LABORATORY OBSERVATIONS ON THE USE OF GEOBAGS AS SCOUR COUNTERMEASURE FOR WINGWALL ABUTMENTS

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This paper presents observations and data from laboratory experiments involving the use of geobags as a countermeasure to protect bridge-abutment foundations from failure attributable to scour of the alluvial-river channel in which they are placed. The experiments were conducted using a pile-supported wingwall abutment that retained an erodible embankment, and they involved live-bed flow conditions. The observations show that geobags, deployed as an apron, can be effective in reducing scour depth at an abutment, but scour itself may be shifted to a location flanking or downstream of the apron. Additionally, the observations indicate the importance of protecting the bed region beneath and immediately behind the abutment's pile cap. The observations are sufficiently general as to pertain to other forms of scour countermeasure.

1 Introduction

There is evident promise that bridge-abutment failure owing to scour can be reduced significantly by armoring the river bed at the abutment from erosion, or by minimizing the hydrodynamic forces exerted on the bed near an abutment. The present paper presents findings on the use of geobags placed as a bed-armoring apron around a wingwall abutment. The findings comprise a set of general observations as well as specific conclusions regarding the use of geobags. The observations and conclusions may also apply to other forms of bed armoring, such as riprap or various concrete elements, placed around wingwall abutments.

Geobags are a potentially practicable alternative to riprap, as geobags may eliminate riprap drawbacks such as the winnowing of underlying bed sediment, the availability of suitable rock, and timely delivery of rock to a bridge site. Geobags consist of geo-fabric bags filled with local sand, gravel near the bridge site, or could be filled with concrete.

The writers' flume experiments were conducted with the following objectives in mind:

1. to investigate the effectiveness of geobags as an alternative abutment-scour countermeasure to riprap;
2. to develop recommendations for the placement of geobags; and,
3. to provide a relationship for sizing geobags.

The insights from the experiments are sufficiently general as to apply to other forms of scour countermeasure, and are the focus of this paper. Geobag sizing is not discussed herein, other than to say that geobag weight should minimally be comparable to riprap.

The experiments-were conducted using wing-wall abutments, of the overall form depicted in Figure 1. They were conducted with the assumption that the channel bank upstream and the downstream of the abutment has eroded back to expose the abutment fully. This condition likely aggravates abutment scour since the abutment becomes more exposed to the approach flow and thereby increases local flow velocities and turbulence.

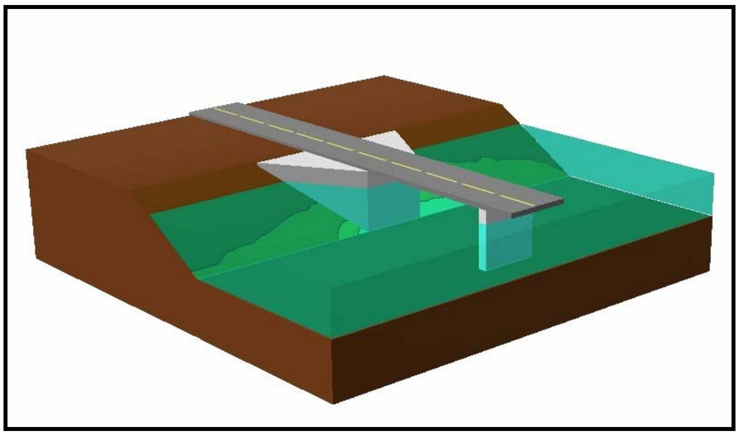

Figure 1. A wingwall abutment.

2 Experiments

The experiments-were conducted using a 27.4m-long, 0.91m-wide and 0.45m-deep sediment re-circulating flume. Uniform sediment with a median diameter d_{50} of 0.45mm was placed as a 0.23m-thick layer along the whole length of the flume. They were conducted under live-bed flow conditions, with u_*/u_{*c} = 1.5 (where u_* is the shear velocity, and u_{*c} is the critical value of the shear velocity associated with bed-particle entrainment. Flow depth was Y_0 = 100mm. The critical shear velocity u_{*c}, was determined from the Shields diagram to be 0.55m/s.

The geobags were 22-mm thick, which corresponds to the typical median diameter of riprap used for many abutments in rivers whose currents are about 0.55m/s.

