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A Case Study on the Assessment of Damaged Cause for the Damaged Reinforced Concrete Pier

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Abstract : In this thesis, appearance inspection, compressive strength of concrete test, arrangement of bar inspection, survey, and bearing stress analysis were performed on a damaged coping of reinforced concrete pier to investigate the damage cause. According to the performed a series of inspections, it was found that the coping of pier was damaged during PSC (Pre-stressed Concrete) beam construction. In this thesis, the repair method for damaged pier was studied. The repair procedure used in this thesis was follows : chipping for damaged part, clean by high-pressure, installation of wire mesh, coating of surface hardening, construction of section restoration material, copula grinding, and prevent coating for far-infrared radiation.

Key words : damaged coping, compressive strength test, arrangement of bar inspection, survey, bearing stress analysis, assessment damage cause, PSC beam construction, repair procedure

1. Introduction

The purpose of the work reported in this study was to assess of damaged cause for damaged concrete pier and to suggest rehabilitation method. Therefore, appearance inspection, compressive strength test, arrangement of bar inspection, survey, and bearing stress analysis were performed on a damaged coping of reinforced concrete.

In this study, a PSC beam bridge with span 3@25 m, width of 20.9 m, and inverse T-type abutment and Π-type concrete pier is selected to estimate the damaged reinforced concrete pier structure .

2. Inspection of Damaged Concrete Pier

As damage investigation results, local damage with width of 2.0 m, height of 1.5 m, and thickness of 10 cm was observed on the upper face of coping of pier P1. The local damage was extended to support concrete of shoe.

It was observed that the depth of damage was similar with covering depth and the corrosion of reinforcing bar did not happen. The whole views of damaged pier P1 was shown in Fig. 1 ~ Fig. 2 and the details picture of cutting section for damage part was shown in Fig. 3.

3. Analysis of Damaged Cause

To analyze damage cause of damaged coping, edge distance, compressive strength, arrangement of reinforced bar, and bearing stress were investigated.

3.1 Shoe support

The investigated concrete pier in this study have four

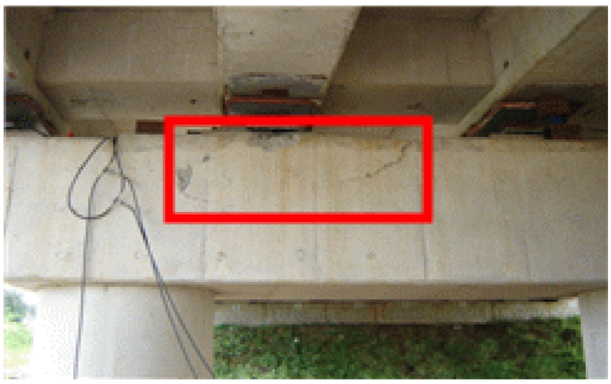

Fig. 1. Front view of damaged concrete pier.

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Fig. 2. Detail panorama of damaged concrete pier.

Fig. 3. Detail view of damaged concrete pier after cutting.

elastomeric bearings. As the inspection result for upper part of pier P1, it was observed that support concrete of shoe was exfoliated from upper part of coping. The damage of elastomeric bearings and sole plates did not observe. The whole views of damaged concrete of shoe in pier P1 was shown in Fig. 4.

To analyze whether edge distance is damage cause, the edge distance of four shoe on the pier P1 was measured and then it was compared with design criteria for bearing support. The surveying results of edge distance was presented in Table 1.

According to the specification, edge distance between edge of shoe and center of pier must be more than calculated length by equation (1) and equation (2) [1].

Fig. 4. Damaged concrete of shoe support.

Table 1. Results of edge distance

Measurement location	Shoe 1 (cm)	Shoe 2 (cm)	Shoe 3 (cm)	Shoe 4 (cm)
Direction to abut. 1	44	44.5	42	42
Direction to pier 2	43	42.5	44	44.5
Designed edge distance	20 + 0.5 L = 20 + 0.5 × 25 = 32.5(cm)			

1) In case that the span length of beam does not exceed 100 m

$$S = 20 + 0.5\,L \tag{1}$$

2) In case that the span length of beam does exceed 100 m

$$S = 30 + 0.4\,L \tag{2}$$

where, L : Span length (m)
S : Edge distance

As shown in Table 1, The edge distances of all shoes well met design criteria according to edge distance inspection results. Hence, it was concluded that a lack of edge distance did not cause the damage of coping.

