A Study on Scenarios for Derivation of Emergency Recovery Method of Waterfront Structures

Hyuk-Jin Yoon, Sang-Jae Han, Jae-Hyun Jung

Abstract **— Civil engineering structures constructed on rivers are placed in an environment exposed to frequent flood damages. Since the loss of levee due to flood and bridge scour are major causes of sudden structural collapse, emergency recovery construction must be quickly carried out before long-term recovery.**

This study refers to the relevant rules and practices for types of damage caused by bridge scour and loss of levee due to flood, preparing flowcharts for quick selection of emergency recovery process and deriving decision-making trees. The characteristics of the decision-making trees derived applied variable considerations on changes in the standards, addition of construction methods, and addition of examples.

Keywords **— Decision-making trees, emergency recovery**

I. INTRODUCTION

Many road and railway structures are constructed adjacent to rivers and valleys. As damages from wind and flood such as typhoons can frequently occur in rivers and valleys, structures can receive damages from excessive deformation and loss due to slope failure caused by erosion and loss of the levee. Since waterworks structures (levee, retaining wall and slope) adjacent to traffic facilities can suspend or restrict the use of facilities to arouse damage on residents or economic loss, they must be recovered quickly. Many road and railway structures are constructed adjacent to rivers and valleys. As damages from wind and flood such as typhoons can frequently occur in rivers and valleys, structures can receive damages from excessive deformation and loss due to slope failure caused by erosion and loss of the levee. Since waterworks structures (levee, retaining wall and slope) adjacent to traffic facilities can suspend or restrict the use of facilities to arouse damage on residents or economic loss, they must be recovered quickly.

Erosion and loss of levee and revetment adjacent to roads and railways cause partial loss of roadbed and levee body to result in suspension of operation or economic loss. When damage occurs, the first-line workers need to quickly devise effective and applicable emergency recovery method and immediately apply the method to the site in order to prevent additional damages. Unlike reinforcement and restoration, emergency recoveries performed immediately after damage are mostly carried out to prevent further spreading of damage. Recovery works such as reinforcement and restoration involve deduction of optimized construction methods based on safety diagnosis and design, but they require time for a series of processes and cannot be quickly applied to facilities which demand emergency action. Improvement works carried out to prepare a fundamental solution to damage require about 7~8 months until commencement of construction. According to the analysis of the implementation status for disaster recovery projects, it should take 3~8 months for budget allocation, deliberation on the design and commencement of construction from the time of damage based on calculation, but actual projects were found to generally take 7~8 months because of delay in response of the government and procedure (survey, design, bidding, commencement) (Ha, H.S, 2012)[1]. Therefore, when a recovery work starts in April or May and construction is not finished until the rainy season, damage can recur. According to National Institute for Disaster Prevention (2001), there is a lack of detailed technical guideline that provides recovery methods for each facility and process according to different types of damage for first-line recovery workers[2]. Since recovery works intended to prevent spreading of damage relied on experiential methods of the past, workers do not have manuals and are simply relying on experiences.

In order to select the most appropriate construction method at a specific site, different conditions such as design condition, ground condition, construction condition and environmental condition must be taken into account. Han, J.G. et al. (2008) applied the AHP technique to select reinforcement method for cutting slopes [3]. Factors of assessment include environmental effect, economic feasibility, constructability, maintenance, stability and durability. As a result of survey on expert preference, stability and durability were found to be the most important factors of assessment.

However, as it is difficult to secure design conditions at the site of damage in case of emergency recovery work performed to prevent spreading of damage prior to long-term recovery, construction method must be selected based on constructability, environmental effect and specification. In addition, since the decision-making process in selection of emergency recovery method must be quick and clear, the AHP(Analytic Hierarchy Process) technique that requires collection and analysis of expert opinions and the neural network in which decision making process is black box may not be appropriate [4]. On the contrary, decision-making trees based on flowchart are more practical because tracking of the

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decision-making process is transparent. Also with the development of big data mining technique, flowcharts can be easily converted to decision-making trees with automated prediction. Selection of recovery method can be performed at the site using smart phones. Finally, flow charts for the deriving decision-making tree can be used for effective disaster resources assessment and allocation for emergency response[5].

II. EMERGENCY RECOVERY SCENARIOS

A. Scouring of Bridge Foundation

National Institute for Disaster Prevention (2000) reported that 53% of bridge damages caused by flood in bridges on small rivers are "loss of substructure from the scouring of riverbed". When loss of pier substructure occurs due to scour, bridge bearing and structure are also affected by differential settlement of foundation and pier overturn to result in relatively small damages such as cracks and deformations, as well as phenomena such as collapse. In this study, an emergency recovery scenario was devised for "loss of substructure from the scouring of riverbed" with highest frequency of damage in the past.

