

# Experimental Study on Stability of Levee Protection Method

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## Abstract

For the retaining wall and technologies to protect river levee, many patents were applied and numerous new technologies were developed according to the installation method and material. This study installed a magic retaining wall block, which was developed as new technology product to protect river levee from running water, in actual size experimental water channel and evaluated the hydraulic performance and the stability of technology based on the increase in the flow velocity and discharge by steps. This study divided the experiment into a total of six steps and conducted it accordingly. According to the experiment results, there was no deformation of the surface of the magic retaining wall block or any soil loss at the bottom either, under the condition of maximum flow velocity of 5.37 m/s (discharge of 7.40 m<sup>3</sup>/s). To analyze the occurrence of scour and the possibility of soil loss at the bottom of a structure due to a high flow velocity, this study conducted an image analysis of Case 6 under the condition of maximum discharge, using a drone. According to the results of an analysis through the drone, there was no soil loss or flow change due to a scour at the bottom of the magic retaining wall block. The results of this study will serve as references in designing a technology applying a magic retaining wall block, and present the methods and procedures to evaluate and verify the development of any further new technology.

## Keywords

Magic Block, River Levee, Velocity, Discharge, Soil Loss

## 1. Introduction

A large-scale localized torrential downpour due to a climate change is difficult to predict

and interpret. And, its occurrence frequency increases continuously so that an efficient and active measure is necessary. Especially, the loss and collapse of river bank due to flood bring significant damage, so various new construction methods for securing the stability of bank and protecting river bed are being developed both at home and abroad.

According to domestic studies on the stability of levee, construction methods are being developed through patents and most studies focus on the evaluation of stability of piping and levee slope due to permeation. Kang *et al.* analyzed and evaluated the stability through the sensor installed on the levee after carrying out the penetration simulation of levee using SEEP/W which was two-dimensional abnormal-unsaturated penetration model [1]. Lee *et al.* assumed that the collapse mechanism of river levee and the hydraulic phenomenon are same in all collapses, established physical levee collapse numerical model and suggested the levee collapse discharge formula [2]. Park *et al.* carried out 2-dimensional hydraulic analysis by reflecting accurate topography before and after the project execution and suggested the hazard evaluation method of levee based on the result in order to confirm the effects of river dredging project [3], and Lee *et al.* reviewed domestic and overseas safety evaluation techniques for levee and presented the improvement measures for domestic design standards [4]. Kim *et al.* carried out the real-scale verification experiment of SPF (Scouring Protection Form) method which was the river bed protection method, calculated the critical velocity of the method and present the design standards according to the placing method [5].

The result of analyzing domestic and overseas research trends on the stability evaluation of levee showed that studies on the analysis of penetration behavior according to the stability evaluation and measurement of levee against extreme floods were carried out. Pradel and Raad evaluated the stability of levee according to the penetration effects [6], and Meer *et al.* carried out the comparison between the stability evaluation method of levee in Holland and U.S. [7]. Walder and Oconnor and Peng and Zhang carried out the stability evaluation of levee against the flood runoff, presented the critical velocity through the numerical analysis and carried out studies on the securing of stability of levee against a rapid change in the water level [8] [9]. However, most domestic and overseas studies focused on the theory analysis and numerical analysis for the flood occurrence and securing of stability of levee, and the studies on the overflow and penetration of flood water level were carried out mainly.

Various patents and new technologies were developed for retaining wall for protecting a river levee according to the installation method and materials, but since it is difficult to verify the methods developed as new technologies and patents in real-scale, it is difficult to present the result of study. Therefore, the new technology method (magic retaining wall block) developed for protecting the river bank from running water was installed on the real-scale experimental waterway in this study and the hydraulic performance evaluation and stability evaluation of the method were carried out by increasing the flow velocity and rate gradually and presented the preliminary data for installing the method in future.

