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Bridge Pier Scour Protection by Sack Gabions
돌망태에 의한 교각세굴 방지

Yoon, Tae Hoon* / Kim, Dae-Hong** / Lee, Ji-Song***
윤 태 훈 / 김 대 홍 / 이 지 송

Abstract

Experimental studies were conducted in a clear water condition to investigate the functioning of a sack gabion as a scour countermeasure at bridge piers. For different sizes of fill materials of sack gabions no difference was observed in the initial movement of sack gabions. Significant factors on the dislodging of sack gabions are approaching flow depth and velocity, pier width, and thickness and length of sack gabions. It was observed that the stability of the sack gabions is increased in a collective body of riprap stones than the placement of individual riprap stone. The length of a sack gabion has significant effect on its initial movement and the stability of a sack gabion was found to be increased by lengthening the length of gabions. The experimental results were used to derive formulas sizing gabions for scour protection at bridge piers.
keywords : sack gabion, clear water condition, scour countermeasure, riprap, stability

요 지

정지상조건에서 교각주위에 부설되는 보호공으로서 돌망태의 성능을 조사하기 위하여 실험이 수행되었다. 돌망태의 채움재료로서 사석의 크기는 돌망태의 시동에 영향을 주지않음이 밝혀졌다. 돌망태의 안정에 중요한 인자는 접근유속과 수심, 교각의 크기, 돌망태의 길이와 두께 등으로 조사 되었다. 같은량의 사석을 사용하는 경우 개체사석보다는 돌망태와 같이 집합체로서 안전성이 크게 증가된다. 돌망태의 길이가 시동에 특히 중요한 인자로서 길이를 증가하면 안전성이 증가한다. 또한 실험 결과는 교각주위 돌망태 크기의 결정식 유도에 사용되었다.
핵심용어 : 돌망태, 정지하상조건, 세굴보호공, 사석, 안정성

* Member, Professor and Dean, Department of Civil Engineering, Hanyang University, Seoul, Korea
한양대학교 토목공학과 교수
(E-mail : thyoon@email.hanyang.ac.kr)

** Researcher, Water Resources Institute, KOWACO, Deajon, Korea
한국수자원공사 수자원연구소 연구원

*** President, Kyung In Canal CO., LTD., Incheon, Korea
경인운하주식회사 대표이사

1. Introduction

In attempting to prevent local scour around bridge piers, numerous methods have been devised. These devices include structural additions to piers, various mats placed at the base of piers, rock ripraps, concrete blocks and gabions placed around piers. Such devices can be grouped into three categories; armoring countermeasures, flow altering countermeasures and structural additions. Gabions have been mainly used in river training, channel protection, bank protection, and protection for inlet and outlet structures. Of the devices the sack gabions, specially, are increasing in use as an alternative to ripraps as a scour protection devices around bridge piers because ripraps are not available or expensive in certain areas. The gabions have many distinct advantages over other devices such as flexibility, strength, permeability, durability, economy and ecology. It is especially economical because of easy installation, little maintenance, ease of finding suitable fill materials on site or from nearby quarries. Maynord(1995) proposed a design procedure for a sizing gabion mattress based on depth averaged velocity for channel protection. The objective of this paper is to investigate a sack gabion as a scour protection device and to present a method determining the size of gabions in clear water condition.

2. Experiments

Experiments were conducted using a 20m long, 0.6m deep and 0.90m wide flume with a recess of 2×0.15m filled by sand. Three different circular piers fabricated from acrylic plastic cylinders having diameters 2, 3, and 5cm were used. The sack gabions have three different lengths and a single diameter. The gabions were placed in a circular area of diameter of 20cm around the pier. Except the area filled by gabions, the floor of the flume was finished by a mortar, and all the experiments were performed in a clear water condition, and the piers were placed in the movable bed portion of the flume.

First the predetermined pier and sack gabions were placed in the sack gabion area, and the tailgate at the end of flume was raised. The flow was increased slowly until the desired discharge was attained such that the sack gabion remained stable. By adjusting the tailgate, observations were made for dislodging of the sack gabions. Some sack gabions at the sides of pier were first dislodged and moved downstream from the sack gabion area, which define a critical condition of sack gabions. When this critical condition was reached, the undisturbed water depth was measured and the cross sectional area was obtained. The critical velocity uc was calculated as the given discharge divided by the cross sectional area. The sack gabions placed not in the flow direction initially were observed to move first and to be aligned by themselves to the flow direction. For this reason, the gabions were placed parallel to the flow direction throughout the experiments.

