A Bridge Scour Management System

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Abstract

Channel scour, especially bridge pier scour, is the leading cause of bridge failures. Researches for reducing bridge failures during floods have been concentrated on analysis, inspection and countermeasure of bridge scour for the decades. Recently, prioritization and maintenance scheme of bridge scour have become a more concern, which should be based on the reasonable evaluation and inspection. A bridge scour management system is developed to evaluate the vulnerability of bridge piers to scour and to assist in establishing effective calamity measures, considering the locality and scour characteristics. The prioritization scheme on bridge foundation to scour consists of 2 parts; prioritization for field inspection (initial screening) and evaluation of vulnerability including scour analysis. The bridge scour evaluation including site investigation is performed with the order of priority determined in the initial screening process. The Bridge Scour Management System is programmed using the techniques of the geographical information system(GIS) for the storage, retrieval, and display of information regarding to bridge scour. The vulnerability of bridge piers is categorized into 7 groups in the system, based on the conventional analysis of the bearing capacity of bridge foundation as well as on the analysis of the effects of floods on the foundation, on foundation type, on foundation depth, on foundation width, and on present scour condition. After categorizing all the bridges of interest, the compiled and plotted information in the database can be utilized in planning the scour examination schedule for maintenance and in timely decision-making with respect to remediation of scour critical bridges. Information retrieval and statistics regarding to bridge scour is available in accordance with bridge owner, road number, priority and inspection date. For the verification of this system’s feasibility, case studies on 20 bridges, which include the initial screening, field inspection, scour evaluation, and categorization of the scour vulnerability of bridge foundations, are presented.

1. INTRODUCTION

It is commonly known that bridge scour is the most common cause of bridge failures (Shirhole and Holt, 1991). It is highly likely that scour will occur during floods in Korea because of the increased instability of river beds for reasons such as the high bed slopes which is common in mountainous regions, the fact that more than two thirds of the annual precipitation falls during the summer, and because of the frequent extraction of aggregates and dam construction, etc. For the last 10 years, the number of bridge damage cases caused by scour and the instability of the rivers during floods in Korea has reached approximately 100 cases on average per year. Such failure was characterized as being more concentrated to the small and medium sized rivers than large sized one. However, the damage increased greatly due to the meteorological disasters accompanied by localized heavy rain in 2002/2003 and abnormal heavy rain during the events of typhoon Rusa and Mammy, thus there have been increasing cases reporting bridges that crossed very little water in the dry season and even the large-sized bridges on the national road came to fail due to scour, etc. during flood events. This has been caused by the existing inefficient field inspection and maintenance countermeasures that didn't consider the significance of bridges and the danger of scour during floods. Therefore, in order to secure the stability of bridges, it is necessary to prepare a bridge scour management system for effective maintenance considering the local characteristics as well as carrying out the exact assessment and field inspection of scour depth based on a precise analysis.

A variety of efforts related to the management system have been made during that time; Ho et al.(2002) has developed a GIS-based bridge scour prioritization system for the efficient and economic maintenance and reinforcement of bridges in New England State (U.S) (See Figure 1) and Palmer and Turkiyyah(1997) has developed the system of assessing the bridge scour vulnerability and river stability using Bayesian module (See Figure 2). In this study, the status of the existing bridge scour management system was analyzed and the method of deciding bridge scour danger with multidisciplinary concept using the correlation between bridge scour and bearing capacity of bridge foundation taking the domestic situation into account was developed. Based on this result, a reasonable bridge scour management system was developed where the efficient anti-disaster measures can be established and the safety of bridge can be secured during flood events.

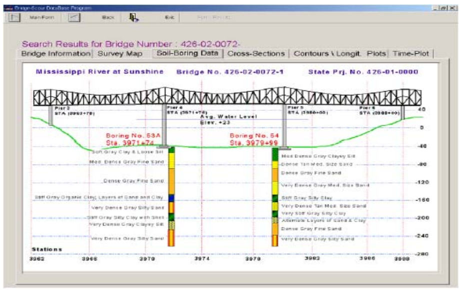

Figure 1. GIS-Based Bridge Scouring Prioritization (Ho et al, 2002)

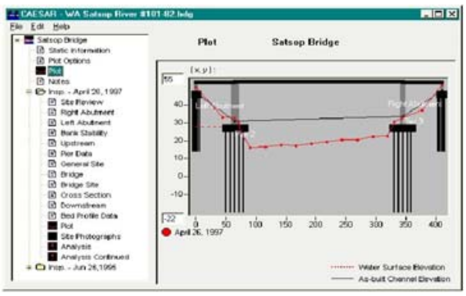

Figure 2. CAESAR system (Palmer and Turkiyyah, 1997)