## 2. Method of Study

### 2.1. Target for Study

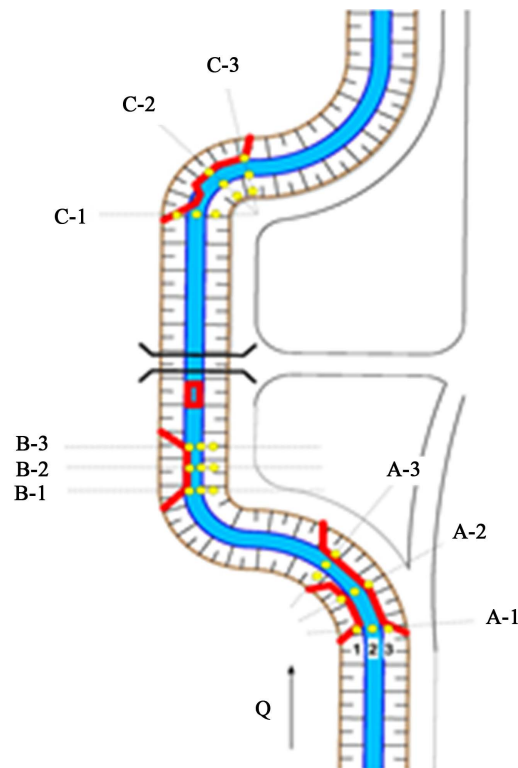
The magic retaining wall block is the method developed by Ecotop Co. and construction without using bolts and reinforcing bars and this technology also has secured the economic feasibility due to the reduction of construction costs. Also, it is eco-friendly method that soil filling and landscaping forestation are possible due to interlocking retaining wall block, so it can be installed on the slope by installing blocks in step type (**Figure 1**). The blocks used in this study are the concrete products with the size of 250 mm in diameter and 200 mm in height that synthetic fibers (PVA fibers) are used to improve the strength. Also, S-shaped block combination is applied in every direction to secure structural stability and this technology enables buffering effect through the up and down movement of blocks for differential settlement [10].

### 2.2. Experiment Condition and Method

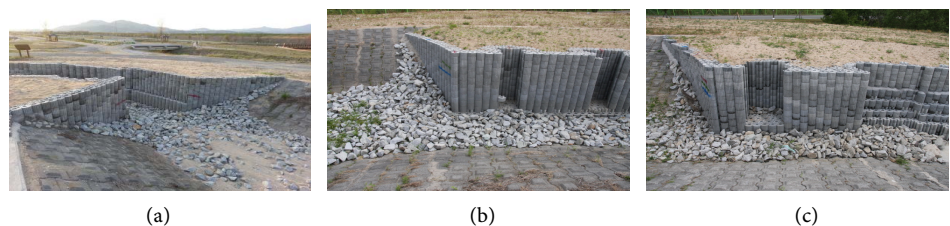
The final objective this study was the real-scale verification of new method and this experiment of the method was carried out at the River Experiment Center (REC) of the Korea Institute of Civil Engineering and Building Technology where the adjustment of flow rate and real-scale installation were available. The existing foundation layer was hardened evenly for installing the magic retaining wall block and the block was installed according to the installation manual of structure. There were 3 installation sections, and A section was installed separately into the left bank and right bank and B and C sections were installed on the left bank where the flow velocity was relatively fast (**Figure 2**). **Figure 3** shows the product installation section. The experiment was divided into 6 conditions according to the flow rate and the flow velocity was measured using the flowtracker according to the experiment condition. The flow velocity was measured using the two point method according to the depth and the momentary maximum



