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ORIGINAL ARTICLE

The stability of gabion walls for earth retaining structures

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Abstract The stability of earth retaining structures in flood prone areas has become a serious problem in many countries. The two most basic causes of failure arising from flooding are scouring and erosion of the foundation of the superstructure. Hence, a number of structures like bridges employ scour-arresting devices, e.g., gabions to acting on the piers and abutments during flooding. Research was therefore undertaken to improve gabion resistance against lateral movement by means of an interlocking configuration instead of the conventional stack-and-pair system. This involved simulating lateral thrusts against two dimensionally identical retaining wall systems configured according to the rectangular and hexagonal gabion type. The evolution of deformation observed suggested that the interlocking design exhibits better structural integrity than the conventional box gabion-based wall in resisting lateral movement and therefore warrants consideration for use as an appropriate scour-arresting device for earth retaining structures.

1. Introduction

According to the US Federal Highway Administration, up to 60% of bridge failures were caused by natural phenomena, especially from flooding [1]. It is apparent that since the past two decades, this ratio has not appreciably changed in many countries.

The two leading causes of failures from flooding are scouring (which can also occur without flooding) and debris impact against bridge superstructure. This debris can also reroute flows, resulting in aggravated scouring and/or increased horizontal pressures acting on bridge piers and abutments.

As known, scouring is the result of the erosive action of running water, which excavates and transports material away from the banks of streams and waterways. Different types of material scour at different rates and conditions, i.e., loose granular soils would scour more rapidly compared to cohesive soils. In addition, shifting of the stream may aggravate scour by eroding the approach roadway or changing the waterway's flow angle. Lateral movement of a waterway is affected by stream geomorphology, diversions, and characteristics of its bed and bank materials. For this purpose, gabions have long been used as scour-arresting devices on bridge abutments and piers. Apart from fortification against flooding, gabion walls are also suited to the following cases:

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1. Poor orientation of bridge piers with respect to water flows.
2. Large restrictions in flow imposed by the bridge superstructure.
3. Fine-grained materials, susceptible to move with a small increase in flow velocity.
4. Unpredictable increases in the water flow, e.g., during monsoons.

1.1. Gabion wall failures in hostile environments

Despite many apparent advantages of gabion walls in protecting bridges against aggravated scour, failures can occur if the walls are subjected to high magnitudes of lateral forces. The sudden increase in lateral thrusts tends to cause side-shifting of adjacent gabion units configured in a conventional stack-and-pair arrangement. The end result is usually large-scale lateral movement of the affected abutment or pier.

Conventional bridge designs often initially incorporate drainage mechanisms behind the backwalls and wingwalls of their abutments. The mechanism is usually achieved by depositing free-draining backfill material behind the wall, collecting the seeped-through water and discharging it into an inlet connected to a storm water system. However, clogging of the drainage system can result in accumulated hydrostatic pressure behind the wall over time, subjecting the pier and/or abutment to overstressing, consequently leading to unacceptable lateral movement. (The damage is usually more severe is cold countries, owing to repeated freezing and thawing of the accumulated water.)

When gabions are used to fortify bridge abutments and piers, the integrity of structural fixity remains the core factor in preserving bridge stability in such hostile environments. In a conventional stack-and-pair configuration of gabion units, resistance to the lateral shifting on individual units rests almost exclusively to the tie wires connecting adjacent units. There is virtually no contribution of the remaining structural components constituting the gabion unit in resisting these aggravated lateral forces, e.g., the frame, mesh, or stone fill. Since gabions are essentially gravity structures, which rely on their weight to achieve stability against lateral forces, any increase in gravity function would entail increasing their individual masses. This solution may not only be inefficient from a material perspective, but also pose settlement problems.

To resolve this problem, a research was undertaken to examine the feasibility of using an interlocking configuration of gabion units, instead of the traditional stacked-and-paired system. The system employs a continuum of hexagonal gabions to interlock with one another by virtue of shape and configuration. The new gabion design is functionally similar to the conventional box gabion, but modified conceptually in accordance with the York method used in concrete wall facings [2].

1.2. The interlocking gabion design

A simple observation of naturally occurring structures (e.g. bees' nets or crystalline arrangement for metals) suggests that in any structural continuum, interlocking properties and individual unit shape determine overall structural performance. An extrapolation of this hypothetical principal in cellular-based retaining structures, e.g., gabion walls suggest the following two possibilities:

1. A hexagonal-shaped gabion displays better strength capabilities as opposed to the conventional rectangular-shaped gabion.
2. A retaining wall composed of an interlocking system of individual gabion units display better overall structural integrity compared to a system of conventional stacked-and-paired gabions units.

These questions effectively reflect the principle that form influences function. To this end, the results of individual and cumulative experimentation investigating the hexagonal gabion's responses to external load vis-à-vis the traditional design would be examined. The findings intend to promote a new and useful contribution to the field of design and construction of such structures by disseminating the research results to the attention of engineers and offering alternate design solutions.

1.3. Technical and functional characteristics

Gabion walls are cellular structures, i.e., rectangular cages made of zinc-coated steel wire mesh and filled with stone of appropriate size and necessary mechanical characteristics. Individual units are stacked, paired, and tied to each other with zinc-coated wire (or fasteners) to form the continuum. The choice of the materials to be used is fundamental for obtaining a functionally effective structure. In particular, the mesh must satisfy the requirements of high mechanical and corrosive resistance, good deformability and lack of susceptibility to unravel. The conventional gabion possesses some peculiar technical and functional advantages as follows:

1. They are reinforced structures, capable of resisting most types of stress, particularly tension and shear. The mesh not only acts to contain the stone fill but also provides a comprehensive reinforcement throughout to structure.
2. They are deformable structures, which (contrary to popular opinion) does not diminish the structure but increases it by drawing into action all resisting elements as a complex reinforced structure, facilitating load redistribution.

They are permeable structures, capable of collecting and transporting groundwater and therefore, able to attenuate a principal cause of soil instability. The drainage function is further augmented by evaporation generated by the natural circulation on air through the voids in the fill.

They are permanent (and therefore durable) structures, with a virtually maintenance-free regime from effects no more severe than the natural aging of any other structure (with the exception of highly corrosive environments). Furthermore, their characteristics over time tend to gravitate toward establishing a natural state of equilibrium.

They are easily installed, i.e. that deployment is possible without the aid of special equipment of highly trained personnel. This aspect is notably important in river and marine reclamation, where rapid intervention to retain soil is often necessary and/or when post-deployment modifications are necessary.

2. Theory

Although retaining walls imply resistance to movement, some forms of horizontal and vertical wall yield are still anticipated.