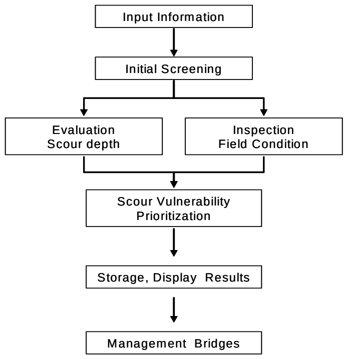

Figure 3. Flow chart of the bridge scour management system

Figure 4. The bridge scour management system

2. BRIDGE SCOUR MANAGEMENT SYSTEM

2.1 Composition of system

The bridge scour management system that was developed in this study consists of 4 parts such as GIS(Geographic Information System) based data input/output, prioritization decision of bridge scour inspection, decision of bridge scour vulnerability, schematization of results and database system. Part of data input/output is arranged input/output, correction and deletion of field inspection prioritization information and site investigation information, part of field inspection prioritization decision relates to the basic information for the bridges and sites collected through the existing literatures or data, including the system deciding field inspection prioritization. Part of the vulnerability rating decision is the core element of this bridge scour management system including the system of assessing expected scour depth, bearing capacity of foundation-ground system, and of deciding the vulnerability of bridge foundation due to scour. Part of the result schematization & database system includes the summary reporting on the bridges whose vulnerability rating were decided and database management of the collected data, which allows searching of bridge following the various lines and the associated statistic analysis. A flow chart of this bridge scour management system and the initial screen of program are shown in Figures 3 and 4.

2.2 Decision of field inspection prioritization

It will require a considerable amount of time in order to assess the scour stability on bridge foundation, analyze scour influential factors, and prepare proper countermeasure, and it is non-economic and unreasonable to survey all the bridges with lower scouring danger in a lump. Accordingly in this study, a simple and systematic method of deciding field inspection prioritization to carry out the reasonable and economic field inspection in detail within the limited budget amount was developed.

The method developed for deciding bridge inspection prioritization consists of 2 procedures: initial screening and field inspection prioritization decision. Field inspection prioritization is decided using some information from which influential factors of scour and river instability and the significance of bridges, etc. can be considered. The influential factors of scour, river instability and bridge significance that have effect on the bridge failure are in very broad ranges and diversified covering the specification of bridge, characteristic of foundation, basin property, river bed property, hydraulic/water gate property, socio-economic characteristic, etc. as shown in Table 1. Therefore, in order to decide reasonable field inspection prioritization with constant criteria about the number of bridges within the short period, it is necessary to select highly effective information that can be easily secured. Thus, in this study, 4 criteria from the existing data surveyed and analyzed that enable the simple and efficient field inspection prioritization have been chosen, which was reported through the existing survey as follows; (A) Information regarding whether the bridge substructure is in dangerous situation or not, (B) Type of bridge foundation, (C) Traffic volume and (D) River bed slope that is provided from the report on the river maintenance basic plan of each river.

TABLE 1. INFLUENTIAL FACTORS OF SCOUR, RIVER INSTABILITY, AND SIGNIFICANCE OF BRIDGE

Category	Influence factors
Bridge	bridge type, bridge length, bridge width, maximum span length, number of span, etc
Foundation	foundation type, foundation width, foundation depth, pier type, pier width, etc
River	width, valley setting, floodplain width, vegetation along bank, channel sinuosity, etc
Streambed	bed slope, bed materials, sand dune, streambed elevation, etc
Hydraulic and Hydrologic factors	design flood, design water depth, design water velocity, daily maximum precipitation, etc
Social and economical factors	traffic, rehabilitation cost, bypass cost, etc

* : Criteria for determination of field investigation priority

The initial screening process classifies bridges into 3 categories only using the information of bridge foundation types. That is, in case of the caisson foundation that has relatively high stability against scour, it will be assessed as lower danger for which the lowest priority of field inspection is given. Furthermore in the event that the information on foundation is not known, U (unknown) rating is given so that those bridges could be surveyed and analyzed independently, and all other bridges are regarded to have the potential vulnerability of scour, for which the priority of field inspection will be determined according to the decision method.

Initially, in accordance with the existence of scour danger (yes, no) for the bridge substructure in underwater inspection report, bridges are classified into 2 groups broadly, and the bridges that are reported dangerous of scour will be rated at the top priority of field inspection. Bridges that are not reported dangerous in present are divided into 2 groups such as spread footing, pile foundation from the aspect of foundation class. Then, based on the traffic volume and river bed slope, they will be divided into each 3 groups, being divided in total 20 grades of field inspection priority. Algorithm to decide the field inspection priority described as above is shown in Figure 5. In this case, the group A, B and C means less than 5,000 vehicles, 5,000 ~ 10,000 vehicles and more than 10,000 vehicles of daily traffic on average respectively.