**Figure 1.** Eco-retaining wall blocks.



**Figure 2.** Installation section and measurement site.



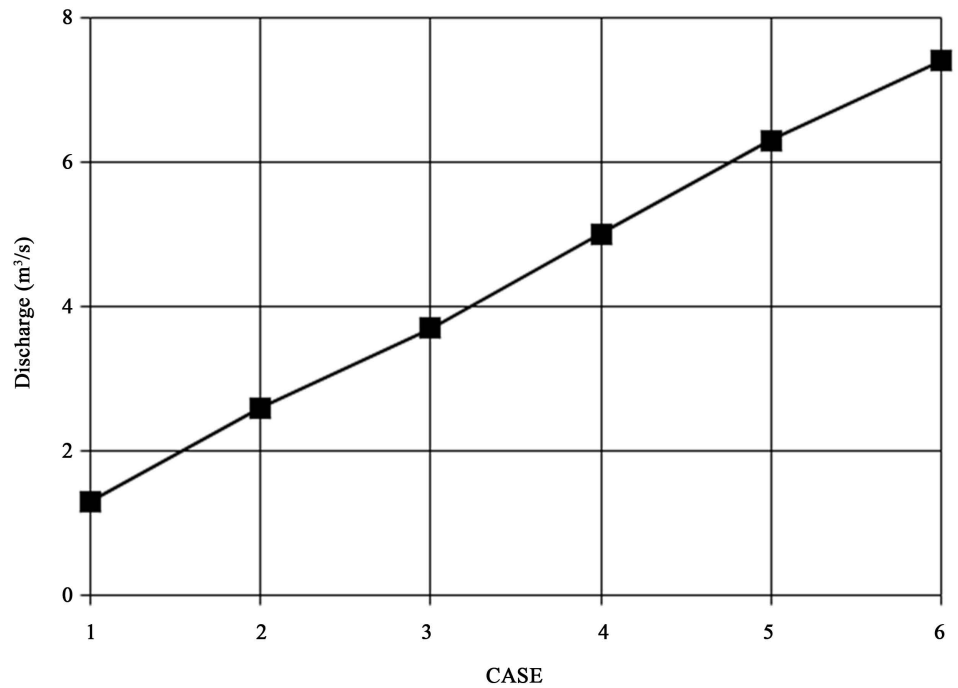
**Figure 3.** Installation of eco-retaining wall blocks. (a) A zone; (b) B zone; (c) C zone.

velocity was applied. Also, 2 - 4 hours were set as the flow time for each experiment by considering the pump condition due to the real-scale experiment and the stability on the surface of the magic retaining wall block and the stability of underpart after flow time were evaluated. In the maximum flow rate stage, the existence of scouring below the structure was analyzed using a drone. **Table 1** and **Figure 4** show the experiment condition for each case.

### 3. Contents and Result of Experiment

#### 3.1. Case 1

The flow rate condition in Case 1 is  $1.30 \text{ m}^3/\text{s}$  and the measurement result off low velocity for each siding is as shown in **Table 2**. In case of A section, the maximum flow velocity was  $2.32 \text{ m/s}$  and the maximum flow velocity was shown in the right bank. The maximum flow velocity in B section was  $2.31 \text{ m/s}$  and the maximum flow velocity in C



