tr>
<td></td>
<td>Total cost: Cut 20%</td>
</tr>
</tbody>
</table>

**Figure 5 Comparison of methods**

### 5. Construction results

Records and photographs of Fukabari are shown below.

1. **Aomori Port Honkou Area Berth**
   - Number: 35 blocks

2. **Osaka Nanko Ferry Terminal**
   - (No.1 Pier, No.2 Pier)
   - Number: (No.1 Pier) 64 blocks (No.2 Pier) 52 blocks
   - Construction Period:
     - (No.1 Pier) May 2015 – Aug. 2015
     - (No.2 Pier) May 2017 – Jul. 2017

3. **Fukushima Matsukawaura Fishery Port**
   - Number: 5 blocks
   - Construction Period: Sep. 2019

**Pic. 1 Aomori Port**

**Pic. 2 Osaka Nanko Ferry Terminal**
6. In return

In this paper, Fukabari Method is introduced as an effective method to solve the various problems regarding the reinforcement of existing pier. The method realizes the reinforcement while making the maximum use of the existing members and short service down time. As aging infrastructures are rapidly increasing, it is expected that the strategic maintenance, reuse and renewal of the infrastructures by using Fukabari Method will contribute to the reduction of maintenance and management costs in social capital stocks.

Technology Developer:
JFE Engineering Corporation
Infrastructure Engineering Sector
Contact:
JFE Engineering Corporation
http://www.jfe-eng.co.jp
TEL: +81-3-6212-0841
FAX: +81-3-6212-0067
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