3.2 Concrete compressive strength

To analyze damaged cause of damaged coping of concrete pier, NDT (Non-destructive Test) method for the evaluation of concrete compressive strength was schmidt rebound hammer testing. Location of NDT was shown in Fig. 5 ~ Fig. 6.

The calculation of compressive strength by schmidt rebound hammer testing was used equation (3) [2]. The

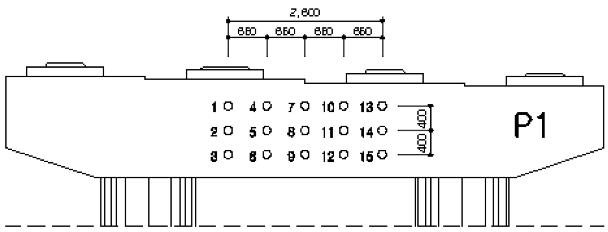

Fig. 5. Measurement location of NDT at direction to abutment 1.

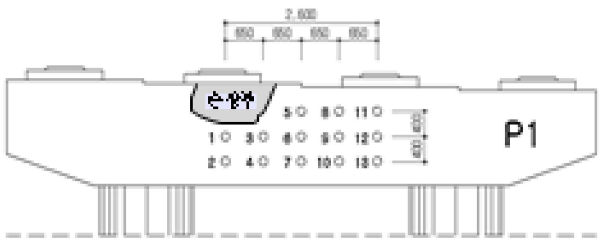

Fig. 6. Measurement location of NDT at direction to pier 2.

Table 2. Results of NDT

Measurement locaton		Number of measurement point	Strength (MPa)		Safety ratio(%)
Lane	Direction		Estimated strength	Specified strength	
Northbound lane	Abut. 1	15	27.2	24.0	113
	Pier 2	13	26.7	24.0	111
Southbound lane	Abut. 1	9	29.1	24.0	121
	Pier 2	9	27.0	24.0	112

estimated compressive strengths by the data of schmidt rebound hammer testing presented in Table 2.

$$F(MPa) = -18.0 + 1.27R_0 \tag{3}$$

As testing result, the compressive strength of pier P1 was about 11~21% higher than specified strength of concrete of 24 MPa. Therefore, lack of the compressive strength was not mainly cause for damage at coping of concrete pier.

3.3 Arrangement inspection of bar

A arrangement spacing of bar and thickness of concrete cover was measured to investigate the state of arrangement of bar.

Inspection results for arrangement of bar was shown in Fig. 7 ~ Fig. 10 and Table 3 shows the inspection results for arrangement spacing of bar and thickness of concrete cover.

Table 3 Results of the bar arrangement inspection, bar spacing and thickness of concrete cover was measured to be constructed to meet design standards [3,4].

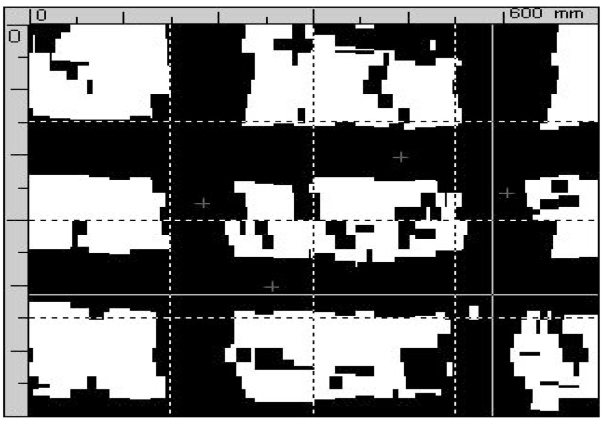

Fig. 7. Results of bar arrangement inspection at direction to abutment 1 in the northbound lane.

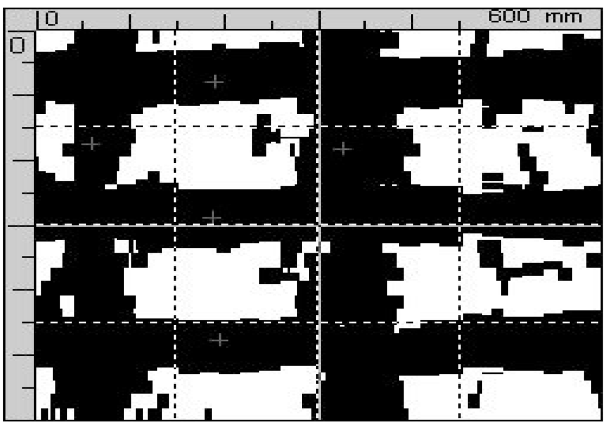

Fig. 8. Results of bar arrangement inspection at direction to pier 2 in the northbound lane.