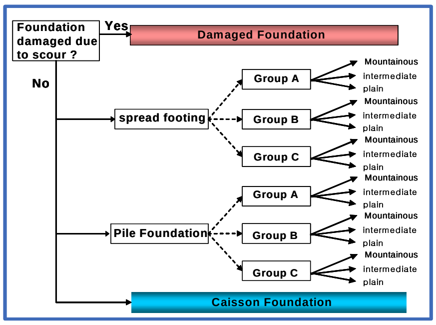

Figure 5. Method of field inspection prioritization decision

2.3 Bridge scour vulnerability rating

Rating decision of bridge scour vulnerability is made from the expected scour depth carefully analyzed through detailed field inspection and scour analysis, its associated decrease in the bearing capacity of foundation-ground system, specification of bridge foundation, existing scour status, etc. Regarding the assessment of scour vulnerability of combined system consisted of bridge pier, foundation and ground, significance of the geotechnical factors have been analyzed (De Falco et al., 1997), and furthermore the method to consider the time effect and soil property in the event of analyzing scour on fine-grained soil has been developed (Briaud et al., 1999; Kwak, 2000).

In this study, bridge scour vulnerability assessment method based on multi-disciplinary concept that can include the geotechnical factors related to the bearing capacity of foundation-ground system and all the hydraulic influential factors that are necessary to analyze scour stability was suggested. This is based on the suggestion of Federico (2003) that enables the analytical quantification of the stability of bridge foundation by considering the bearing capacity change and safety factor of foundation-ground system as well as the analysis of the effect of scour on bridge pier, foundation and ground during flood events.

In the event of scour occurrence, the material on the ground near bridge pier and foundation are carried out and thereby it reduces the bearing capacity of foundation-ground system and safety factor as well. Accordingly, vulnerability of bridge from scour can be determined by comparing the bearing capacities of foundation-ground system before and after scour occurrence. Furthermore bridge scour vulnerability μ can be explained in the concept of safety factor (Federico, 2003). In designing the bridge foundation, the safety factor on the bearing capacity of a typical foundation-ground system is 3.0. Therefore, the safety factor of the bearing capacity of bridge foundation before scour occurs can be defined as 3.0 and the safety factor decreases as scour occurs.

$$\mu = \frac{q_{ult}^{normal}}{q_{ult}^{scour}} = \frac{q_a \cdot (S.F.)_{normal}}{q_a \cdot (S.F.)_{scour}} = \frac{S.F._{normal}}{S.F._{scour}} \quad (1)$$

Here, $q_u^{(normal)}$ and $q_u^{(scour)}$ mean the ultimate bearing capacity of the foundation-ground system before and after scour respectively, q_a means the allowable bearing capacity of the foundation-ground system, $S.F._{normal}$ and $S.F._{scour}$ are safety factors of foundation before and after scour respectively. Therefore, the vulnerability μ can be determined from the safety factor of bearing capacity of foundation-ground system as the scour occurs. The bridge scour vulnerability rating was proposed based on the safety factor and vulnerability μ of foundation-ground system following the scour occurrence, which is shown in the Figure 6.

As shown in Figure 6, in the typical case where expected scour depth is less than foundation embedded depth, classification was done in three stages which starts from Level 3 as the safety factor of foundation bearing capacity changes due to the progress of scour; Level 5 for the safest stage with the $S.F > 2$, Level 4 with $1 \le S.F < 2$ and Level 3 with $0 \le S.F < 1$. In cases where the expected scour depth is higher than the embedded depth, during the occurrence of flood with design frequency, bearing capacity of foundation-ground becomes 0 after result that all the grounds near the foundation is lost. In case scour depth is larger than foundation embedded depth, bridge will be destructed and actual bridge will not exist. However, in this study, in order to assess the existing potential scour danger based on the expected scour depth in relation to the design flood, and prepare the efficient countermeasure against the future flood and maintenance, the likelihood that the expected scour depth against flood could be larger than foundation embedded depth was considered. Furthermore in Figure 6, Level 0 refers to just the order from the conceptual meaning, which is very serious status in the progress of scour or has significant problem in the entire stability of the bridge, requiring urgent countermeasure.