**Figure 4.** Discharge on CASE.

**Table 1.** Condition of experiment.

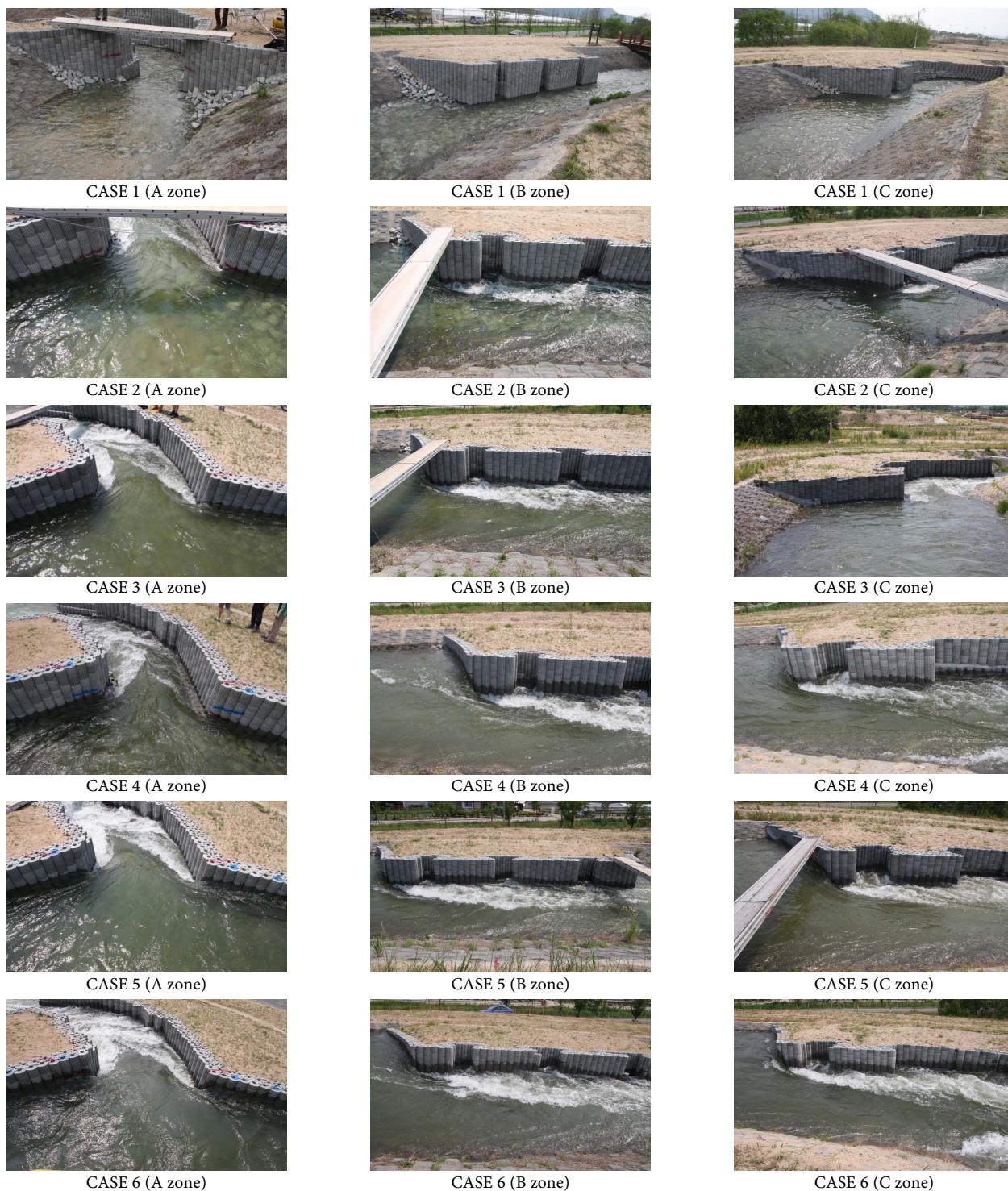
CASE	Pump	Discharge (m³/s)	Experiment time (hr)
1	A	1.30	2
2	A, B	2.60	4
3	D	3.70	4
4	B, D	5.00	3
5	A, B, D	6.30	4
6	C, D	7.40	2

**Table 2.** Experimental result on the Case 1.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	0.54	0.99	1.07
A-2	1.27	1.43	2.08
A-3	0.54	1.29	2.32
B-1	1.76	1.71	1.49
B-2	2.05	1.70	1.52
B-3	1.88	2.31	2.15
C-1	-	0.93	-
C-2	-	1.32	-
C-3	-	2.26	-



section was 2.26 m/s. The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 1 (**Figure 5**).



**Figure 5.** Flow condition on CASE.

### 3.2. Case 2

The flow rate condition in CASE2 is 2.60 m<sup>3</sup>/s and the measurement result of flow velocity for each siding is as shown in **Table 3**. In case of A section, the maximum flow velocity was 2.56 m/s and the maximum flow velocity was shown in the middle. The maximum flow velocity in B section was 2.76 m/s and the maximum flow velocity in C section was 2.26 m/s. The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 2 (**Figure 5**).

### 3.3. Case 3

The flow rate condition in Case 3 is 3.70 m<sup>3</sup>/s and the measurement result of flow velocity for each siding is as shown in **Table 4**. In case of A section, the maximum flow velocity was shown in the left bank, the maximum flow velocity was 3.21 m/s. The maximum flow velocity in B section was 2.71 m/s and the maximum flow velocity in C section was 2.95 m/s. The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 3 (**Figure 5**).