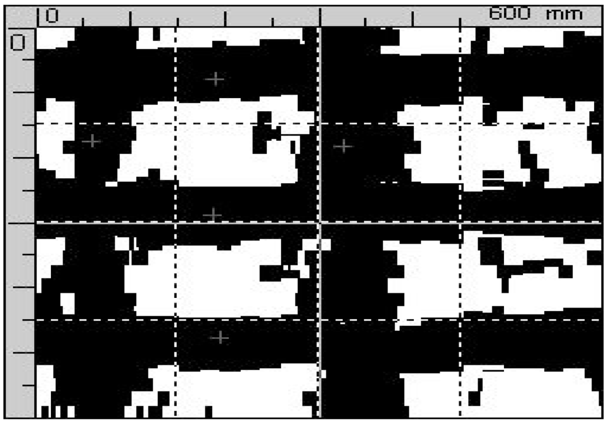

Fig. 9. Results of bar arrangement inspection at direction to abutment 1 in the southbound lane.

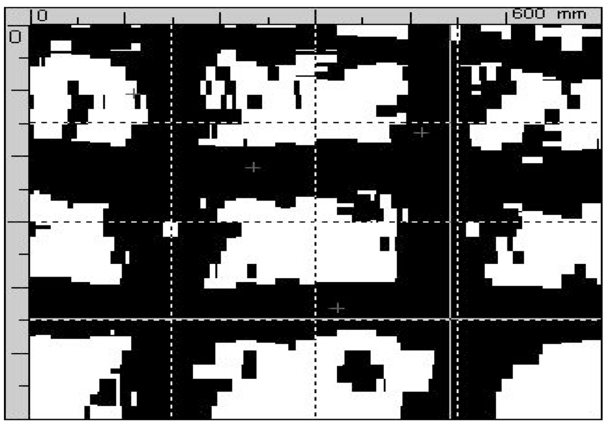

Fig. 10. Results of bar arrangement inspection at direction to pier 2 in the southbound lane.

Table 3. Results of bar arrangement inspection

Measurement locaton		Arrangement spacing of bar (mm)		Thickness of cover (mm)	
Lane	Direction	Measurement value	Design value	Measurement value	Design value
Northbound lane	Abut. 1	215	200	101	40
	Pier 2	213	200	108	40
Southbound lane	Abut. 1	187	200	98	40
	Pier 2	197	200	98	40

Therefore, arrangement of reinforced bar is not affected damage to the coping

3.4 Bearing stress during construction

Target structures of the present study during the construction of PSC beam rise after using hydraulic jacks hydraulic control contiguous to the beam and lowered the base unit mounted in a special way by the bridge construction is done upper side construction.

In this study, the study of minor damage to the bridge to investigate the cause of the injury type and injury size and investigation of construction method PSC Beam, After you have lowered through continuous mold in the process of oil jack Skillful characteristic of failure or lack of workers due to local load concentration was presented as one of the factors.

Upper side construction of this bridge to the hypothesis, add foot concrete platform and come in contact at the corner of coping $W \fallingdotseq 220$ mm, $L \fallingdotseq 300$ mm capacity of jacks 150 tonf were mounted on the base plate. And removed the superstructure iron plate sequentially and fell the girder.

This is also a small construction errors (Hydraulic control, and communication between the worker and the worker Skillful characteristic, etc.) by the applied stress and hence a very high bearing is likely to cause local damage is expected. Fig. 11 shows the construction of the bridge superstructure of this study is the device configuration.