The wingwall abutment used for the experiments had wingwalls set at 45^o to the bridge axis, and was pile-supported. It retained an erodible embankment, and was aligned perpendicular to flow. Figure 2 shows the dimensions of the abutment used.

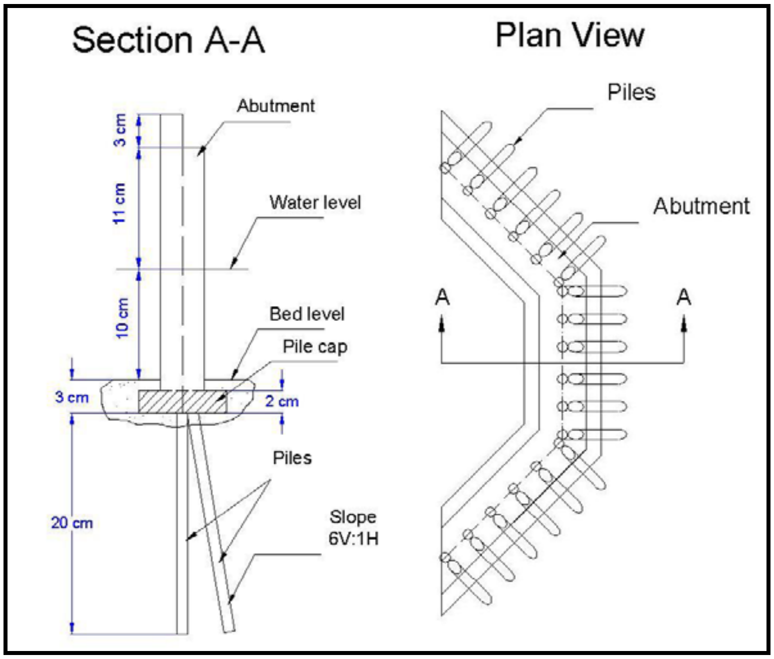

Figure 2. Model dimensions of the 45°, pile-supported, wingwall abutment used in experiments

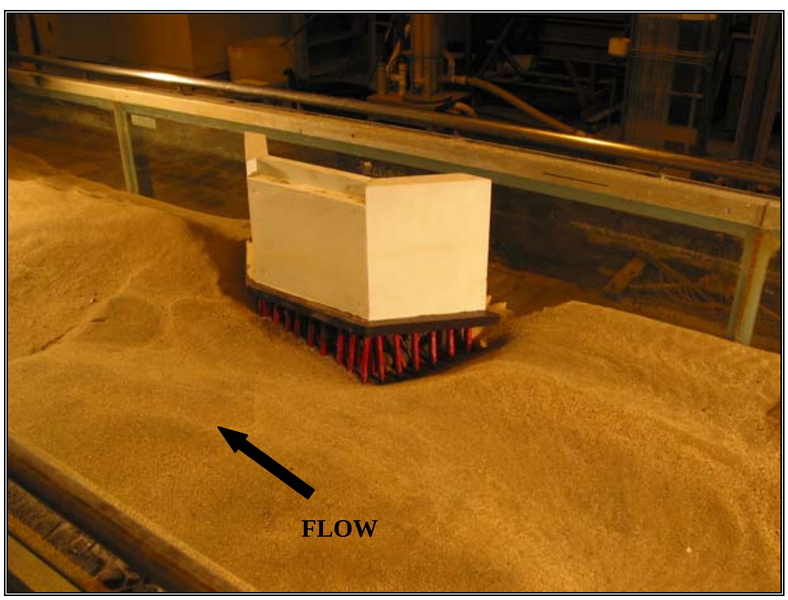

Figure 3. Scour development when only the erodible embankment was armored.

A total of twelve experiments were conducted. Table 1 lists and describes them. Full details concerning the experiments are given in Korkut (2004). The earlier experiments in the series sought to illuminate the flow field around the wingwall abutment, and to see how scour developed and the embankment retained by the abutment eventually failed. Those experiments also gave baseline data on scour at an unprotected wingwall abutment (Figure 3). The subsequent experiments were conducted to evaluate and heuristically develop a geobag deployment that would prevent scour from developing at the abutment as well as upstream and downstream of the abutment. Figures 4 and 5 show the initial deployment of geobags as an apron, and then the disruption of the apron by scour.

