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GEOBAG FOR SUSTAINABLE RIVERBANK PROTECTION

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Abstract*-Application of geotextile materials brings a new era to riverbank protection works through enhancing the durability of traditional sand filled bag. Geotextile sand filled bags or 'geobag' have many success stories in the coastal environment as submerged embankments, groins etc. Due to cheap labour and the abundance of sand, geobag structures are an environmental friendly and cost effective protection approach for the Jamuna riverbank in Bangladesh. The failure mechanisms of geobag structures are still not fully understood. This study aims to influence future sustainable design guideline for geobag riverbank protection work. To enhance the fundamental knowledge of failure progression in geobag structures, a number of laboratory experiments have been carried out. Observations from these experiments will eventually be used to validate an existing numerical model.*

Keywords: Geobag, Sustainability, Riverbank, Protection

1. INTRODUCTION

Recently, sand filled geotextile bags (**geobag**s) are being considered as a means of long term riverbank protection. Easy handling, involvement of local people and availability of local materials make the geobag a cost effective measure; the use of geobags may also be considered to be an environmentally friendly measure. However, both in coastal and riverbank protection, 'failure' mechanisms are still not well understood, and as a result Geobag structures often fail to reach their design life. Unfortunately there is no design guideline for geobag applications in coastal or river bank protection works. So far the technical information available in the literature is based on the geobag performance in coastal protection works i.e. mostly wave action on geobag structure. only the few scale model experiments of Zhu et al. [1], NHC [2], Korkut et al. [3] and Yang et al. [4] have investigated the performance for geobag protection works in rivers. On the other hand, several attempts have been made to understand the performance of geobags (sand filled geotextile bags) in coastal applications. This presents a summary of the contribution to the body of knowledge from these researches on the (i) bag design specification, (ii) geobag structure construction specification, (iii) the mechanical properties of bag, and (iv) the active hydraulic forces on the structure (Table 1).

Previous laboratory studies have shown that physical properties (i.e., filling ratio, fabric), mechanical properties (friction between geobags, overlapping of geobags), hydraulic properties (i.e., flow acting on the revetment, water depth variations), and revetment construction (i.e. the steepness of the slope, orientation of the bag with respect to flow) are the important influencing factors for geobag revetment performance.

To date, only a few parameters have been explored with relation to geobag revetment performance in a riverbank protection context, however, these studies do not consider the hydrodynamic forces associated with varying water depth and geobag protected riverbank toe stability. As a result, details of the local failure process in the riverbank protection context remain unknown. This emphasises the need for further laboratory experiments on geobag revetment performance at the local scale. As physical model results are influenced by scale effects and experimental limitations (e.g. accuracy and coverage of laboratory measurements), additional numerical models are required to determine the hydraulic loading and movement of each individual/discrete geobag in a revetment.

The first published paper on sand filled bags for bank protection appeared over more than four decades by Venis [5]. For emergency flood protection sand bags are the first choice for temporary protection. So, there are a large number of guidelines available around the world on bag design specifications, construction method and placement. These features are different than this study meant to be. For reviewing the existing guidelines, the emergency sand bag guidelines are not considered for protection against the significant amount of hydraulic forces arising in riverbank revetment.

Table 1: Findings on costal geobag structures

Parameters		Findings
Physical property	Fabric	Nonwoven needle – punched geotextile [6, 7 , 8, 9].
	Seam strength	Should be at least 80–90% of the tensile strength of the fabric [10, 11].
	Sand filling ratio	To avoid 'interlocking' problem among bags, the fill ratio should be approximately 80% [12, 13].
	Saturation of the fill	A low degree of saturation (i.e. dry sand fill) increases the capacity of the sand to absorb energy during impact on the bottom of the bag [14].
Revetment construction	Slope steepness	With experience from different type layer–to–layer over lapping, such as – face to face [5], 50% overlapping [10, 15-17],; the optimum setup can be achieve from 50% overlapping.
	Drop test	Irrespective of the initial orientation, laboratory experiments showed geobags sink under water with the largest axis towards stream wise direction if a sufficient water depth is available [18].
	Geobag launching	In the field, bag placement with its longest axis as a function of water depth between 15 m to 22 m, and a standard deviation of less than 1 m can be achieved in launching accuracy if the water depth is limited to 10 m [14].
Mechanical property	Interface Friction	The average friction angle between geobags found to be 30° [10, 13].
	Permeability	The total forces and moments for geobag displacement in a structure depend on the wave pressure propagation inside the internal gaps between bags [17].
	Deformation	The infill sand accumulates at the seaward end and leads to the deformation of the latter part of the bag. This reduces the contact areas with the neighbouring bags [17]. Then internal movements of the sand are activated by an incremental horizontal displacement of the geobags. Pilarczyk [12] reported bag rolling initiation due to internal sand movement caused by surrounding flow velocity more than 1.5 m/s.
Hydraulics	Incipient velocity	Geobag becomes unstable above a flow velocity of 1.5 m/s [12].
	Forces	In wave flume experiments, the coefficient of drag and lift forces found as a function of Reynolds numbers and the roughness of geobags (if $10^4 > Re > 10^6$) [17].