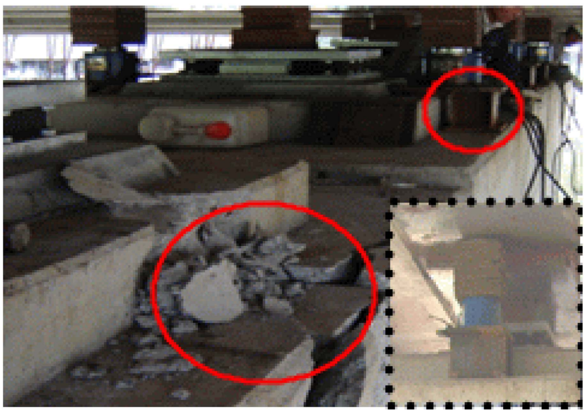

Fig. 11. Panorama of PSC girder installation method.

In this study, related to defects and damage caused to the bearing stress was investigated. Coping with a damaged bridge bearing stress and the potential to allow the bearing stress were compared.

Allowable bearing stress of concrete f_{ba}, according to the bridge design code is the following equation (4) [5].

$$f_{ba} = 0.25\sqrt{\frac{A_c}{A_b}}f_{ck} \le 0.5 f_{ck} \tag{4}$$

Where, A_c : The concrete whole surface which Supports
A_b : Bearing area under bearing load
f_{ck} : Specified strength of concrete

Thus, mounted in the construction process by considering the hydraulic jack and the base plate allowable bearing stress f_{ba} are calculated as follows:

$$A_c = 300 \times 200 = 66{,}000(\mathrm{mm}^2) \tag{5}$$

$$A_b = \pi \times 220^2/4 = 38{,}013(\mathrm{mm}^2) \tag{6}$$

$$f_{ba} = 0.25\sqrt{\frac{A_c}{A_b}}f_{ck} \le 0.5 f_{ck} = 0.25\sqrt{\frac{66,000}{38,013}} \times 24$$

$$= 7.91\,\mathrm{MPa} \le 0.5 \times 24 = 12(\mathrm{MPa}) \tag{7}$$

Allowable bearing stress f_{ba} is 7.91 MPa.

Descending process of the bridge girders in the superstructure as a fixed load considering the empty weight. Reaction to occur at intermediate support points inside each of which is shown in Table 4.

In this case the damage occurred inside the main girder bottom bearing stress can occur as follows.

Table 4. Support reaction

Location	Shoe 1 (tonf)	Shoe 2 (tonf)	Shoe 3 (tonf)	Shoe 4 (tonf)
In the northbound lane	98.26	104.69		90.93
In the southbound lane	101.08			98.62

$$P = 104.69 \times 1000/2.5 = 41{,}876(\text{kgf}) \tag{8}$$

$$A = 300 \times 220 = 66{,}000(\text{mm}^2) \tag{9}$$

$$f_b = \frac{41{,}876 \times 10}{66{,}000} = 6.35(\text{MPa}) \tag{10}$$

Where, P : Working load
A : Jack bearing Installation area on the lower beam
f_b : Jack bearing Installation bearing stress on the lower beam

In the above results on the lower beam of 300 × 220 mm bearing mount jack and made a normal descent process is a safety factor of about 1.25 appears to be secure.

However, the bridge design standards due to the deflection and eccentric load to bearing greater stress on the receiving end if allow bearing stress equation (4) to take the value is multiplied by 0.75.

Thus, allowable bearing stress f_{ba} and safety factor SF are as follows.

$$f_{ba} = 0.75 \times 7.91 = 5.93(\text{MPa}) \tag{11}$$

$$SF = 5.93/6.35 = 0.93 < 1.0 \tag{12}$$

So, Safety factor is below 1.0 and cause of damage or defect is likely to be offered. Descending process of the current damage of the PSC beam is a large stress is generated locally. This exceeds the allowable bearing stress was believed to be due to the bearing stress.

4. Analysis of The Effects of structure Safety

4.1 Appearance inspection

As a function of local bearing stress caused damage to concrete piers in the top of coping. Absence of additional structural damage as the cause of the collapse have a big impact on the stability of the whole can.

In this regard, results of visual inspection was performed, Part of the concrete piers (P1) on the separation and exfoliation, except for minor structural cracks or base unit of the shoe, sole plate and dislocation were not observed.

4.2 Survey

In this study, damage to piers to evaluate the structural stability of infrastructure, displacement was examined. To investigate the displacement of the damaged bridge reflectorless optical detector (SOKKIA, SET-3B) was used. Coping at the top end of the pier by examining the slope of the edge of each pier displacements were damaged. Measurements of Survey points are Fig. 12.

