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A Method of Section Replacement for Pile-Bent Pier Rehabilitation

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Abstract. This paper presents a case of repair practice for a concrete bridge that was classified as imminent failure condition. The bridge is slab-type with an equal span of 10 meters long. Each pier is built up of six driven concrete piles. Over 30 years, critical deterioration occurred to concrete pier columns with many severe corrosion spots on reinforcing bars. A concept of section replacement was used to develop a repair technique to remove an entire body of deteriorated materials and restore with selected new materials, was used to develop a repair method. The method involved several stages of works that included: site investigation, damage inspections; work area preparation and installation of temporary structure; material replacement; and work completion. The lesson learned from repair practice suggests the number of key success factors that are needed to complete the task safely.

Background

In Thailand, pile-bent pier is commonly used to support concrete slab bridges. Refer to typical types given by Department of Highways [2]. It is simply constructed by multiple driven piles arranging as foundation and then all pile heads are capped together with a concrete beam casted in-place. An upper part comprises concrete columns of equal section to those piles extended to reach a level of bridge supporting beam.

The bridge in this case study is located in a central region province. A photograph is shown in figure 1. It is 8 m wide and 130 m long, supported by 14 piers on an equal distance of 10 m pier-to-pier. All plies and upper column have the same cross-section size of 400x400 mm.

Figure 1. Photograph of bridge and site condition

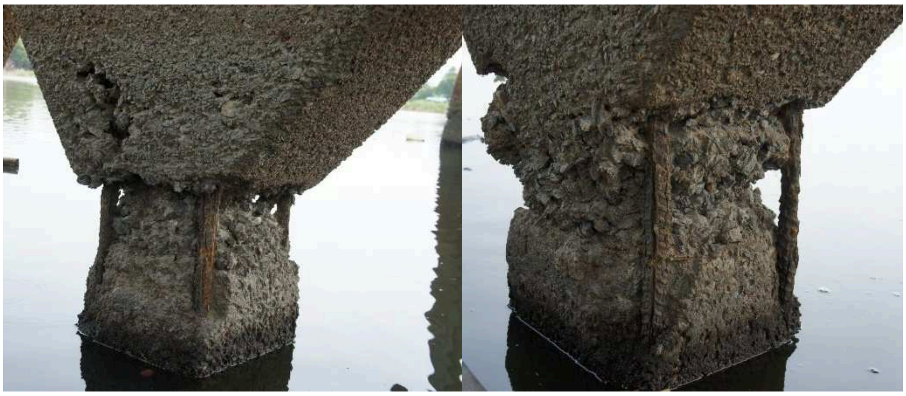

Figure 2. Damage of concrete and severe corrosion of reinforcing bars

At the age of nearly 30 years, the bridge was facing serious deterioration of substructure, particularly the piers in which subjected to tidal influence zone. Many visible damage spots were found. It was assumed that the causes of damage may be induced from many environmental factors. The local officials who responsible to maintain serviceability of the bridge were requested to develop an action plan to solve this problem. In 2013, an investigation team visited the site and reported on the condition of the piers. There was extreme deterioration of the concrete body between the pile heads and the cap beam. By visual inspection, obvious removal of entire covering concrete was found together with severe corrosion of reinforcing bars (see Fig. 2). With reference to condition rating provided by AASHTO [1], this bridge was classified to imminent failure condition (see table 1). Temporary cement grouting was done to reduce further damage while waiting future corrective actions. Traffic through the bridge was completely closed due to safety requirement

Table 1. AASHTO Condition rating descriptions

Code	Description
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION - some minor problems.
6	SATISFACTORY CONDITION - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION - out of service - beyond corrective action.

Concept of Rehabilitation Technique

Based on available budget and a good condition of superstructure, repair of substructure was alternative instead of entire bridge replacement [4]. Generally, there were choices of available repair methods, for example, pier column encasement, pier column jacket, FRP wraps, pier widening, and etc. [2]. Due to the major section loss, pier widening (adding new piers to the existing deteriorated pier) was technically sound, but however, not financial feasible. So a repair concept had to deal with deteriorated portion replacement. Unlike encasement and jacketing methods, the repair method for this case involved defining how large the defects to be removed and what materials to be replaced with. Stability of the entire bridge during repair operation was also considered crucially which it required a good temporary structural system. So the method was established to fix each pier separately using self-support system as temporary structure (see Fig. 3).