**Table 3.** Experimental result on the Case 2.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	1.36	1.40	1.36
A-2	0.67	2.19	2.45
A-3	2.29	2.56	1.77
B-1	1.99	1.86	1.68
B-2	2.71	2.05	2.76
B-3	1.88	2.43	2.40
C-1	1.14	1.21	1.20
C-2	0.95	2.26	2.12
C-3	2.01	1.02	1.12

**Table 4.** Experimental result on the Case 3.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	2.45	2.56	2.35
A-2	3.21	2.90	2.84
A-3	0.58	2.36	2.87
B-1	1.71	2.63	1.50
B-2	2.27	2.31	2.09
B-3	2.71	2.67	2.30
C-1	1.00	1.14	1.25
C-2	2.11	2.73	2.95
C-3	2.45	1.44	1.08

### 3.4. Case 4

The flow rate condition in Case 4 is 5.00 m<sup>3</sup>/s and the measurement result of flow velocity for each siding is as shown in **Table 5**. In case of A section, the maximum flow velocity was shown in the left bank, the maximum flow velocity was 3.71 m/s. The maximum flow velocity in B section was 3.17 m/s and the maximum flow velocity in C section was 3.13 m/s. The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 4 (**Figure 5**).

### 3.5. Case 5

The flow rate condition in Case 5 is 6.30 m<sup>3</sup>/s and the measurement result of flow velocity for each siding is as shown in **Table 6**. In case of A section, the maximum flow velocity was shown in the left bank, the maximum flow velocity was 4.57 m/s. The maximum flow velocity in B section was 3.34 m/s and the maximum flow velocity in C section was 3.31 m/s. The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 5 (**Figure 5**).

**Table 5.** Experimental result on the Case 4.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	2.95	3.06	2.73
A-2	3.71	3.57	3.44
A-3	1.58	3.26	3.70
B-1	2.11	3.13	2.13
B-2	2.76	2.82	2.58
B-3	3.07	3.17	2.83
C-1	1.55	1.65	1.75
C-2	2.62	3.13	2.95
C-3	2.87	1.74	1.68

**Table 6.** Experimental result on the Case 5.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	3.25	3.26	2.97
A-2	4.45	4.57	4.07
A-3	3.20	3.53	3.97
B-1	2.33	3.28	2.52
B-2	2.99	3.12	2.86
B-3	3.34	3.34	3.08
C-1	1.76	1.77	2.05
C-2	2.92	3.31	3.30
C-3	3.09	1.99	1.78



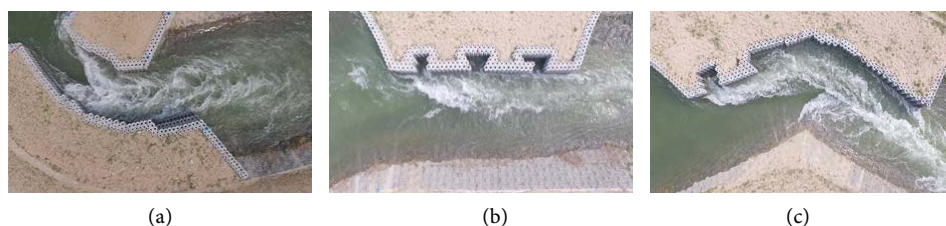
### 3.6. Case 6

The flow rate condition in CASE6 is  $7.40 \text{ m}^3/\text{s}$  and the measurement result of flow velocity for each siding is as shown in **Table 7**. In case of A section, the maximum flow velocity was shown in the left bank, the maximum flow velocity was  $5.37 \text{ m/s}$ . The maximum flow velocity in B section was  $3.89 \text{ m/s}$  and the maximum flow velocity in C section was  $3.87 \text{ m/s}$ . The result of observation on the loss and destruction of magic block after the end of experiment showed that the stability could be secured at the flow rate and flow velocity that corresponded to Case 6 (**Figure 5**).

Also, high flow velocity created scouring under the structure and loss of soil, it was observed in Case 6 which was the maximum flow rate condition using a drone. The result of observing the flow in the waterway through the drone showed that there was no soil runoff and flow change due to scouring under the magic block (**Figure 6**).

