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Experimental study of the mechanical behaviour of double twisted steel mesh gabions

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Abstract

The study of the mechanical behaviour of gabion elements is a fundamental prerequisite for an improved understanding about the overall mechanical performance of retaining structures realized using this construction technique. The paper discusses the first part of a wide experimental research program. The current article is limited to the description of the modalities to define a comprehensive experimental campaign, which involves both compression and direct shear tests. The testing matrix is designed considering several variables related to the two main components of the basic constructive element, steel cage and filling material respectively. The setup of instruments and the testing procedure are also discussed in the paper.

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Keywords: Experimental test; gabion; double twisted steel mesh; retaining structures

1. Introduction

The use of double twisted mesh gabions is a well-established technical solution for the construction of retaining structures. Nevertheless, despite the wide diffusion of this methodology, the knowledge on the overall mechanical behaviour of gabion elements is rather limited. Only a small number of studies focused on the structural behaviour of a single gabion are available [1-4]. Other studies deal with specific aspects or discuss topics only partially related to

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the final scope of this investigation [5-8]. On the other hand, the main part of the researches are focused on the understanding of the overall structural behaviour of retaining gabion structures [9-13]. Furthermore, although the gabion is a composed element (containing cage and filling material), the influence of each component on the overall performance is almost not assessable, especially in terms of deformation.

The current research aims at deeply understanding the contribution of each element to the final mechanical behaviour. The paper discusses the first part of a wide experimental research and the modalities to design a comprehensive testing program are presented. An in-depth description of the parameters mainly influencing the mechanical behaviour of gabion elements under different loading conditions are also addressed. The considered variables are related to both the containing element (gabion) and the filling material (stones). Furthermore, different loading and boundary conditions are planned: compression tests in unconfined and confined conditions, shear tests on single gabions and sliding tests on two superimposed elements. Finally, the paper deals with the testing layout and the setup of instruments, thus completing the description of the research. The experimental campaign will be started in the next period, then the test results will be presented in future papers.

2. Aims and methods

The aim of this study is the understanding of the mechanical behaviour of a gabion, considered as a constituting element of a whole retaining structure. This investigation will be carried out through a comprehensive experimental campaign. The overall mechanical response of a specimen is influenced by several parameters, hence they are considered for the definition of the testing matrix. Taking into account the constituents of a specimen, the main variables can be subdivided into two groups: the steel cage (gabion) and the filling material (stones). The full list of considered parameters is presented in Table 1. In this light, the current research aims at evaluating the capacity of each variable in influencing the overall behaviour, thus leading also to a consequent optimization of materials. The full testing matrix is composed considering all the variables listed in the following.

Table 1. List of main considered parameters.

Steel Cage	**Filling Material**
Gabion Typology	Nature of filling material
Mesh dimension	Shape
Wire diameter	Mean dimension
Mesh direction	Physical characteristics
Presence of bracings	Mechanical characteristics
Edge closure method	Filling methodology

2.1. Steel cage

The gabion typology shall consider the two main product categories, namely woven and welded gabions. Both groups are included in this experimental study.

The considered mesh sizes are 6×8, 8×10 and 10×12 in the case of woven mesh, where the first number identifies the width “M” (Fig. 1a) expressed in centimeters. Furthermore, the gabions are normally realized using different wire diameters, namely 2.7 mm or 3.0 mm. In addition to these measures, the 3.9 mm wire diameter is usually adopted to realize the so called “strong face gabions”, which are characterized by the external side of the cage having the larger diameter. This feature allows for the out-of-plane deformations of a retaining structure to be limited. A further variable related to the mesh considers its orientation, depending on the production methodology. The cage can be realized either with vertical or horizontal mesh orientation (Fig. 1b). This is mainly due to the design and installation criteria of a retaining structure and this is mainly influencing its deformation capacity.

The second relevant case considered in this study is the welded gabion. The most commonly adopted dimensions are 100 mm × 100 mm and 50 mm × 100 mm, as horizontal and vertical measures of the mesh respectively. Two bar diameters are usually adopted for welded mesh gabions, namely 4.0 mm and 5.0 mm.

As common elements between the two described categories, namely woven and welded gabions, the characteristics of bracings and the edge closure method are influencing the overall mechanical behaviour. Thus, they shall be considered into the testing matrix. The typology, number, position and wire diameter of bracings are the relevant considered parameters. “Delta-” (Fig. 1c) and “hook-”shaped bracings are considered, with 2.2 mm and 3.9 mm wire diameter respectively. 8 ties per gabions is the typical configuration.

The two common edge closure solutions are considered in this study (Fig. 1d): selvedge wire with diameter of 2.2 mm, to be manually installed, and C-rings, to be installed with Spenax tools.

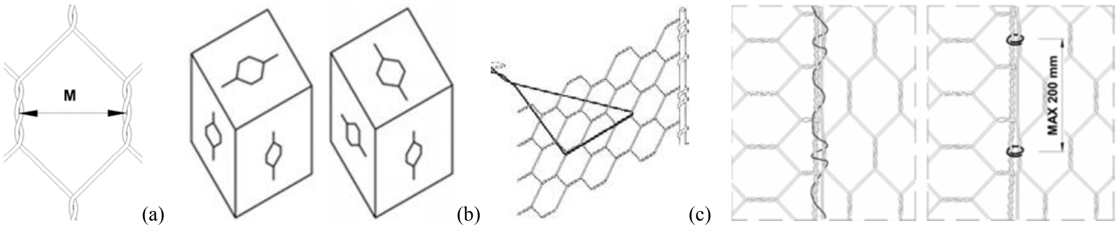

Fig. 1. Exemplification of relevant features of gabions: (a) mesh dimension; (b) vertical and horizontal mesh orientation; (c) typical “D-shaped” bracing; edge closure with lacing wire and C-rings respectively.