Four different sack gabions were used in the experiments and their dimensions are given in Table 1. For channel protection, the mattress thickness in the tests of Simons et al.(1984) ranged from $1.33D_p$ to $3D_p$, where D_p is the

Table 1. size of sack gabions

No.	Riprap Diameter D_p(mm)	Gabion Thickness t (mm)	Gabion Length L (mm)
1	2.67	7.2	14.4
2	2.13	7.2	7.2
3	2.13	7.2	14.4
4	2.13	7.2	28.8

average filling riprap diameter. Maynord(1995) proposed a minimum gabion thickness of $t=2D_p$. However, since the thickness of riprap scour countermeasures at bridge piers are suggested to be three stone diameters(d_{50}) or more (HEC18), the same criterion was adopted in this study, i.e., the diameter of the gabions was determined based on the thickness of three layer of riprap stones.

3. Experimental Results

The initial movement of gabions occurred at sides of the pier and the dislodged gabions were moved towards to the center of the flume just behind the pier. In some cases the movement of gabions behind the pier at high velocities was observed. In all cases no movement of the gabions in front of the pier was noted.

Tests were conducted to investigate the behavior of gabions made from different sizes of fill materials. Fig. 4. shows critical velocities for two different gabions filled by ripraps having median particle size, d_{50} of 2.13mm and 2.67mm. The results are almost identical implying that the size of fill materials makes no difference in the initial movement of gabions in the form of collective body.

For the same quantity of ripraps placed around bridge piers, ripraps in a sack gabion are more resistive to flow than individual riprap and this fact is demonstrated in Fig. 5.

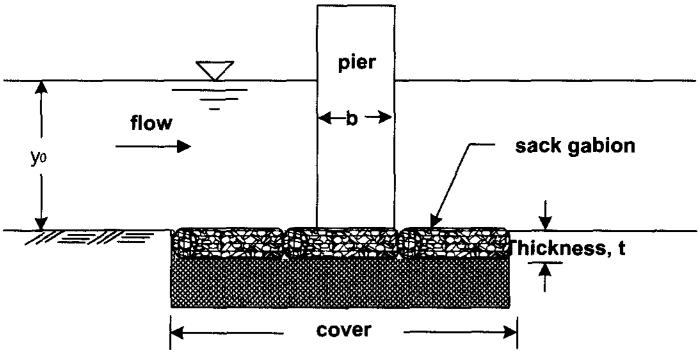

Fig. 1. Definition sketck of layout of sack gabion

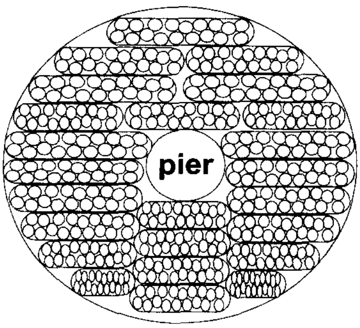

Fig. 2. Layout of sack gabion around a pier

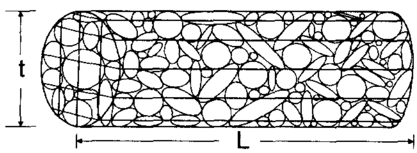

Fig. 3. Sketch of sack gabion

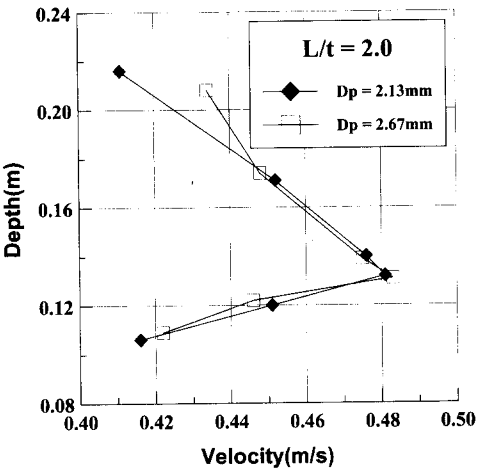

Fig. 4. Critical velocities of sack gabion with different sizes of fill materials