2. AIM OF THE STUDY

The main aim of this study is to influence the future sustainable guidelines on the design of geobag riverbank protection works. To achieve the specific aim a laboratory experiment study was carried out to develop an improved understanding of geobag stability under hydrodynamic loadings. Thus experiences from laboratory and field are finally combined to contribute to future design guideline preparation.

3. EXPERIENCES FROM JMREM

Since last decade Jamuna Meghna River Erosion Mitigation (JMREM) project in Bangladesh is using geobag as a means of riverbank protection. Field experiences are:

Bag design specification

According to JMREM [19] the original specifications of sand is of non–plastic, non–saline, free from silt, clay, roots, and other organic materials. The minimum grain size was of 0.08 mm and the range of Fineness Modulus is from 1 to 1.3 [19]. Bag size of 1.03 m × 0.70 m with 80% fill ratio provides a weight of 126 kg.

Construction specification

In the field, the most commonly achieved pattern after launching is one layer of geobags [19]. But using a running bond of placement, a complete coverage could be achieved with two layers of bags [19] whereas the JMREM [20] suggested that the bag layers should be 3 layers. However, presently there is no precise rule for target bonds among bags while revetment constructed. As dumping of bags resulted in reduction in thickness, the JMREM [20] project concluded with two concepts, are:

(i) a mechanized system to provide a more reliable coverage through lowering the bag wastage;

(ii) manually bag dumping from river surface.

Due to practical and local interest the second concept has been practicing even though this requires more bags. Geotechnical slope instability is a common immediate reason for failure of riverbank protection. In the consolidated soils commonly found along river banks, slopes of 1V:2H are at the borderline of stability [20].

Maintenance and inspection

The normal maintenance for geobag revetment is expected to start about 5 to 10 years after implementation of protection upto deeper scour levels [19]. JMREM [20] recommended monitoring as an integral part against revetment stability. As per recommendation these can be done through:

(i) large scale river survey (bathymetry and flow measurements);

(ii) river survey along the protected banks by means of diving investigations both for general checks at locations of specific interest and annual checks with detailed bankline survey.

Presently the Maintenance and Evaluation division of Bangladesh Water Development Board (BWDB) is responsible for monitoring.

Hydraulic parameters

The JMREM [20] suggested:

- design velocity is of 3 m/s; and
- in determining design depth, a consideration of 7 m toe scour should allow for implemented geobag revetment;

For major rivers in Bangladesh, the prediction of riverbank erosion and future planform developments has been carried out by the Center for Environmental and Geographic Information Services (CEGIS). The prediction tool based on low–water satellite images is relevant for riverbanks. Daily water level and flow velocity measurements are carried out by the BWDB in specified stations.

4. LABORATORY EXPERIMENTS

The processes involved in the failure of geobag revetments have been experimentally investigated by means of several laboratory experiments run. For this study, a scale of 1:10 (L) has been selected based on the Froude scaling law. As it was not practical to manufacture a scaled down model of the constituent materials within the geobags (geotextile and sand), so some material distortion exists in the study. From the Froude law, the velocity scale relates to the geometric scale in terms of $L^{1/2}$, so the relevant scale ratio was 3.17.

Nonwoven geotextile Secutex® 451 GRK 5 C was used for bag preparation and sand with a Fineness Modulus of 1.72 and a dry density of 1.83 was used for bag filling. As described in Section 3, the 126 kg geobag offered the best performance in Jamuna riverbank protection work, the study considered this size to be scaled down for the laboratory experiments. An 80% filling ratio for each bag was used to achieve the bag size of 0.103 m by 0.07 m of 0.126 kg to replicate the 1.03 m by 0.70 m bag of 126 kg used in field. The density of the dry geobag was found as 1596 kg/m^3. A revetment slope of 1V: 2H was maintained through this study as Korkut et al. [3] noted it as the maximum acceptable slope using geobags and also to replicate the previous laboratory work undertaken by NHC [2].

4.1 Laboratory outcomes

The hydrodynamic forces on the geobag revetment were evaluated through several individual experimental runs for four different water level conditions. Bag failure initiation was observed along with velocity measurements and the effect of bag wetness (evaluated through change in mass and bag travel distance).