3 Efficacy of Geobags

The experiments show that geobags can reduce scour depth immediately at an abutment. However, scour may occur at the perimeter of the apron formed of geobags, or a short distance downstream from the apron. Figure 4 indicates the scour locations. Accordingly, scour depths were measured at three locations:

1. maximum scour depth measured in front of the abutment (A in Figure 4);
2. maximum scour depth measured in front of the apron protection (B in Figure 4); and,
3. maximum scour depth measured far from the abutment (C in Figure 4).

Geobags configured in a riprap configuration as commonly used by the Iowa Department of Transportation for bridges are shown in Figure 4. The results indicate that the apron of geobags did not entirely eliminate scour at the abutment, because of edge erosion along the perimeter of the apron, and subsequent erosion of sediment from beneath the exposed pile cap. Scour at the abutment was eliminated when the geobags were deployed with additional geobags placed under the pile cap to prevent the winnowing erosion of embankment soil through the exposed region beneath the pile cap (Experiment 7). However, though the abutment was protected, the bed scoured downstream of the geobag apron, with scour depths exceeding the maximum scour depth at the abutment for the baseline case (Experiment 1).

Also, the protection provided for the embankment sideslope enabled the side slopes to remain stable. The experiments listed in Table 1 showed that the edge failure is the principal factor that results in the failure of the geobag apron, as in Figure 5. Such failure can be eliminated or substantially reduced by connecting the geobags forming the apron, and by ensuring that the pile cap remains well protected.

4 Efficacy of Lowered Pile Cap or a Pile Curtain

Investigated briefly in the study is the merit of lowering the pile cap so as to protect the embankment fill behind the abutment. An experiment showed that a lowered pile cap (without geobag apron) resulted in maximum scour depth of d_{smax} = 0.182m (Experiment 12) at the upstream corner of the abutment. This depth exceeded the baseline scour depth

(Experiment 1), which was 0.165m. Use of a lowered pile cap is likely acceptable, provided the abutment site overall could withstand the greater scour depth.

Table 1. List of experiments-involving geobags using the form of wingwall abutment shown in Figure 2.

Experiment	Description
1: Baseline Scour	This experiment was conducted to produce reference baseline scour depth that can be used to determine the scour-reducing influence of a geobag apron.
2: Embankment Protected with Geobags	The side slopes of erodible embankment behind pile-supported abutment were protected with geobags. No geobag apron.
3: Geobag Protection Under the Pile Cap	Geobags were placed under the pile cap in addition to the side slopes to prevent winnowing.
4: Testing Performance of Riprap I	This experiment conducted to test performance of riprap to protect pile supported wing-wall abutment with erodible embankment.
5: Testing Performance of Riprap II	Experiment 4 repeated with rigid embankment.
6: Protection of Apron and Embankment	Geobags placed in a manner replicating the riprap configuration found to be commonly used for Iowa DOT bridges.
7: Geobags under the Pile Cap	Previous experiment repeated with geobags placed under the pile cap as a filter.
8: Partially Tied Geobag Apron	Only the geobags at the upper and the lower layers of the apron tied together.
9: Further-Tied Geobags	In addition to the two rows of the apron, the geobags at the half downstream part of the upper layer of the apron toe tied together.
10: Fully-Tied Apron of Geobags	The entire apron of geobags tied together.
11: Steep Embankment Slope	Performance of the geobag system used in the previous experiment tested for a steeper embankment side slope.
12: Pile cap lowered, no geobags	The pile cap placed deeper in the bed.

The results of the experiments are plotted in Figure 6, which shows how appropriate geobag use may reduce scour-depth at the abutment (d_{sA}), but with the consequence of shifting scour to positions B (d_{sB}) and C (d_{sC}); positions indicated in Figure 4).