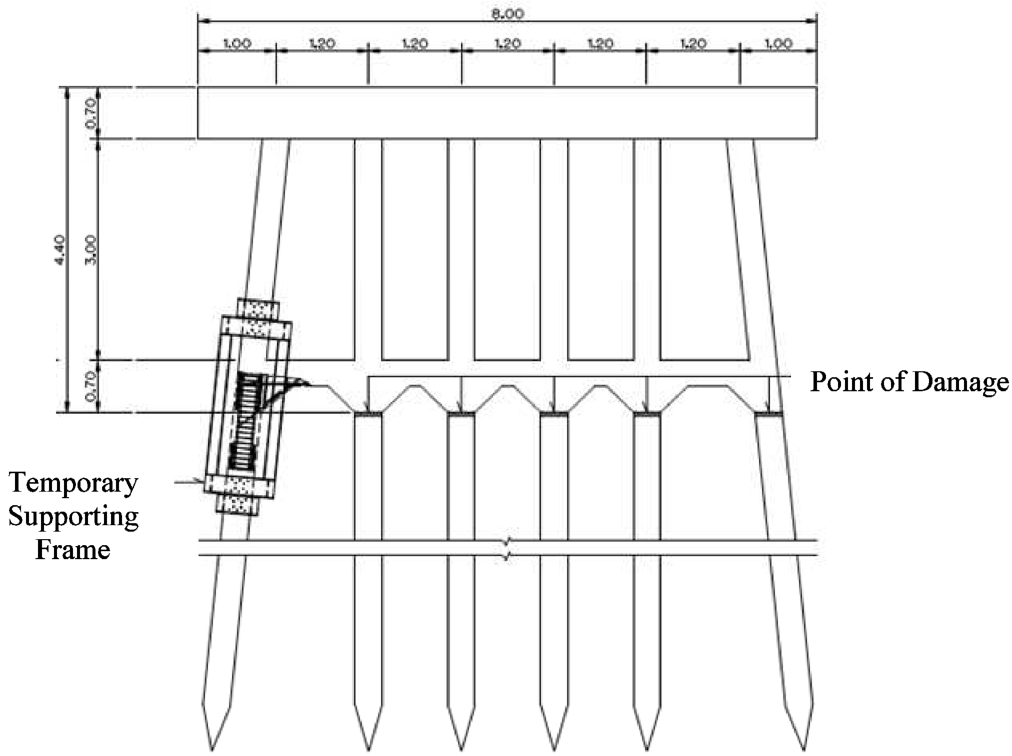

Figure 3. Conceptual schematic of repair method

In order to evaluate how large the defects to be removed, non-destructive tests on concrete strength using Schmidt hammer were performed along the upper and lower part of the damage position. Technically, the strength values should increase with distance from the center of damage portion. With this technique, upper and lower cutting edges for material removal can be simply defined where the strength achieves an acceptable value. As a result, evaluation indicated that the cut-off lengths sufficient to cover the damage zone varied between 0.80 and 1.30 m.

The temporary structure for a pier being repaired would fully sit on its pile. The column load transfers to the upper part of the frame using chemical bolt connection and the lower part also fixes to the pile with the same type of connection. The main elements of the frame use hot-rolled channel sections fabricated by welding. Designing number of bolts and steel section sizes are based on column load calculation (not shown herein). The detail drawing is given in figure 4.