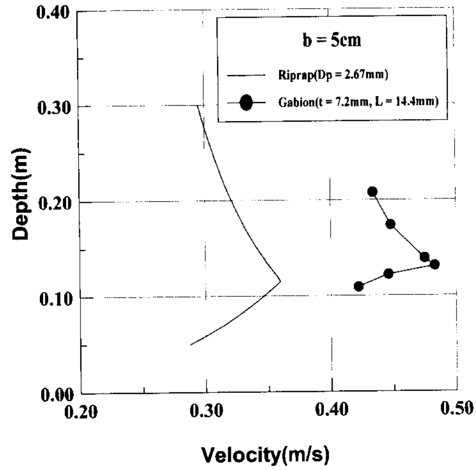

Fig. 5. Comparison of critical velocities of individual riprap and a collected body of ripraps(Gabion)

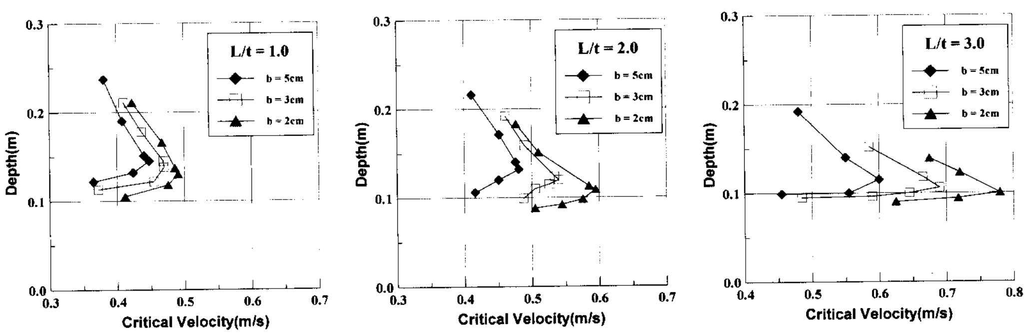

Fig. 6. Effects of gabion length, pier diameter and flow depth on critical depths

The sack gabion filled with about 18 riprap stones in median grain size of 2.67mm has much higher critical velocity than a single riprap stone of the same size placed in three layers. In the figure 7.2mm/2.67mm = 2.7 implies that the ripraps are placed in overlapped three layers.

As can be seen in Fig. 6. the critical velocities decrease with increasing diameter of piers as observed in ripraps placed around circular piers(Yoon, 1997). This implies that the pier size is one of dominant factors on the stability of both ripraps and sack gabion as a scour countermeasure. The two different regions for low and high flow depths were observed as in riprap countermeasures for scour protection around bridge piers. The initial movement of sack gabions are very sensitive to its length. The critical velocities increase with increasing length as can be seen in Fig. 7., hence it proved that the longer sack gabion becomes more stable. For instance, the critical velocities are increased 30 to 60% depending on the diameter of pier by lengthening the

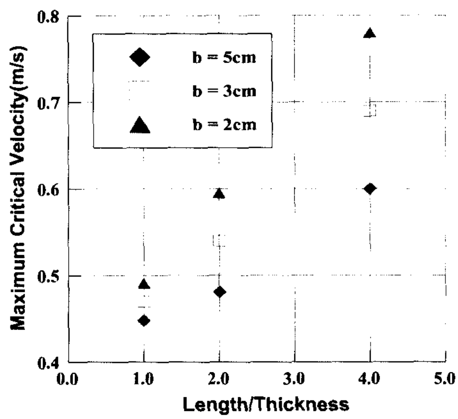

Fig. 7. Maximum critical velocity Variation with length of gabion

gabions from L/t=1 to 4.

4. Formulas for Sizing Gabions

The pertinent variables applicable to the stability of the sack gabions are

$$f(y_0, u_c, L, t, b) = 0 \quad (1)$$

Where y_0 is the approach flow depth, b is the pier width, u_c is the critical approach velocity averaged over flow depth, L is the length of sack gabion and t is the diameter of sack gabion. Maynord(1995) adds other governing factors on stability such as riprap gradation, wire size, coating, mesh opening, and filter requirements. However, from Fig. 5. it can be presumed that the gradation of ripraps is not a significant factor.