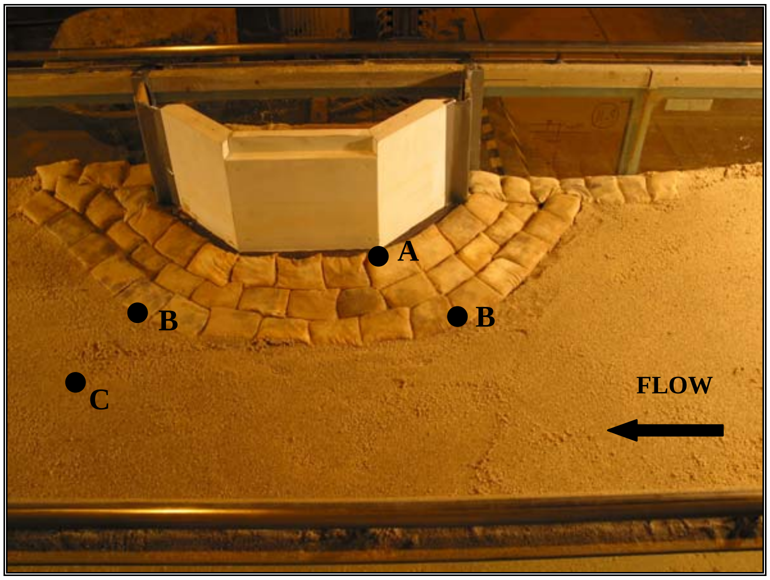

Figure 4. Geobag apron placed in similar deployment as often used for riprap layout used by the Iowa DOT abutments; the geobags were unconnected; and, the embankment sideslope was protected. Points A, B, and C mark the locations of the maximum scour depth observed in the experiments.

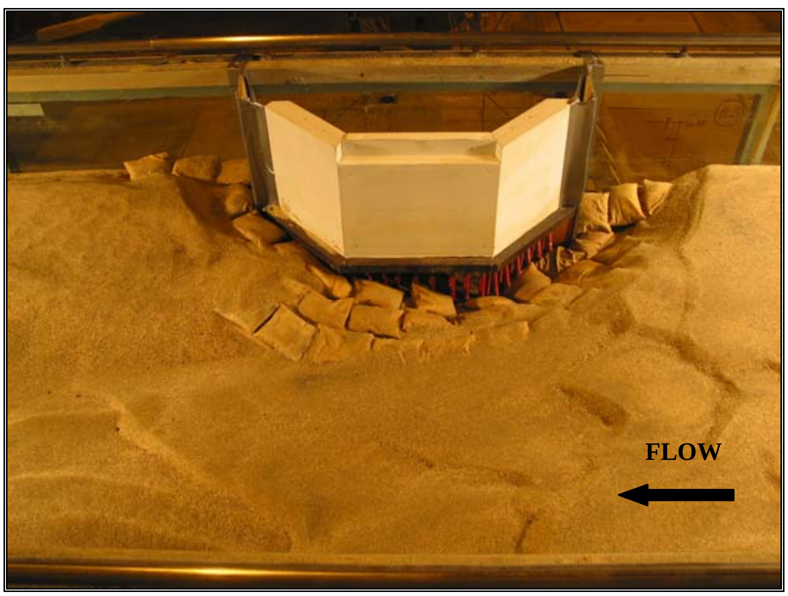

Figure 5. The scour hole developed for the geobag configuration shown in Figure 4.

5 General Observations and Conclusions

Scour cannot be eliminated completely by scour countermeasures, but instead is pushed away from an abutment. Figure 7 shows that no scour developed at the abutment itself, but significant scour occurred near the downstream edge of the apron of geobags. It is important, therefore, to be careful as to where the scour shifts. It should not be shifted towards the riverbank, or to a neighboring pier. Doing so would cause further problems such as the failure of the riverbank or the total scour around the pier. The experiments-show that it is necessary to protect the following regions of the river bed and banks near an abutment:

1. the river bed at the abutment pile cap;
2. the riverbank immediately upstream of the abutment, and a short distance downstream of the abutment;
3. the sideslopes of embankment immediately behind the abutment (standard stub for a wing-wall abutment or spill-through abutment); and,
4. the area beneath and immediately behind the pile cap.