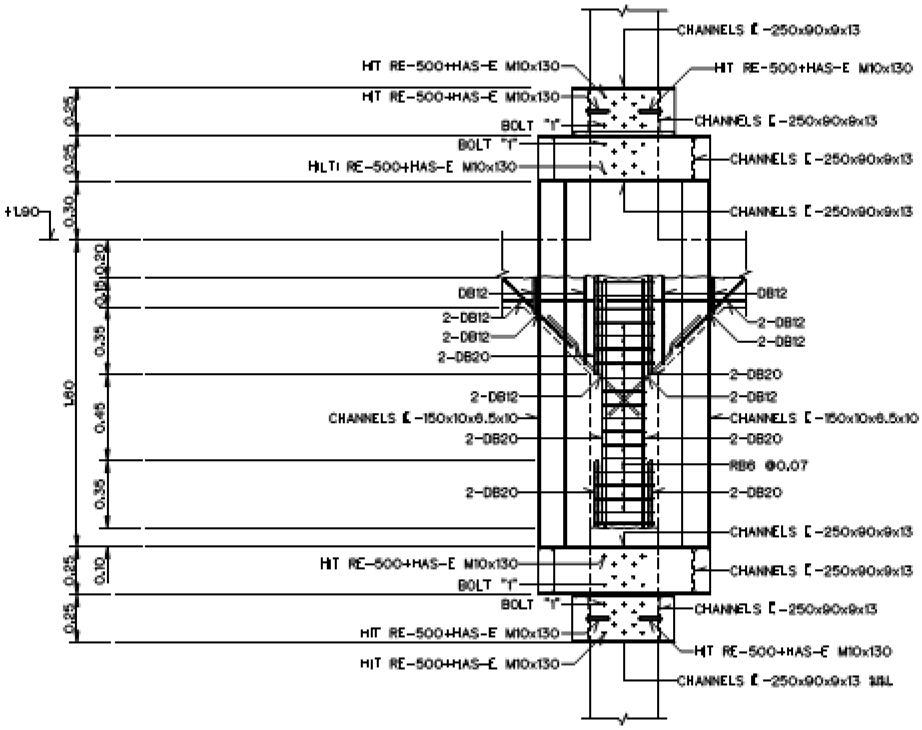

Figure 4. Drawing of temporary structure and rebar detail

Method and Work Procedure

A photograph of working area and installation of temporary support is given in figure 5. Preparation stage of work requires a temporary berm around the pier and pumping out the water to make the work space dry. The berm was built with a side slope approximately 1:1 using clay material taken from the stream bank nearby the bridge. Small wooden platforms were installed to provide safety during operation because the ground was so muddy which very difficult to stand and place heavy materials and tools. After the work area prompt to operate, there were choices to which pile to be commencing. Although the design suggested that the support frame could fully receive the column load safely, however, we did not go with all six plies at the same time. Conservatively, the plan was considered to separate the repair work in three sequences: 1) work begun on two external piles (left and right end) until repair completed then; 2) moved to two internal piles and repeated the same task then; 3) moved to the last two piles to finish rehabilitation of all six piles.

Figure 5. Work area preparation and installation of temporary structure

Installation of temporary support needed good-skilled workers because the pier columns were considered very weak and at high risk of failure. The installed frames had to be inspected very carefully by engineering supervisor before concrete section removal. Since the concrete body had been completely removed by pneumatic breaker, rust on the bar surface would be cleaned using steel brush otherwise bars were cut if very deep corrosion appeared. In most case we intended to keep the length of existing reinforcing bars as much as possible to provide enough overlapping length to be welded with new bars. See the mentioned procedure in figure 6. Since the new bars had been placed, formwork was then encased. Early strength concrete was used to restore the section. By using this type of concrete, the formwork was allowed to remove after 48 hours. However, the temporary structure (steel frame in Fig.6) would need to be there for another few days to ensure the new section could carry the column load safely. Finally, all new surfaces were furnished with waterproof coating. The photograph of completed repair pier is shown in figure 7.

Figure 6. Concrete removal and reinforcing bar replacement (procedure from left to right)

Figure 7. Completed pier repair

Concluding remarks

This paper introduces the method of pier column repair for pile-bent substructure and describes the work procedures for repair practice. The challenge to the repair work was the imminent failure condition of the pier columns. Remaining concrete and steel bars across the deteriorated sections needed to be fully removed. Given the case presented, experience gained through field practice suggests six key success factors as follow:

- Damage inspection and condition rating;
- Planning for repair sequence of pier columns;
- Work area preparation and water protection;

- Installation techniques for temporary structures;
- Overall stability monitoring of bridge during the period of repair; and
- Work completion that involves selection criteria for replacement materials and surface finishing.

Finally, very well-trained workers and a smart planning sequence that can allow multiple times of reuse of temporary structural frame are recommended for cost minimization.

References

[1] AASHTO, Guidelines for Historic Bridge Rehabilitation and Replacement, American Association of State Highway and Transportation Officials, Washigton DC, 2008.

[2] S.W. Ainge, Repair and Strengthening of Bridge Substructures, M.Sc. Thesis, Marquette University, Wisconsin, 2012.

[3] Ministry of Transport, Standard Drawings for Highways Construction. Department of Highways, Bangkok, Thailand, 1994.

[4] TRB, Cost-Effective Practices for Off-system and Local Interest Bridges, NCHRP Systhesis 327, Transportation Research Board, Washington DC, 2004.