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An Experimental Study on Lifting of Bridge Deck without Core Drill

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Abstract

This paper aimed to resolve the problems of requiring numerous core drillings for the conventional demolition process of bridge decks that uses a crane and wire ropes. Consequently, a lifting technique with a crab-type equipment that works for both cranes and excavators was developed for cut bridge deck members. The development process for this lifting technique was introduced and verification tests for this technique were conducted by manufacturing an actual bridge deck. As a result, lifting test using a crane showed an unstable operation with one side tilting, whereas lifting test using a 10W excavator showed a stable operation. Therefore, it was determined that this technique could be applied to the demolition process of bridge decks in the future. Furthermore, construction periods were analyzed when the developed technique was applied to an actual demolition of a bridge deck. The analysis results showed that the new technique reduced the construction period by 30% since no core drilling was required and consequently, reduced construction cost. In addition, with a reduced construction period, blocking of traffic was also minimized, which minimized traffic congestion. This was expected to reduce indirect social costs that rise from construction and road blockage.

Keywords : bridge deck demolition, deck lifting, No core hole, crab type of lifting equipment, construction period

INTRODUCTION

Around the world, the aging of existing bridges built in the 60s and 70s is becoming an issue, and the entire replacement of such old bridges is virtually impossible due to budgetary problems. Therefore, there is a demand to prepare measures for local replacements of old and damaged bridges, and the deterioration of these bridges tends to be concentrated on bridge decks that are in direct contact with the vehicles.

The most important element in the local replacement work of such old bridge decks is to remove the existing bridge deck as quickly and safely as possible, and to replace it with a new bridge deck so the original functions are restored. Therefore, to prevent an increase in the indirect social costs resulting from traffic congestion due to local replacement works of bridge decks, there is a high demand for a bridge-deck replacement technique that minimizes traffic interruption. For a quick replacement of existing bridge decks, the demolition process of existing bridge decks must be carried out quickly and safely before the replacement process can begin. The demolition process of bridge decks is usually carried out in the order of core drilling → cutting → lifting. However, there are major problems for the conventional demolition process of bridge decks, as shown in Fig. 1.Bridge deck segments cut using a wheel saw or a diamond wire saw are lifted using a crane, and transported to a crushing site to be processed as waste after loading it on a trailer. When lifting with a crane using conventional wire ropes, it can be dangerous since the cut concrete structure has heavy weight. Four core drillings per segment are required when using wire ropes to lift to install the wire rope, and causes delay in construction and an increase in construction costs.

In particular, placing wire ropes in the cut segments for structures like bridges located over rivers and streams require aerial work platforms, which is time consuming. In addition, the workers have to install the wire ropes directly from the aerial work platform, which has been causing many safety issues. The core drilling process delays the construction period due to the difficulties in drilling numerous holes so demolished structural members that have been cut can be lifted. Therefore, a technique that minimizes drilling is required to solve this particular problem. In the process of lifting, most of current crane lifting methods have problems of delaying work due to the installation of wire ropes required for lifting.

Furthermore, safety problems such as falling accidents are always a possibility since the wire rope installation requires workers to perform the duties on aerial work platforms. In addition, since bridge decks targeted for demolition is always an aged structure, safety problems such as breakage of lifting holes and bending failures are always a problem. Thus, developing a technique that addresses these issues is required. Particularly, conventional methods for managing bridge deck members that were cut mainly use the crane lifting method. However, most decks targeted for demolition are aged 30 years, 40 years or more, and there have been cases of serious safety accidents from bending failures or breakage of lifting holes due to decreased concrete strength, corrosion of steel, missing rebar, etc. Therefore, a new technique for lifting demolished and cut bridge deck members is required to resolve the aforementioned problems. This paper aimed to introduce the development process of a new concrete lifting technique, which lifts cut bridge decks without core drilling. It also performed verification experiments, and compared and analyzed the conventional method with the developed technique in terms of reducing the construction period.