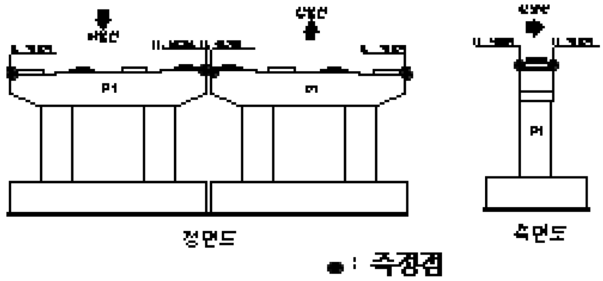

Fig. 12. Survey inspection points.

As a result of measurement investigation, Phase difference between vertical and horizontal level of damage to bridges was about 2 mm. Given the measurement error or construction error can be evaluated with very small level.

In addition, Considering the vertical gradient on the bridge design drawings bearing the device level, respectively, when compared with the design value 0.162 m, 0.165 m, as the measure appeared to have about a 3 mm difference.

Damaged bridge piers based on damage assessment of the displacement is negligible.

4.3 Comparison of nondestructive response for the damaged coping

In this study it were evaluated the range influence of local bearing load or impact load. For the damaged coping and sound coping was evaluated the difference of concrete quality variation. Hereunder the ultrasonic pulse velocity tests were measured, and the location is illustrated in Fig. 5 and Fig. 6 for the northbound lane, in Fig. 13 for the southbound lane.

Descending process of the current damage of the PSC beam is a large stress is generated locally. This exceeds the allowable bearing stress was believed to be due to the bearing stress. It is estimated the main damage cause when deflection or eccentric load act the edge of bearing concrete. The damaged concrete is restrict to concrete exfoliation.

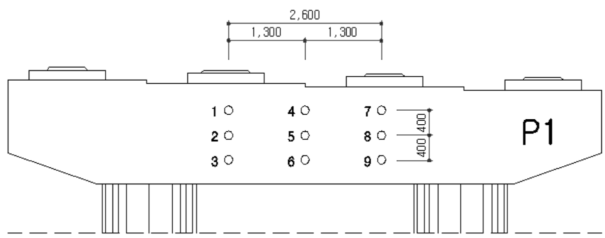

Fig. 13. Measurement location of NDT at direction to abutment 1 and pier 2.

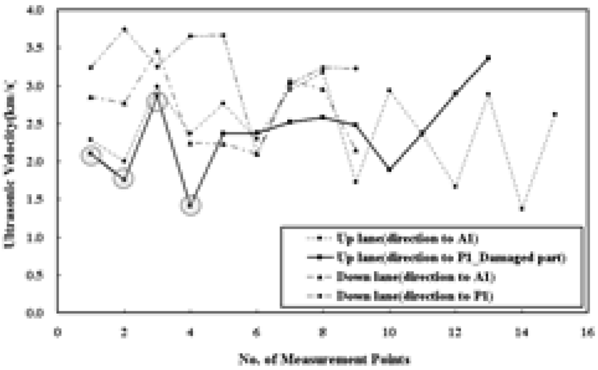

Fig. 14. Test results of ultrasonic velocity.

5. Repair Methods of Damaged Coping

It is proposed the repair procedure and section of repair method for damaged coping.

1. Chipping for damaged concrete
2. Clean by high-pressure
3. Installation of wire mesh
4. Coating by antibacterial, surface strengthen and systemic, water-soluble primer (SLC-1000)
5. Construction of section restoration material : antibacterial, water-soluble epoxy mortar (SLC-4000)
6. Copula grinding
7. Prevention coating for far-infrared radiation emission and antifouling, surface reinforced materials

6. Conclusions

1. Edge distance for the shoe support satisfy the specifications.
2. Results of nondestructive test for the concrete compressive strength, the estimated strength is more than the specified strength.
3. Results of nondestructive test for the bar arrangement inspection (arrangement spacing of bar, thickness of cover), satisfy the specifications.
4. It is compared calculated bearing stress with allowable bearing stress. By the results of bearing stress analysis, the safety factor is less than 1.0. It is estimated the main damage cause when deflection or eccentric load act the edge of bearing concrete.
5. By the appearance inspection, survey, test results of ultrasonic pulse velocity were inspected around the damaged coping. damaged concrete is restrict to concrete exfoliation.
6. It is proposed the repair procedure and section of repair method for damaged coping.

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