### 4. Conclusion

The purpose of this study was to evaluate the stability of new technology method, and the stability of the method was verified using the test bed where real-scale installation and experiment were available. The target for experiment was magic retaining wall block, and it was determined whether the structure was destroyed or not for each flow rate stage. Also, the magic retaining wall block in this study was located in the loop where direct external force rather than the horizontal force of flow velocity applied, so



**Figure 6.** Analysis using drone. (a) A zone; (b) B zone; (c) C zone.

**Table 7.** Experimental result on the Case 6.

Line	Velocity (m/s)		
	Left	Center	Right
A-1	3.73	3.66	3.73
A-2	5.24	5.37	5.07
A-3	4.52	4.15	4.75
B-1	2.83	3.83	3.25
B-2	3.39	3.35	3.26
B-3	3.78	3.89	3.57
C-1	2.67	2.76	2.67
C-2	3.32	3.83	3.87
C-3	3.63	2.55	2.48

the analysis of flow velocity rather than tractive force was carried out. As a result of carrying out the experiment in 6 stages, there was no deformation on the surface of magic retaining wall block and loss of soil under the block under the maximum flow velocity of 5.37 m/s (flow rate—7.40 m<sup>3</sup>/s). The result of this study can be used as reference for designing the method applying magic retaining wall block and it will be possible to present a method for evaluation and verification when a new method is developed.

## Acknowledgements

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## References

- [1] Kang, T., An, H., Lee, G. and Jung, K. (2014) Levee Stability Assessment Depending on Levee Shape and Flood Wave. *Journal of Korea Water Resources Association*, **47**, 307-319. <https://doi.org/10.3741/JKWRA.2014.47.4.307>
- [2] Lee, K.H., Kim, S.W. and Choi, B.H. (2015) Discharge Equation Related to a Levee-Break for Flood Hazard Map. *Journal of Engineering Geology*, **25**, 623-627. <https://doi.org/10.9720/kseg.2015.4.623>
- [3] Park, J.H., Kim, T.H. and Han, K.Y. (2016) Hazard Evaluation of Levee by Two-Dimensional Hydraulic Analysis. *Journal of Wetlands Research*, **18**, 45-57. <https://doi.org/10.17663/JWR.2016.18.1.045>
- [4] Lee, S.J., Yoon, K.S. and Kim, K.H. (2002) Comparison of Safety Evaluation Techniques for Levees. *Proceedings of the KSCE*, Seoul, September 2002, 1799-1802.
- [5] Kim, J.T., Kim, C.S., Kang, J.G. and Yeo, H.K. (2014) The Evaluation of Bed Protection as Placing Methods of Mortar. *Journal of the Korea Academia-Industrial cooperation Society*, **15**, 1102-1108. <https://doi.org/10.5762/KAIS.2014.15.2.1102>
- [6] Pradel, D. and Raal, G. (1993) Effect of Permeability on Surficial Stability of Homogeneous Slopes. *Journal of Geotechnical Engineering*, **119**, 315-332. [https://doi.org/10.1061/\(ASCE\)0733-9410\(1993\)119:2\(315\)](https://doi.org/10.1061/(ASCE)0733-9410(1993)119:2(315))
- [7] Meer, M.T., Woldringh, R.F. and Knuuti, K. (2009) Comparison of the Dutch and American Levee Safety Approach. *Proceedings of the ASFPM Conference*, Orlando, September 2009, 59-68.
- [8] Walder, J. and Oconnor, J.E. (1997) Methods for Predicting Peak Discharge of Floods Caused by Failure of Natural and Constructed Earthen Dams. *Journal of Water Resources Research*, **33**, 2337-2348. <https://doi.org/10.1029/97WR01616>
- [9] Peng, M. and Zhang, L.M. (2012) Breaching Parameters of Landslide Dams. *Journal of Landslides*, **9**, 13-31. <https://doi.org/10.1007/s10346-011-0271-y>
- [10] Choi, K.Y., Lee, J.B., Kyoung, M.S. and Kim, J.J. (2014) The Retaining Wall's Behavior for the Restoration of Damaged Soft Soil Area of Rapid Stream River. *Proceedings of the Korea Concrete Institute*, Seoul, April 2009, 55-56.



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