Fig. 1 is a flowchart illustrating the emergency recovery scenario for "loss of substance from the scouring of riverbed". First, meteorological and environmental conditions were taken into consideration for recovery of damage in a facility. Minimal meteorological conditions for damage recovery are rainfall below 5mm, temperature between 0~30 degrees Celsius, and wind velocity below 14m/s, which correspond to normal level (construction can be done with low work efficiency, Korea Meteorological Administration) of the Industry Meteorological Index. Once meteorological conditions are satisfied, emergency recovery work is determined by the surveying depth of scour, subsidence, and exposure of the pile or foundation after removal of debris. Damaged members were surveyed and recovered in the order of foundation, abutment, pier and bridge bearing. Scour occurs in foundation and can affect superstructure in severe cases. Additional damage cannot be prevented simply through recovery of superstructure without recovering foundation. The emergency construction criteria set forth in Fig. 1 are equivalent to safety grade "d", but the possibility of recovery is determined based on water level and flow velocity of rivers. It is difficult to handle debris when flow velocity is too high, and recovery work becomes impossible or dangerous when water depth or temperature is high. It would be appropriate to perform recovery work after conducting a detailed investigation by long-term recovery damage investigation team. The type and method of emergency recovery work were prepared by collecting opinions from experts. However, as an emergency recovery method cannot be deducted as precise techniques applied in design due to lack of basic data such as measurements, testing and boring, the sequence for deduction of construction method was determined based on the items that can be surveyed at the site. Since the piers overturn and excessive crack are damages that require review on reinforcement load carrying capacity, damage survey (special inspection) was performed to deduce a recovery method that reflects the necessity for reinforcement of load carrying capacity.

Table 1: Physical properties of soil and its consolidation characteristics

Reason for Damage	Structure Member	Conditions of Location	Reason
Pier foundation damage due to scour	Pier, abutment	Meandering portion (bilge), steep river (mountain river), merging flow unit	River flow velocity changes (vortex phenomenon), changes in topography
Overflow due to lack of freeboard	All	Steep river (mountain river), merging flow unit	Water level rising, sediment inflow, riverbed erosion, lack of freeboard
Tilting due to debris	Pier, abutment	Steep river (mountain river), merging flow unit	Pressure increase due to debris, scour of foundation
Length of the bridge shortage	Girder	-	Length of the bridge shortage compared to the width of the river

Connection damage due to insolvency of abutment protection	Abutment	Meandering position (bilge), steep river (mountain river), merging flow unit	Water level rising, water pressure increase