With regard to the specific use of geobags for wingwall abutments, the following conclusions can be drawn:

1. Geobags are a promising alternative to riprap for use as a bridge abutment-scour countermeasure.
2. It is necessary to connect the geobags placed as an apron around an abutment. The initiation of the failure of geobag apron shown in Figure 5 was due to the failure of an individual geobag placed in front of the abutment.
3. It is necessary to place geobags (or riprap) immediately under the pile cap in order to prevent the winnowing of embankment sediment from beneath the pile cap.
4. Geobags may serve as a useful alternative to a geo-synthetic filter cloth placed beneath a riprap apron, because geobags are more readily placed than is a filter cloth, especially in flowing water.

Reference

Korkut, R. (2004). “Geobags as Abutment-Scour Countermeasure” MS thesis, Civil and Environmental Engineering Department, The University of Iowa, Iowa City, IA, USA.

Acknowledgement

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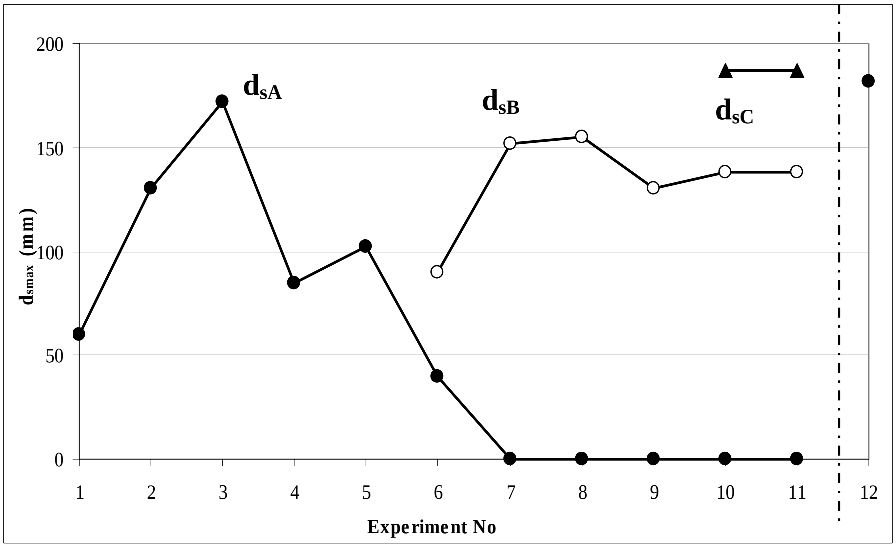

Figure 6. The maximum scour depths measured for three locations as indicated in Figure 4: A in front of abutment, B. in front of apron, and C. downstream from the apron. Experiment details are in Table 1.

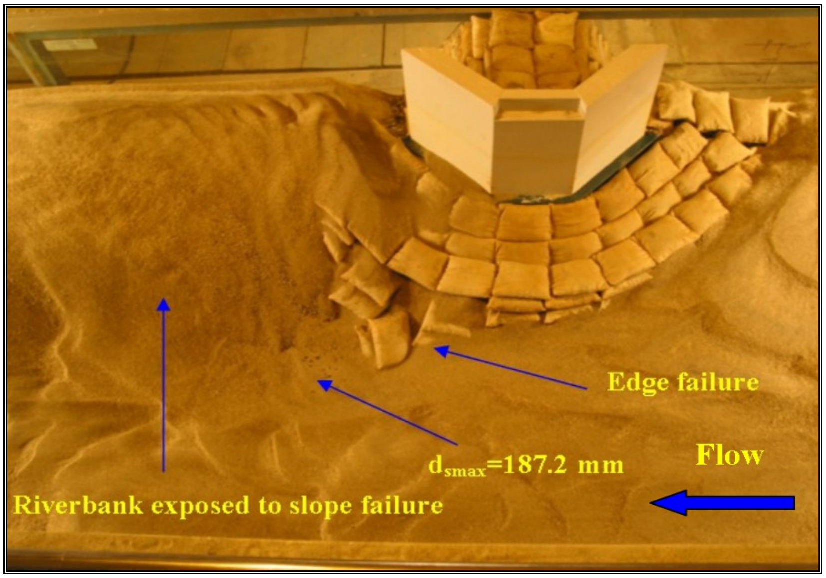

Figure 7: The deep scour depth led to both edge failure and the slope failure of the apron toe and the downstream riverbank, respectively.