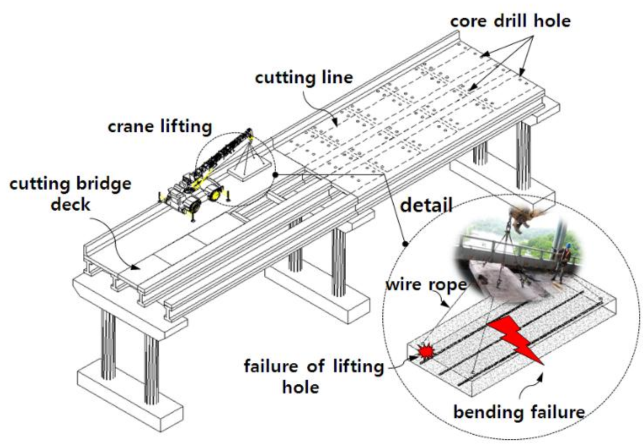

Figure 1. Problem of the conventional method

TECHNOLOGY DEVELOPMENT PROCESS

Alternatives Suggestion

To solve the problems of the conventional method, as shown in Figure 2, a technique for lifting bridge decks that uses a crab-type lifting equipment, which works for both cranes and excavators, and does not require core drilling was developed. The aforementioned conventional method that deals with demolished bridge members needs multiple core drillings to demolish bridge decks, resulting in issues such as delayed construction periods, breakage of lifting holes, and bending failures. For this reason, crab-type equipment was developed exclusively for demolishing bridge decks. The developed equipment is shaped like a crab and can operate like an excavator, so core drilling is not needed. Furthermore, the bottom-supporting frame of the crab-type equipment is inserted beneath the cut concrete bridge deck, providing support.

Thus, it can solve the bending failure problem of the conventional lifting method that uses a crane and wire ropes, and it can prevent the core drilling holes from breaking. Moreover, the construction period can be reduced significantly since core drilling and wire rope installation are not necessary. This provides a demolishing technique for bridge decks that can minimize high indirect social costs resulting from traffic interruption. Meanwhile, the developed technique was designed so it can work either with a crane or an excavator. It was designed so cut bridge deck segments of 5m or less can be lifted with a 10W excavator. For cut bridge decks that are 5 m in length or longer, the new technique allows easy attachment to a crane. When cut structural members are moved to load them on to a trailer by using a crane, they must be rotated. During this rotating process, the center of the lifting location on the heavy member and force of inertia can cause a twisting problem. In order to solve this problem, a bridge deck fixing equipment was installed on the crab-type equipment.

Detailed Description of the Developed Technique

The developed technique for treating demolished cut bridge deck members that do not have core drilling can be used for either an excavator or a crane, and has a crab shape as shown in Figure 2. The crab-type frame consists of an upper cover frame and a lower support frame. The bottom of the bridge deck is placed on the crab- type frame. As mentioned above, in the conventional lifting process using wire ropes, failures occur from bending, but the lower supporting frame of the crab-type frame prevents such bending failures. For bridge deck demolition, using an excavator is significantly more economical than using an expensive crane.