The maximum velocity at the initiation of bag failure was 1.1 to 1.3 m/s, representing a field velocity of 3.5 to 4 m/s (calculated using scale 1:10), which is of the same magnitude (2.9 m/s) to that previously reported for revetments with similar side slopes of 1V:2H ([2]).The initial failure modes for each water level (W L) condition were:

- Condition A (W L up to 49% of the geobag revetment height): geobag displacement due to pressure differences between the main flow and void flow with internal sliding;
- Condition B (W L of 50 to 64% of the geobag revetment height): pressure differences between the main flow and void flow, sliding of the bag;
- Condition C (W L of 65 to 84% of the geobag revetment height): uplifting, sliding or/and pullout of the bag; and
- Condition D (W L of 85% to 100% of the geobag revetment height): overtopping washing away or pulls geobags from the revetment.

Based on the laboratory outcomes a failure map has prepared for supporting future decision makers (Fig.1).

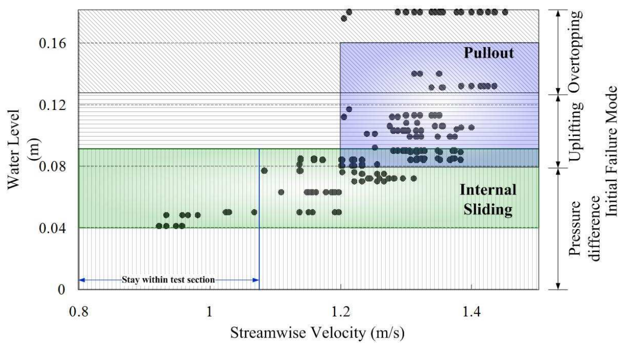

Fig 1: Failure map of geobag revetment (using laboratory measured data)

5. APPLICATION OF THIS STUDY IN DESIGN GUIDELINE

In this study, as the laboratory experiments were carried out using the scaled down geobags, an intensive measurement program of performance details could be acquired from the laboratory experiences and thus contribute to geobag revetment construction specifications and hydraulic parameters for the design guideline preparations.

The present practice of JMREM is to place a batch of geobags near the top of the bank literally just below low surface water level and the launching on slope of the river followed by the same manner of the quarry rocks [19]. The assumption behind this practice was that the geobags would slide from the dumped batch in an orderly manner in layers while toe scour progresses and thus a protected slope of 1V:2H could be achieved [19]. Here an important factor was unknown i.e. the portion of batch revetment height, contributing to slope formation. Possibly an idea can be drawn from the findings noted down under W L condition C while hydrodynamic forces acted on the bottom part of the revetment height (upto 45% of the revetment height from the bottom) experienced geobag displacements.

Overtopping observed in laboratory, the possible negative effect of this observation can be easily predicted in terms of achieving the revetment performances. In JMREM, this feature is considered through a geo–mechanical slope stability conclusion and the remedial approach above the low water level is adopted by using a sand/cement grout–filled mattress, concrete blocks, or other hard elements in geobag revetment. As this study meant to focus only the hydraulic stability concern so within the study scopes the present practice seemed a good practice and should continue to withstand against the overtopping.

During experiments in laboratory, findings showed the water flow velocity of 3.5 m/s to 4 m/s causes geobag movement initiation. This can confirm the required design velocity (i.e., 3 m/s) for JMREM can be achieved reasonably with geobags [20].

6. CONCLUSION AND RECOMMENDATIONS

The most important conclusions of this study can be summarised as follows:

- Laboratory experimental runs illustrated some distinct incipient failure mechanisms related to water level. In general, these failures were initiated through combinations of pressure differences between the main flow and void flow, partial or full uplifting, overtopping, pullout, or internal sliding. Thus through this study, decision makers will be benefited while formulating future design guideline.

- The laboratory outcomes highlighted the influence of the water level on the failure locations of geobag revetments. Despite the difference in model scale, the incipient velocity measurements showed good agreement with previous experimental work by NHC[2].

The laboratory experiments could provide information on geobag practical application in some extent. The flow nature in the field, which would be different from the experimental setup in laboratory, and also the riverbed erosion and the scouring nature of riverbank needs careful consideration. However, to overcome the scale effect a numerical model study is required. Measured data from laboratory experiment can be helpful for the model setup. An immediate potential research issue concerns the implementation of geotechnical stability models of the geobag revetment. This will allow simulation of features of permeability and durability of geobags in terms of river bank environment. This needs to be more on basic geotechnical knowledge based. Thus this study can a sustainable basis for future design guideline preparation.

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