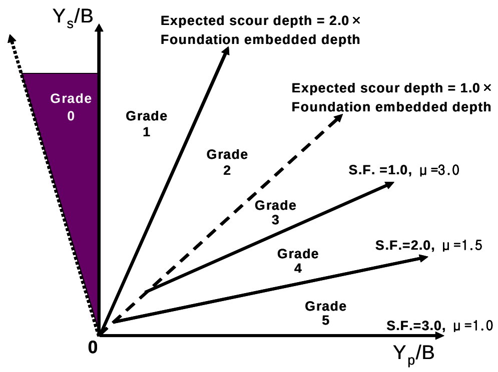

Figure 6. Bridge scour vulnerability rating system

3. CASE STUDIES

3.1 Selection of the subject bridges

In order to verify the site applicability of the developed system, a series of case studies were carried out on the actual bridge sites. The case studies were performed as shown in the flow chart of the developed the bridge scour management system. For the bridges within the territory of Gangneung National Road, the procedure included site investigation, bridge scour analysis against design flood, its associated assessment of bearing capacity of bridge foundation and decision of vulnerability rating and comprehensive estimation on the bridge management system.

Bridges within the Gangneung National Road territory recorded in BMS (Bridge Management System) were 112 places in total. From these places, 80 bridges remained after excluding simple span bridges that has no bridge pier and other bridges whose information such as type of foundation, embedded depth, etc. were not known. Field inspection prioritization was decided through the analysis of these 80 bridges and the detailed analyses were finally focused on 20 bridges based on the result of field inspection prioritization. For each of the selected final 20 bridges, scour analyses was carried out in relation to the design flood of the relevant river, and expected scour depth was calculated. Aside from which, bearing capacity of bridge foundation was estimated using the site investigation results including boring tests with BMS data. Bridge vulnerability rating was decided comprehensively considering the bridge scour stability assessment and bridge foundation stability found from site investigation and the decreased bearing capacity caused by the occurrence of scour based on this. Vulnerability rating decided in this way will be the systematic standard for the regular checking and maintenance of the bridge in the future.

3.2 Decision of field inspection prioritization

The field inspection prioritization of a bridge site is determined using 4 pieces of information mentioned in previous section; (A) Information regarding whether the bridge substructure is in dangerous situation or not, (B) Type of bridge foundation, (C) Traffic volume and (D) River bed slope provided in the report on the basic river maintenance plan. Analysis result on the field inspection prioritization for the 80 bridges using the above information is shown in Figure 7.

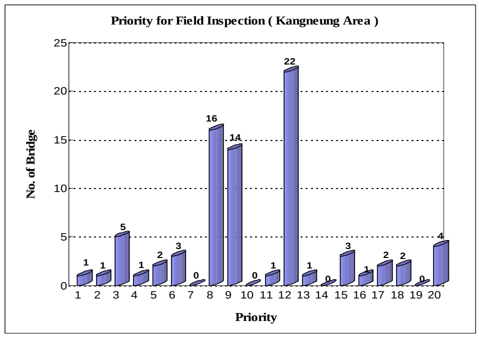

Figure 7. Result of field inspection prioritization analysis

As shown in Figure 7, the subject bridges were distributed at the middle levels in the field inspection priority, showing the levels 8 ~ 12 out of the 20 levels in total, while the bridges showing the other range of levels were approximately 30%. That is, although there were few bridges requiring urgent countermeasure and precise inspection or showing relatively lower urgency in field inspection in detail, most of the bridges had the possibility of scour and potential instability of river during flood events, field inspection of which should not delayed any longer.

3.3 Scour analysis

3.3.1 Estimation of parameters

In order for the various bridges with priorities to be equally included, 20 bridges were selected for detailed analysis. For the analysis of vulnerability rating of the bridges before and after scour, site investigations were conducted on each bridge. The site investigations were performed in the order of prior site survey for each bridge site and for each subsurface exploration. In the prior site survey, the general status of the bridge, bridge specification and foundation type, hydraulic and topographical land property of the river and basin where the bridge is located, and the present degree of scour damage for the bridge were investigated. In the subsurface exploration, geological survey for the bridge foundation ground through boring tests, sieve analysis for river bed material and characteristic analysis for the geotechnical property of the surrounding area were carried out.

In order to estimate the scour depth that occurs near the bridge during flood events, exact assessment and analysis is required on the hydraulic/hydrological factors such as design flow on the flood of design frequency event, approaching flow velocity, design stage, etc. Furthermore characteristics of the ground such as river bed type, layer, river bed material, etc should be analyzed, and also the information on the structural characteristics such as type of bridge pier, foundation specification, etc. Characteristic of river bed material was analyzed through the site investigation, and thus it showed that the river beds of the subject bridges were all flat consisted of coarse-grained soils.

3.3.2 Calculation of scour depth

In this section, the bridge pier scour depth of each bridge was calculated applying the hydraulic and geotechnical parameters that were previously estimated. (Figure 8). In the local scour of bridge pier, the expected scour depth was determined from the average value calculated using the CSU equation, Froehlich's equation, Laursen's equation and Neill's equation that are suggested by the river design standard (2005). Furthermore in case rock exists in the expected scour depth that was obtained by applying the scour equation, the scour depth of the subject bridge was decided taking the rock depth into account.