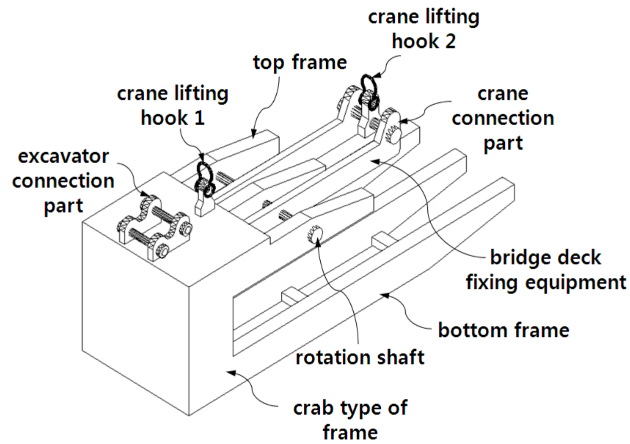

Figure 2. Development of new lifting technique for concrete bridge decks

Considering the economical aspect, a connecting part for excavators was installed in the crab-type frame so bridge decks could be lifted using an excavator. In most demolition processes for bridge decks, the cutting length for bridge decks is usually 5m or less, but in some cases, lengths of 8 m or more must be lifted. Consequently, a crane attachment was developed for the latter case. This crane connection attachment consists of attachments that can be attached and detached at the rotation axis of the shaft. The crane connection attachment consists of crane lifting hooks 1 and 2, a rotation axis of the shaft, and an equipment that presses on the deck member to hold it in place. The crane lifting hooks 1 and 2 hold the center of gravity of the bridge deck during the lifting process to prevent overturning. In order to lift the cut bridge deck and load it on a transportation system such as a trailer, the lifting equipment must swing. During this swinging process, twisting can occur and the cut bride deck can fall. The equipment that holds the cut bridge deck in place prevents such accident. When bridge decks are lifted, the rotation axis of the shaft in the crane connection part moves and automatically presses the bridge deck placed in the crab-type frame. This provides stability during the rotation process by preventing movement. The problem with the conventional method is that wire ropes are used to lift with a crane and manage the cut bridge decks, which requires 4 core drillings for each cut segment. When considering the entire bridge, the required number of core drillings is astronomical. In addition, bending failures occur since bridge decks are lifted by hooking them on at four locations, which causes the member to bend from its heavy weight. This study aimed to resolve such problems by developing a crab-type equipment for managing cut bridge deck members during demolition. Figure 3 shows an example of applying the developed technique to a bridge deck. This technique does not require core drilling because the crab- type frame is attached to a crane or an excavator and the cut bridge deck is lifted by inserting the bridge deck into a groove that is shaped like a crab. In addition, as the crab-type frame supports the bottom of a bridge deck, the bending failure can be prevented. For actual bridge deck demolition processes, most structures are 40 years old or older, which entails decreased concrete strength. Furthermore, construction in the 70s and 80s, had cases of neglecting rebar placements intentionally which means there are possibilities of bending failures when using the conventional method. However, the designed technique can prevent such bending failures. As described above, although most bridge deck demolition processes have cut bridge decks of 5m or smaller in length, some cases require lifting members with lengths of up to 8 m. For this particular case, a crane connection attachment was developed, which are attachable and detachable at the rotation axis of the shaft.