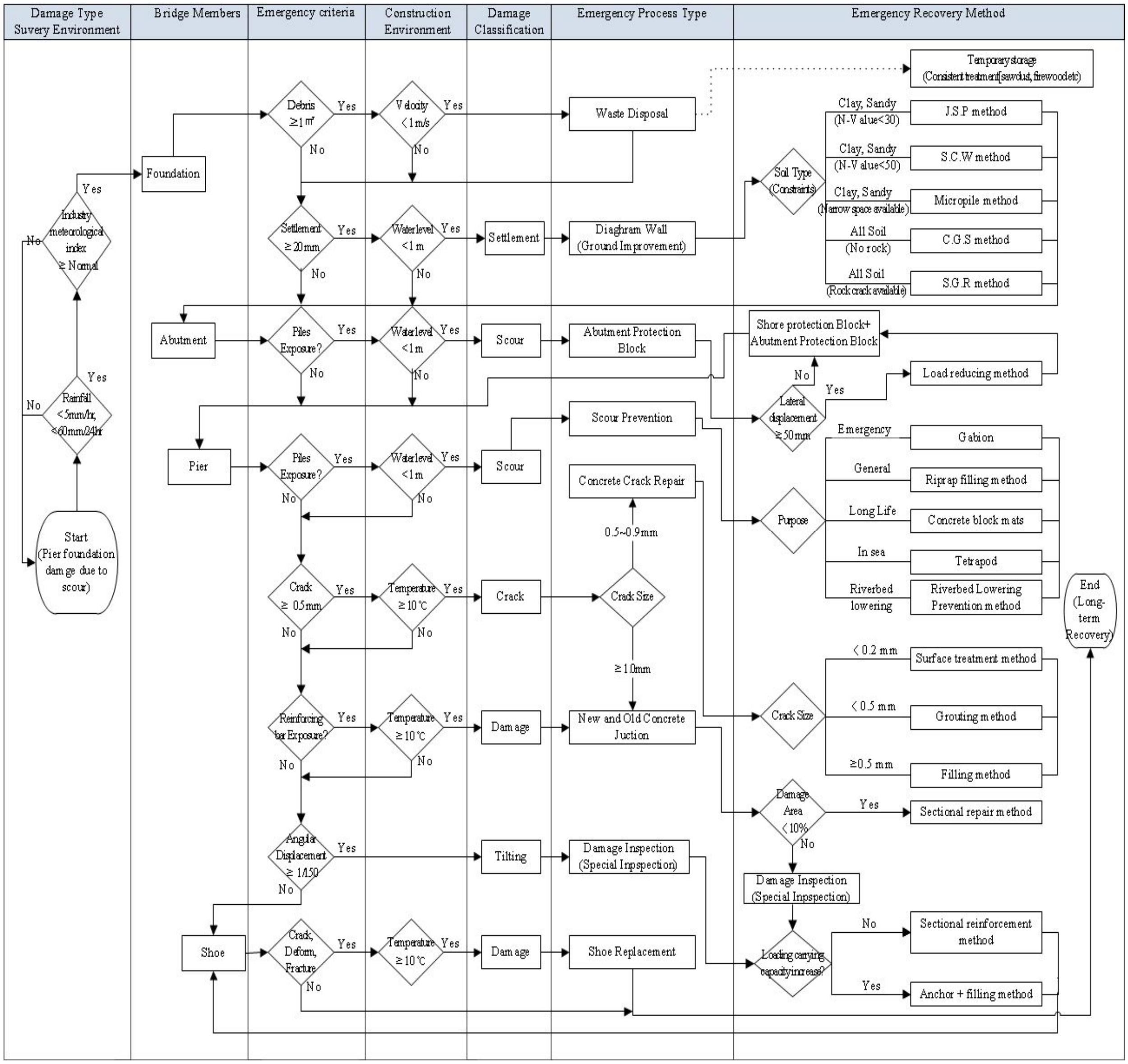

Fig. 1 : Recovery process of bridge pier foundation damage due to scour

B. Overflow of Levee

Among causes of damage in levee, "overflow due to lack of flow area" was assumed as an emergency recovery scenario. There are many reasons that cause lack of flow area such as under-appropriation of design flood, lack of sectional area from excessive flood, lack of sectional area of flow from debris and mudflow, and lack of sectional area of flow from abutment and pier. The preliminary response before the occurrence of damage is also important for overflow of levee because it can bring serious damage in protected lowlands.

Fig. 2 is a flowchart illustrating the emergency recovery scenario for "overflow due to lack of flow area". Likewise for bridge, applicability of emergency recovery on damaged members was investigated for normal level (construction can be done with low work efficiency, Korea Meteorological Administration) of the Industry Meteorological Index. Preventive recovery of overflow was configured based on freeboard. Cofferdam construction can be performed to prepare for overflow when freeboard is less than 1m, and it would be appropriate to perform the construction before starting of rainy season by estimating freeboard with consideration of construction period. After the occurrence of damage, survey is conducted in the order of shore foundation, slope front, covered part, and head of breakwater once debris is removed and survey conditions are satisfied. Major details of the survey include scour and areas of loss. Foot protection work is carried out for scour damage in shore foundation, and detailed construction method is selected considering flow and purpose of use. Foot protection works and slope protection works are performed for loss of slope front, and detailed construction method is selected considering flow and restrictions. Whereas partial loss of the head of breakwater due to overflow can be temporarily restored by removal of backfilling, it is appropriate for long-term recovery damage investigation team to perform a precise survey and improvement work to fundamentally remove the cause when area of loss is large (assumed to be > 5 m2) or flood occurs.