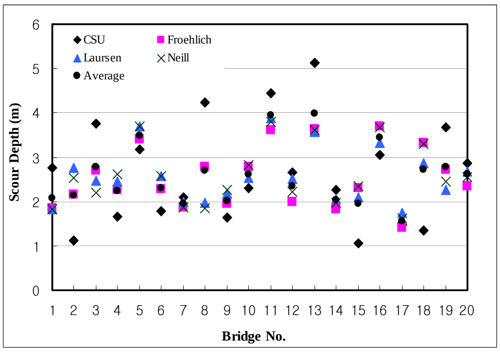

Figure 8. Expected scour depths for subject bridges

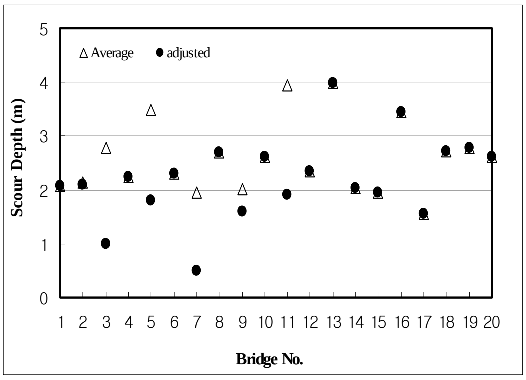

Figure 9. Expected scour depths considering rock layer for each bridges

Expected scour depth of the subject bridges ranged from 2m to 4m except for some bridges. Compared to the average scour depth, the scour depth calculated from the CSU equation, widely-used equation for pier scour depth on coarse-grained soils didn't show any constant tendency. This is because in only case of CSU equation, scour depth is reduced in case of the bridge where boulder stones are spread over the river bed resulted from the consideration of armoring effect by the coarse river bed material. The bridges that have shown this tendency were Bangdo Bridge, Shinpyung Bridge, Woljeong Bridge, Godan Bridge, Namcheon Bridge, Jasan Bridge, etc. However, in case of Yongdae Bridge and Ongnyeo 1 Bridge, etc. lengths of bridge pier were calculated large due to the inflow angle of river flow, and such effect governed them. Therefore the influence by armoring effect was relatively small.

Scour depth calculated by the Froehlich's equation considering inflow angle also showed relatively larger value than the results from Laursen's equation or Neill's equation, which shows similar tendency to the average scouring depth. As Neill's equation considers the water stage and bridge pier width only from several parameters in calculating scour depth, the effect by the bridge pier width is relatively large, and the scour depths of bridges whose bridge pier widths are small such as Gungchon Bridge, Yongdae Bridge, Ongnyeo 1 Bridge, etc. were calculated smaller than them calculated from the other equations.

As the kind and the degree of effect of the parameters considered in each scour equation differs, scour depth of each scour equation on the entire subject bridge didn't show any constant tendency. However, except the Ongnyeo 1 Bridge with large inflow angle, and Songcheon Bridge with higher water stage and higher flow velocity, scour depths by each scouring equation showed the difference within 1m that appeared entirely similar values.

Figure 9 illustrates the scour depths, where ground layer structures were considered, with the average values by all the equations. As mentioned, the scour depths were estimated assuming that scour would not occur within the design period of bridges in case of rock due to its high resistance to scour. In most cases, scour depths were calculated smaller than average scour depths due to the depth of rock.

3.4 Assessment of bridge scour vulnerability

3.4.1 Assessment of vulnerability by analysis

The assessment of the scour vulnerability for the subject bridges is enabled by the analysis of bearing capacity before and after scour considering the expected scour depth carefully analyzed through scour analysis. In this study, bearing capacity and the vulnerability of bridge foundation using detailed site investigation and scour analysis was analytically researched, and also applicability of bridge scour management system developed through the analysis using the program of the BSMS was estimated.

The vulnerability rating system of bridge foundation due to scour is divided into two parts through the comparison between expected scour depth and embedded depth of foundation. When expected scour depth is larger than foundation embedded depth, it is divided into level 1 in danger and level 2 in danger, while when expected scouring depth is smaller than foundation embedded depth, as per the reduction ratio of the bearing capacity of foundation, it is divided into the levels 3 ~ 5. After result of the assessment of bearing capacity of the foundation before and after scour on the subject 20 bridges in this study, the vulnerability assessment for the bridge scour appeared as shown in the Tables 2 and 3.