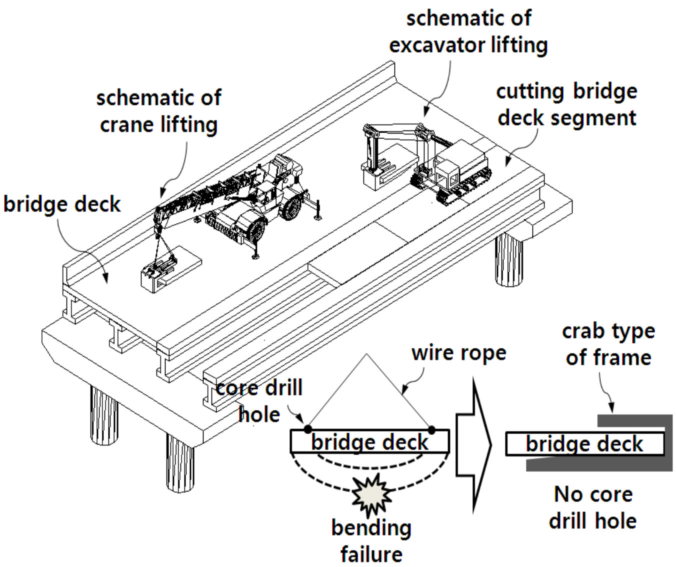

Figure 3 Development of new lifting technology for concrete bridge deck

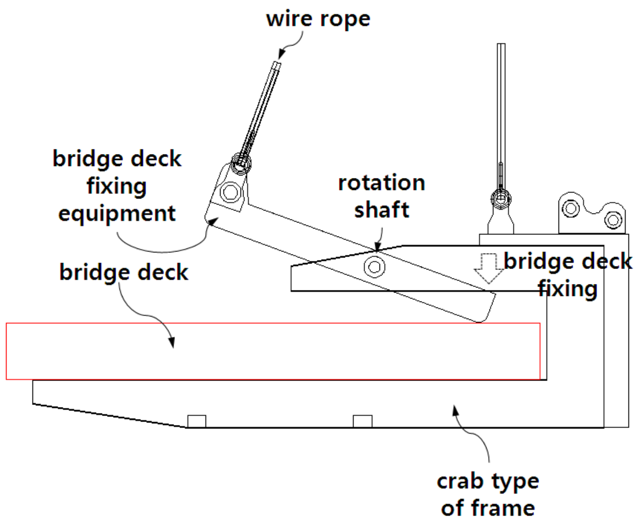

Figure 4. Development of new lifting technique for concrete bridge decks

The reason for specifying the working limit to 5 m for excavators is because an excavator with the largest capacity is 10W, and lifting bridge decks longer than 5 m causes concern of overturning due to the heavy weight. Consequently, equipment that can be used on a crane for cases of lifting structural members that are longer than 5 m in length was designed. There are two problems of using a crane for lifting. The first is keeping the heavy member balanced by holding the center to prevent overturning. The second is slipping of bridge decks during rotation; rotation is required to load the decks onto a transportation system like a trailer. To address the issue of holding the center of such heavy objects, lifting hooks 1 and 2 in Fig 2. were placed. To prevent bridge decks placed on the crab-type frame from slipping and falling during the rotation process, a fixing equipment that presses the bridge deck was designed as shown in Fig. 4. Using hook 2 to lift with a crane hook causes the crane connection attachment to rotate up-and-down with respect to the rotation axis of the shaft. This movement presses down and fixes the cut bridge deck that is inserted in a crab-shaped groove. This prevents the bridge deck from falling during the rotation process.

VERIFICATION TESTS FOR THE DEVELOPED TECHNIQUE

Manufacturing the Test Specimen

For realistic verification tests for the developed technique, the bridge deck specimen was manufactured with length of 5 m, width of 2 m, and thickness of 0.23 m, considering that bridge decks are typically divided into 5 m segments. The concrete strength used for the test was 24 MPa and the physical properties of the specimens are shown in Table 1.

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Table 1. Mock up specimen properties

Gmax (mm)	slump (mm)	W/B (%)	S/a (%)	Unit quantity (kg/m^3)						
				W	C	BS slag	Fly ash	Fine agg.	Coarse agg.	Admixture
25	120	47.2	46.6	122	238	63	70	414	954	2.6

Figure 5 shows the manufacturing process. Curing of 28 days was conducted. An excavator with a 10W equipment and a 50 ton crane were used in the verification tests.

Figure 5. Test scene of concrete pier specimen

Discussion of Verification Tests

To verify the developed technique, tests using a 10W excavator and a crane were performed. Lifting tests for the manufactured specimen were done by connecting the crab-type lifting equipment for bridge decks to a 10W excavator. The weight of the specimen was approximately 6 tons. For actual demolition processes, swinging of lifted cut segments is required to load them on to a truck. As shown in the picture of the verification tests, real-life demolition conditions were considered. The developed equipment was attached to an excavator equipment and the test specimen was lifted to 5 m. A swinging test was done by swinging to the sides while holding it at the height of 5m. The swing test was repeated approximately 5 times, and confirmed stability during operation. (Figure 6)

Figure 6. Test scene of concrete lifting using a 10W excavator

The lifting test using a 50 ton crane was similar to the excavator test. The specimen was lifted approximately to 5m. As shown in Figure 7, it showed tilting to one side and thus, the operation was unstable. It was determined that the equipment that is supposed to hold and fix the bridge deck in the developed equipment did not press down on the specimen well enough, and required further improvement in future research.

Figure 7. Test scene of concrete lifting using a crane

As shown in Figure 8, in order to solve this problem, one side of the bridge deck was lifted by connecting the developed equipment to a crane, and on the other side, two core drills were made on the upper side of the bridge deck to prevent tilting. This bridge deck was lifted using wire ropes As a result, it had a stable operation. However, although this method requires less number of core drillings than the conventional method with four core drillings per segment for lifting with a crane, it still has a problem of requiring two core drillings. Therefore, it is necessary to improve on the issue.

Figure 8. Test scene of bridge deck lifting using wire rope on the opposite side

Construction Period Analysis

The construction periods for demolishing the upper structure of a 4-span bridge with bridge dimensions of L=125 m, B=25 m were analyzed using the conventional demolition method and the developed technique. Table 2 shows the analyzed results; the construction periods were analyzed for the conventional demolition method and the developed technique for demolishing bridge decks in the upper structure of a bridge. The process for using the conventional demolition method was as follows. First, scaffoldings were installed; second, the asphalt pavement was removed; third, a protection fence was demolished; fourth, cutting lines were marked on the bridge decks targeted for cutting; fifth, core drilling was done so the concrete bridge decks that were cut could be lifted; sixth, lifting process for the cut bridge decks was performed using a crane. As shown in Table 2, procedures up to step 3 were the same but procedures from step 4 to step 6 were different. In step 4, the conventional method required marking the cutting lines and the places for core drilling, whereas the developed technique reduced the construction period by a day since the core drilling process was not required.