For the derivation of formulas determining the size of gabions, dimensionless quantities are defined as

$$y_r = y_0/b\,,\quad u_r = u_c/U_c\,,\quad L_r = L/t\,,\quad b_r = b/t \quad (2)$$

where U_c is the critical velocity of riprap placed over entire flume bed without pier and is given by Chiew(1995) as

$$U_c = \{0.056(S_s - 1)gD_p\}^{1/2} \times 7.66\,(y_0/D_p)^{1/6} \quad (3)$$

where S_s is the specific gravity of riprap stone, g is the gravity and D_p is the diameter of riprap stones.

Fig. 8. shows the relationship between nondimensional flow depth and critical velocity for different pier diameters and nondimensional lengths of the gabion (L/t). The curves consist of two line segments with different slopes in opposite sense. As the length of gabion increases, the curves move rightward and this family of curves for different length of gabions and for various pier widths can be combined into a single curve as in Fig. 9.

The two segments of the curve can be represented as

for upper segment,

$y_0 \geq$ 15.53 L-0.198t1.048b0.150

$$L = 1.92 \times 10^{-8} u_c^{5/39} y_0^{2.5} t^{-4.97} b^{0.77} \quad (4)$$

for lower segment,

$y_0 <$ 15.53 L-0.198 t1.048 b0.150

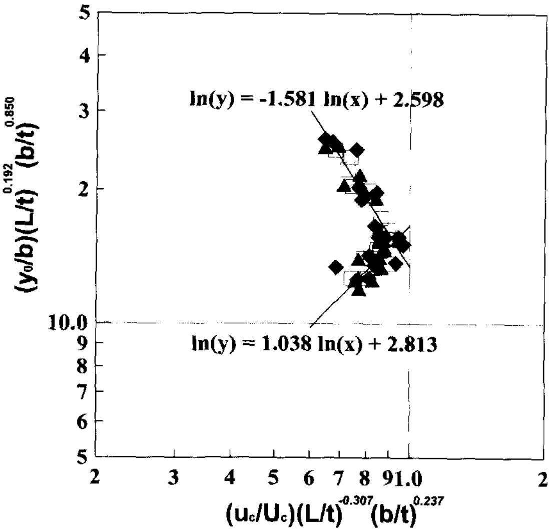

Fig. 8. Relationship of yo/b and uc/Uc for different b and L/t

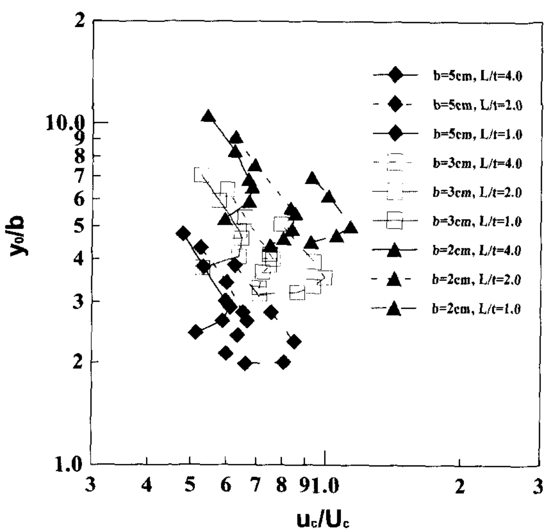

Fig. 9. Representation of various factors by a single curve

$$L = 8.576\, u_c^{1.99} y_0^{-2.25} t^{1.50} b^{0.76} \qquad (5)$$

For given pier width(b), flow conditions(y_o, u_c), the thickness of gabion, t is assumed based on the thickness of three stone layers, then the length of gabion can be determined from eq. 4 or 5 whichever is larger.

5. Conclusions

For examination of the behavior of sack gabions filled by riprap stones as a scour countermeasure at bridge piers and for sizing of sack gabions, experiments were carried out in a clear water condition. The effect of size of filling materials of the gabions on its initial movememt is found to be negligible. It was found that the stability of riprap scour countermeasures can be improved in a collective body rather than an individual riprap. Also observed is that the sack gabions become much more stable by increasing its length. Experimental formulas sizing sack gabion were derived in terms of length and thickness of gabion, critical velocity, approach flow depth and pier width. Additional governing factors on stability such as riprap gradation, wire size, coating, mesh opening, and filter requirements call for further research.

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