As spread footing is constructed on the solid layer having relatively small embedded depth, the reduction of bearing capacity of foundation could be greater even from the occurrence of small scour. As shown in the Table 1, out of 8 bridges where the foundation is not embedded into the rock, 5 bridges showed the decrease of bearing capacity of foundation after the occurrence of scour reaching less than 2.0 in its S.F., that was estimated as the level 4 in its vulnerability rating. Furthermore in case of Gowontong Bridge, Ongnyeo 1 Bridge, Godan Bridge, where the foundation is not embedded in rock, and expected the scour depth is deeper than the embedded depth of the foundation, they showed the results that the bearing capacity of all foundation failed caused by the loss of grounds (Figure 10). In case of those three bridges, after result of comparing the expected scour depth and the embedded depth of foundation regularized with bridge pier width, vulnerability rating appeared into level 2, and it was expected that the stability of foundation would be in serious danger during the occurrence of flood of design frequency event. In case of four bridges where foundation is embedded into the rock (Banddo Bridge, Yongdae

TABLE 2. BRIDGE SCOUR VULNERABILITY ASSESSMENT (SPREAD FOOTING)

Bridge No.	Bridge Name	Adjusted Scour depth(m)	Bearing Capacity (t/m^2)		**Scour Vulnerability**	**Safety Factor (S.F.)**	**Vulnerability Grade**
			Before	After			
2	Bangdo	2.1	7562	7283	**1.46**	**2.06**	**5**
3	Yongdae	1	2811	2697	**1.27**	**2.36**	**5**
4	Shinpyung	2.25	278	113	**2.45**	**1.22**	**4**
5	Gowontong	1.8	317	0	**-**	**0**	**2**
6	Woljeong	2.31	404	235	**1.72**	**1.75**	**4**
7	Jangsoo 1	0.5	6003	5948	**1.12**	**2.68**	**5**
8	Ongnyeo 1	2.7	338	0	**-**	**0**	**2**
9	Godan	1.6	240	0	**-**	**0**	**2**
10	Mooui	2.61	482	291	**1.66**	**1.81**	**4**
11	Hangye	1.9	6205	5926	**1.41**	**2.12**	**5**
12	Ganpyeong	2.35	377	206	**1.84**	**1.63**	**4**
13	Songcheon	3.99	507	215	**2.36**	**1.27**	**4**

TABLE 3. BRIDGE SCOUR VULNERABILITY ASSESSMENT (PILE FOUNDATION)

Bridge No.	Bridge Name	Scour Depth(m)	Exposed Pile Length(m)	Bearing Capacity(t/m^2)		**Scour Vulnerability**	**Safety Factor (S.F.)**	**Vulnerability Grade**
				Before	After			
1	Gungchon	2.07	0.37	66.8	65.9	**1.01**	**2.96**	**5**
14	Hwasang	2.03	0.18	59.2	58.8	**1.01**	**2.98**	**5**
15	Namcheon	1.95	0.00	115.7	115.7	**1.00**	**3.00**	**5**
16	Dongmak	3.44	0.00	1195.3	1195.3	**1.00**	**3.00**	**5**
17	Imwon 1	1.56	0.00	59.6	59.6	**1.00**	**3.00**	**5**
18	Jasan	2.71	0.71	108.8	107.1	**1.02**	**2.95**	**5**
19	Joosu	2.78	0.00	76.9	76.9	**1.00**	**3.00**	**5**
20	Nakpung	2.61	0.61	73	71.5	**1.02**	**2.94**	**5**

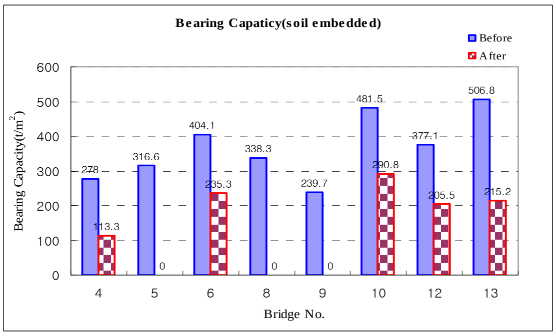

Figure 10. Change of bearing capacity in the spread footing (Non rock-socketed bridge)

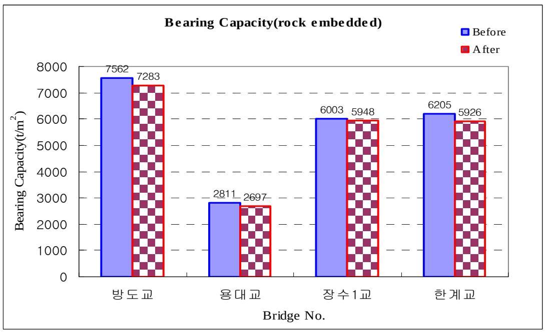

Figure 11. Change of bearing capacity in the spread footing (Rock-socketed Bridge)

Bridge, Jangsu 1 Bridge, Hangye Bridge), the portion of bearing capacity by rock cohesion is relatively high, and the bearing capacity portion by the weight reduced from scour could not have great effect on the entire bearing capacity of foundation, reaching over 2.5 in its bearing capacity safety factor together with the level 5 in its vulnerability rating.(Figure 11).