Table 2. construction period analysis

Conventional demolition method of bridge decks	New demolition method of bridge decks
1 step: scaffold installation (7 day)	***1 step:*** scaffold installation (7 day)
2 step: asphalt pavement demolition (2 day)	***2 step:*** asphalt pavement demolition (2 day)
3 step: protection fence demolition (2 day)	***3 step:*** protection fence demolition (2 day)
4 step: cutting line and core hole marking (2 day)	***4 step:*** cutting line marking (1 day)
5 step: core drill hole (3 day)	***5 step:*** No core drill hole (0 day)
6 step: bridge deck cutting and lifting (7 day)	***6 step:*** bridge deck cutting and lifting (4 day)
Total : 23 day	**Total : 16 day**

For step 5, the conventional method required core drilling, but the developed technique shortened the construction period by 3 days since core drilling was not necessary. For step 6, it was very time consuming for the conventional method to secure the wire rope to the cut segments for bridges that are located over rivers and streams since aerial work platforms were required to complete the task. However, the developed technique did not require wire rope installation, which shortened the construction period by 3 days. The cutting time in step 6 was 4 days for both methods.

CONCLUSION

For the conventional bridge deck demolition method, drilling multiple holes to lift the demolished and cut members using a crane causes delay in construction periods. As a result, there is a need to develop a technique that can minimize core drilling. In this study, a lifting technique using a crab-type equipment

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for demolished bridge decks was developed that can be used for both cranes and excavators. The verification tests and the construction-period analysis results for the new technique concerning actual bridge decks are as follows.

1) Verification tests for lifting cut members of demolished bridge decks were done using a crab-type crane and an excavator. The 10W-excavator showed stable operation during the lifting of bridge decks and was stable during the lifting and swinging tests that were repeated 5 times.

2) The conventional method and the developed technique were applied to an actual demolition process for the upper structure of a four-span bridge. The bridge had dimensions of L=125 m and B=25 m. Construction periods were analyzed for the conventional method and the new technique. As shown in the figure below, the new method shortened the construction period by approximately 30 %, with the conventional method taking 23 days and the new method taking 16 days. (Figure 9)

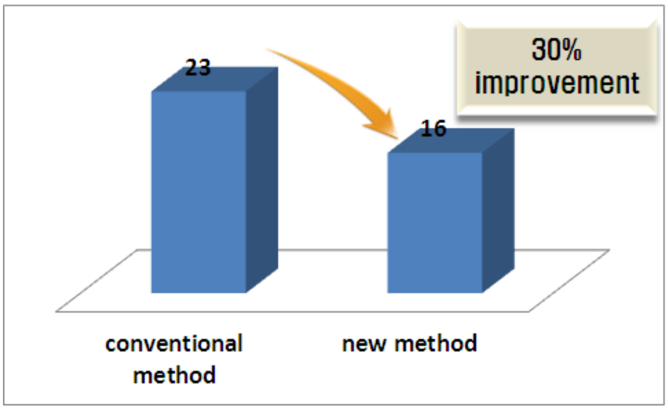

Figure 9 pneumatic analysis result

3) The lifting test with a crane of 50 tons lifted to about 5 m from the ground, as it was done for the lifting test with an excavator. However, one side tilted and showed an unstable operation. It was determined that the equipment that was supposed to hold and fix the bridge deck of the developed equipment failed to press down hard enough on the test specimen, and required further investigation regarding this problem.

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REFERENCES

[1] Ministry of Land, Infrastructure, and Transport (2012). Intelligent Eco-friendly Bridge Technology Development Planning Report

[2] Jungsoo Han (2006). A Case Study on the Demolition of Structures Directly Experienced at the Cheonggyecheon Site, Seoul Cheonggyecheon Restoration Promotion Headquarters

[3] Ki-Yeon Kun (1988). (1988).A Comparative Study on Dismantling Methods of Buildings, Korea Agency for Infrastructure Technology Advancement 88-AD-2

[4] Ministry of Land, Infrastructure, and Transport (2012). Guidance on the Safety Management of Demolition Construction

[5] Byung Uk Yoo (1980). Dismantling Techniques and Accumulation, Gimundang

[6] Korea Agency for Infrastructure Technology Advancement (2005). Advanced Demolition Technologies for Eco-friendly City Regeneration, The Report on the Korea Housing Corporation Research

[7] Bai, Y., and W. Burkett., "Rapid Bridge Replacement: Processes, Techniques, and Needs for Improvements,"ASCE Journal of Construction Engineering and Management, Vol. 132, No. 11, pp. 1139-1147, 2006.