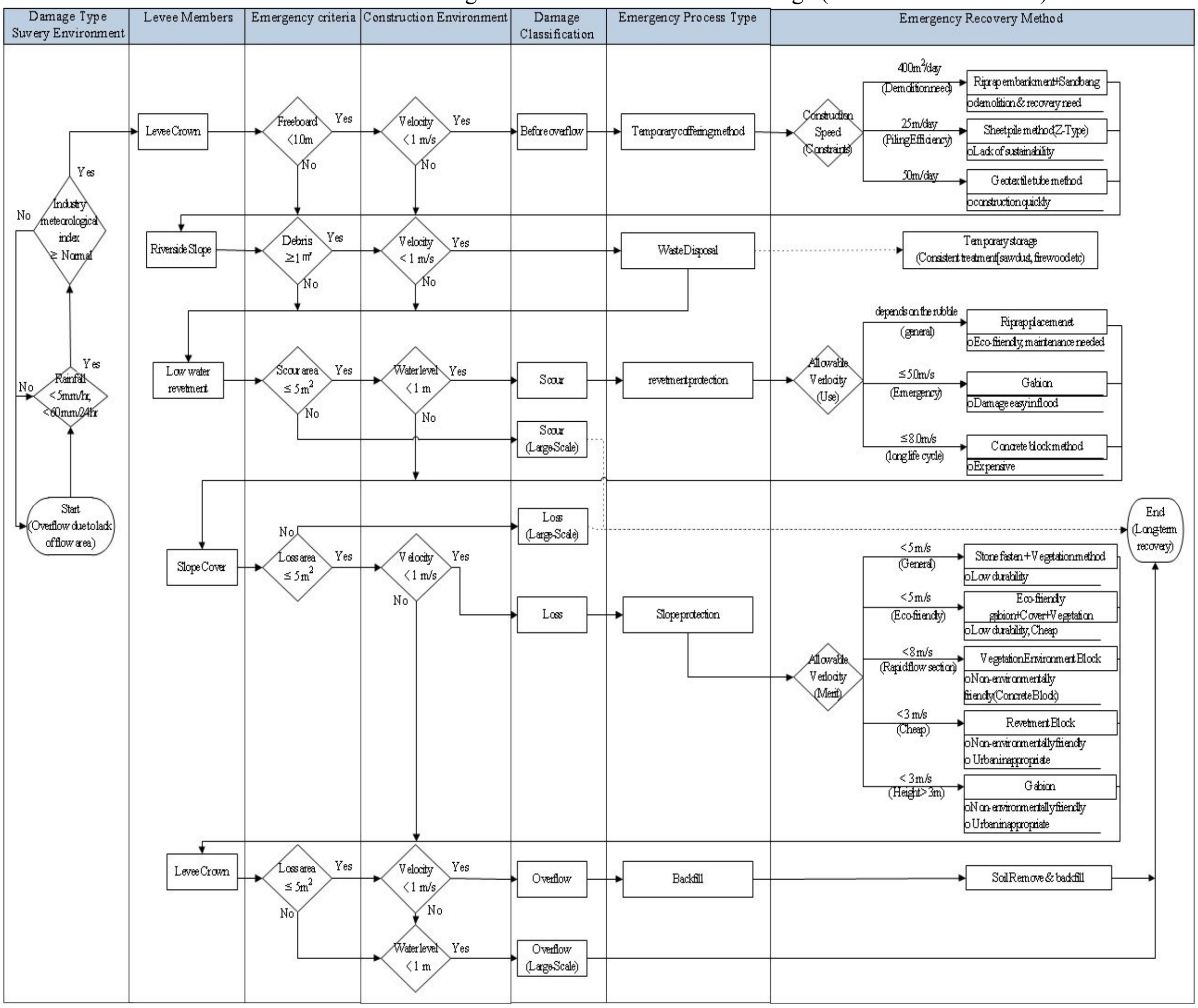

Fig. 2 : Recovery process of levee overflow damage due to lack of flow area

III. Future Research Plan

The emergency recovery scenarios were prepared by reflecting expert opinions, related regulations and recovery examples of the past, but they require verification. Accordingly, verification of the scenarios is to be performed through indoor and outdoor testing and simulation. The emergency recovery scenarios were developed in the form of flowcharts, and they can be automated using decision-making trees. Therefore, first-line workers can make practical use of the recovery scenarios using web service.

IV. Conclusion

In this study, emergency recovery scenarios for the most frequent damages in bridge and levee were examined. The recovery scenarios were prepared with consideration on related regulations, expert opinions and recovery examples of the past.

1) The emergency recovery scenario for the bridge was assumed to be "loss of substructure from the scouring of riverbed". The emergency recovery work was determined with consideration on Industry Meteorological Indices, field survey conditions (water level, flow, etc.) and scale of damage, and the type and method of recovery were deduced based on scale of damage and restrictions.
2) The emergency recovery scenario for levee was assumed to be "overflow due to lack of flow area". Preventive recovery according to freeboard was considered. As for the bridge, the emergency recovery work was determined with consideration on Industry Meteorological Indices, field survey conditions (water level, flow, etc.) and scale of damage, and the type and method of recovery were deduced based on scale of damage and restrictions.

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