As pile foundation is constructed on the layer having relatively weak bearing capacity, it has large embedded depth. Therefore, its bearing capacity of foundation will show more stable level than the foundation of spread footing in the event of scour occurrence. (Table 3). However, in case expected scour depth is larger than embedded depth of footing, the foundation of pile exceeding a certain length will be exposed to the water flow, and then the junction between foundation and footing could be dangerously situated by the effects of lateral flowing water pressure and impact loading. Therefore, through the rating of vulnerability for the bridge by assessing the bearing capacity as well as regular scour inspection for the bridge site, the dangerous situation of foundation exposed to the water flow should be avoided in advance. The status of scour progress should be checked through the field inspection in detail, and the level 4, level 3 or level 0 in case of its serious status should be rated, and appropriate countermeasures should be prepared together with the maintenance guidance. Furthermore, in this study, it was assumed that scour would always occur at the ground over the rock layer for the purpose of establishing maintenance measure to continuously secure the safety of foundation. Therefore, when the analytical result will be applied to practice, it will be necessary to have appropriate measure and maintenance procedure from the engineering judgment of specialists, such as regular monitoring and site investigation in detail, checking of scour progress status, analysis of the scour possibility in the basin, etc.

3.4.2 System Application

In addition to the assessment of scour vulnerability of bridge through analytical research, through the bridge scour management system developed from this study, scour vulnerability assessment on 20 subject bridges were carried out. Initially, the information of field inspection priority for the subject bridges were input in the bridge scour management system, their priority of field inspection was analyzed (Figure 12), Then using the information from the site investigation in detail, concrete information on the characteristics of bridges, rivers, basin and grounds were entered. (Figure 13). In consideration of the entered site investigation in detail and the characteristics of grounds, scour analysis on the flood of design frequency event was carried out. Then the calculation of bearing capacity of foundation and

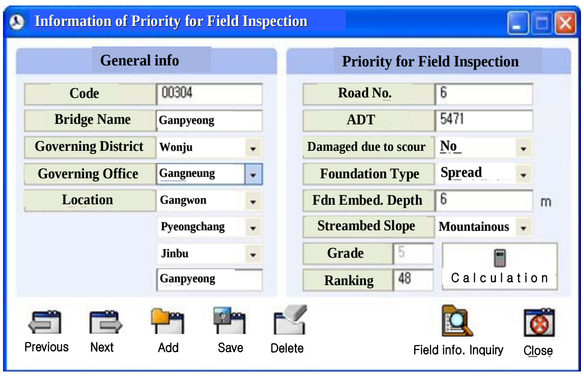

Figure 12. Screen of field inspection prioritization

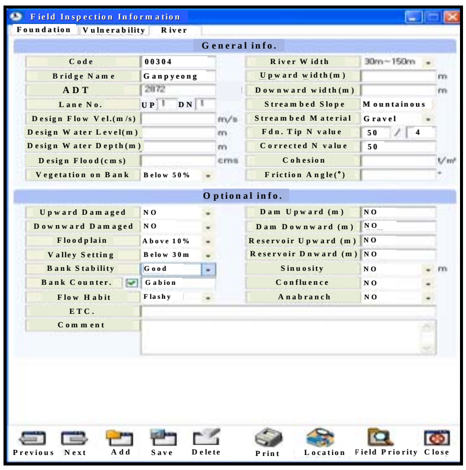

Figure 13. Screen of the detailed site investigation information entered

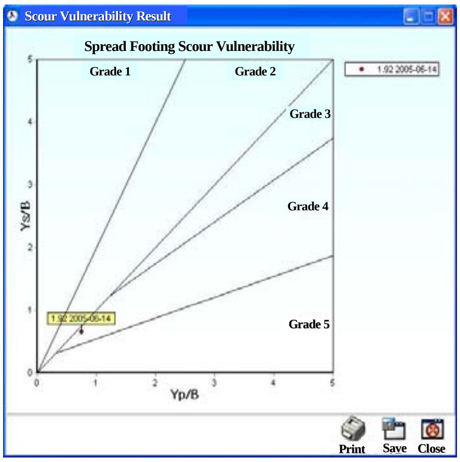

Figure 14. Result of danger assessment of spread footing (Ganpyung Bridge)

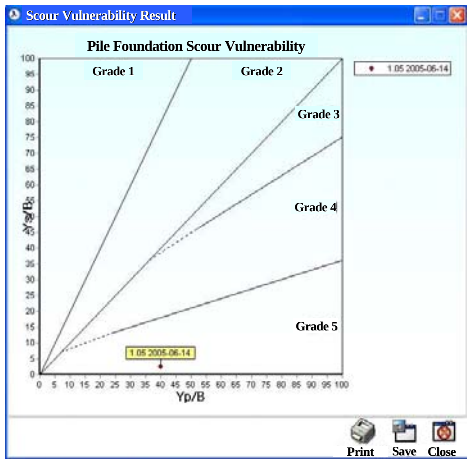

Figure 15. Result of danger assessment of pile foundation (Namcheon Bridge)

assessment of danger before and after scour were carried out in consideration of the analyzed expected scour depth, bridge foundation information and ground property. As shown in the Figure 14, Ganpyung Bridge is the bridge with spread footing, where 2.35m was expected in its scour depth. Therefore its scour vulnerability rating showed the level 4 due to the reduction of bearing capacity of foundation following the loss of grounds, while in case of Namcheon Bridge, which has a pile foundation, its scour vulnerability rating showed the level 5, as embedded depth of foundation was larger than expected scour depth resulting in the smaller reduction in its bearing capacity of foundation due to its scour. (Figure 15). It can be seen that this result is equal to that of the analytical research on the afore-mentioned assessment of scour vulnerability rating on the bridge foundation. An example of report summarizing the information management on the bridges and sites in detail, assessment of scour vulnerability rating, etc. is as shown in the Figure 16.

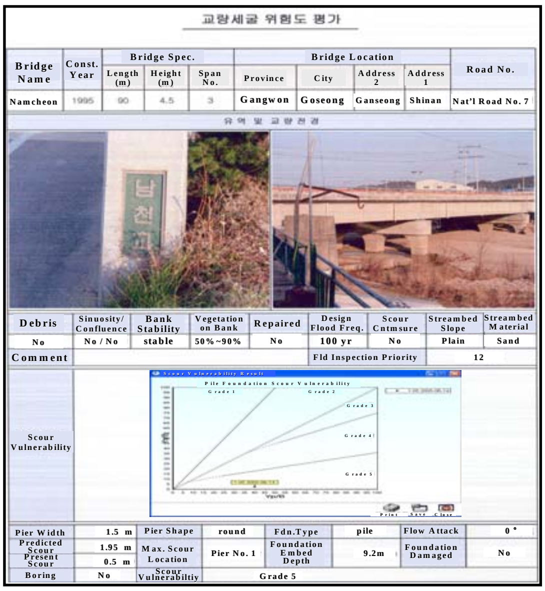

Figure 16. Screen of the report on the summary of scour vulnerability assessment (Gungchon Bridge)

4. CONCLUSION

In spite of the active researches that have been conducted on bridge scour so far, the study on its systematic maintenance system has not been handled yet. The present study has developed the bridge scour management system for securing the bridge safety and establishing the efficient anti-disaster measures. Initially, the method of deciding the priority for site inspection in detail using 4 basic information about the bridge was suggested, and then the method of assessing the bridge scour vulnerability was developed considering the change in bearing capacity of the bridge foundation resulting from the occurrence of scour. In the method of deciding the inspection priority, a logic standard to determine the priority for site inspection in detail can be suggested using the simple information such as whether there is a danger in the bridge substructure or not, type of foundation, daily traffic volume at average, and bed slopes, while in the method of determining the bridge scour vulnerability, the bridge scour danger can be assessed considering the geotechnical influential factors as well as hydraulic influential factors on the basis of the bearing capacity concept of the bridge pier-foundation-ground combined system resulting from the occurrence of scour. The bridge scour management system was developed based on the GIS-based database system together with the aforementioned field inspection prioritization decision method and vulnerability rating decision system.

In order to verify the site applicability of the bridge scour management system, case studies on the actual bridge site were implemented. Detailed case studies were performed concerning 20 bridges located in Gangneung National Road territory, which included the procedure such as the site investigation, bridge scour analysis for design flood, the associated assessment on the bearing capacity of bridge foundation and the vulnerability rating, and the comprehensive evaluation on the bridge maintenance system. After evaluating the bridge scour assessment method and the applicability of the bridge scour management system against 20 bridges within Gangneung National Road territory, the vulnerability rating of the bridge scour assessed using the bridge scour management system showed the same level as that decided from the analytical study, which ascertained that the bridge scour management system developed under this study was suitable for the correct and reasonable bridge scour vulnerability estimation through multi-disciplinary concept. It is thought that, under the background of this research, the bridge scour management system would greatly contribute to establish efficient anti-disaster measures that can ensure the safety of bridges against the occurrence of floods.

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