2.2. Filling material

The overall mechanical behaviour of a retaining structure realized through gabions is also widely influenced by the used filling material. This is then an additional fundamental aspect to be considered in designing the matrix of the experimental campaign. The nature and the shape of the filling material can influence the void index and the density of specimens, thus reflecting on the overall mechanical behaviour of a gabion. Three different stone typologies are taken into account for the realization of samples. Additionally, also the use of sand is considered for some specimens since this is a common solution, especially when greening of the outer surface of the gabion structure is required. The mean dimensions of stones range between 1.5 and 2.5 times the mesh dimensions in the case of full-scale specimens, while a decreasing is required for possible reduced-scale samples. The stone dimension is also influencing the interlock behaviour.

Further fundaments aspects influencing the overall behaviour of gabions are the physical and mechanical characteristics of these filling materials. The first feature is mainly related to the friction angle, which is affecting the shear behaviour and the horizontal deformations of the sample. The second characteristic is essentially linked to the compressive strength of filling materials, thus reflecting on the compressive strength of the whole specimen.

The main stone typology considered in the current experimental program is limestone with sharped shape and high compressive strength (approximate strength level 120 N/mm^2). The second kind of stone is represented by limestone-based pebbles having rounded shape and high compressive strength (approximate strength level 120 N/mm^2). This allows the influence of both different shape and interlock as well as different friction angles of filling materials to be evaluated. The last stone typology has not been already identified. This would have different nature typology (such as basalt or granite) and lower compressive strength. This will allow to investigate the influence of the compressive strength of filling material on the overall behaviour of a gabion.

Finally, two filling methods are usually adopted: hand- or automated-filling respectively. This also has a noticeable influence on the overall behaviour of samples. Indeed, the manual filling allows both a lower void index and a better arrangement of stones, thus reflecting in a better interlocking of filling elements. This is then guaranteeing an improved overall mechanical behaviour of the sample. The manual method is considered for this experimental campaign.

3. Testing configurations

The overall mechanical behaviour of a gabion element will be investigated through a comprehensive set of different combinations of loading configurations and boundary conditions. These have been considered being able to reproduce several real structural conditions. The whole campaign involves both compression and direct shear tests. The current experimental study will be carried out at the Research Institute ISMGEO in Seriate (BG, Italy). The facilities of the laboratory will allow to perform compression tests up to 1000 kN under either load or displacement control. The direct shear machine can reach a maximum shear load of 200 kN, applied under displacement control, and a maximum vertical pre-compression level of 100 kN, applied under Constant Normal Load. The schemes of all the testing configurations is shown in Fig. 2.

A series of three tests per each testing configuration will be carried out. In the case of a series for direct shear tests, different vertical pre-compression levels will be defined in order to evaluate the trend on the σ-τ plan.

The upper side of the samples for both testing configurations, namely compression and direct shear, will be carefully finished in order to allow the vertical load as equally distributed as possible. This will be realized through a first layer with small stone fragments coupled with an additional sand level.

3.1. Compression tests

The compressive behaviour will be studied through two different boundary testing conditions, namely confined on 3 sides and unconfined. The first condition (confinement on three sides) is considered with the aim to reproduce the real behaviour of an outer gabion part of a retaining structure. Indeed, in this case the cage is subjected to a compression load being confined by other gabions on lateral sides and either by a gabion or by soil in the back face. The confinement will be realized through ribbed steel plates mutually joined and adaptable to the geometry of samples. The second case (unconfined specimen) is considered with the aim to characterize the mechanical behaviour of a gabion considered as the basic “brick-element” of a retaining wall. This second testing configuration will also lead to an easier and better understanding about the influence of each considered variable (see section 2) on the overall mechanical behaviour of a gabion. All the specimens subjected to compression tests will have gross dimensions of 1.0 m x 1.0 m x 1.0 m. These overall dimensions have been chosen being representative of a unitary resisting cell of a gabion provided with diaphragms. Finally, the results will also lead to identify if the unconfined compression test could be a suitable and reliable methodology to characterize the overall mechanical behaviour of such a “brick-element”.

The testing control will be divided into two parts. During the first phase, when the gabion exhibits a linear trend, a stepwise load increment will be considered. Each step will consider an increment equal to 50 kPa. A waiting time of 5 minutes will be considered between two subsequent steps in order to allow for the stabilization of the sample. The testing control will be switched to displacement control once the linear trend will be overstepped. This will allow the post-peak behaviour to be investigated.

3.2. Direct shear tests

The shear behaviour will be investigated through a series of direct shear tests on two different kind of specimens, namely a single gabion and two superimposed gabions connected through lacing wire or C-rings. The first testing configuration will allow to investigate the influence of the steel mesh on the overall shear behaviour of a gabion. The second condition will lead to study the mechanical behaviour of the connection between two elements and the sliding between them. All the specimens subjected to direct shear tests will have a plane gross section of 0.7 m x 0.7 m and an overall height equal to 0.8 m. These dimensions are depending on the geometrical characteristics of the direct shear machine.

4. Setup of instruments

Two different layouts of instruments will be adopted depending on the relevant testing method. Both global and local measures are considered. The setups are presented in the following paragraphs.

4.1. Compression tests

Two similar layouts of instruments will be considered for the confined and unconfined tests. A load cell will be placed to monitor the vertical action. Several displacement sensors will allow the overall behaviour of each sample to be controlled.

- three LVDTs control the global vertical displacement of the loading plate;
- a series LVDTs coupled with a rotational are used to monitor the trajectory of local points; the central points of free sides of the gabion (1 for confined tests and 2 for unconfined tests) will be specifically studied;
- three linear wire potentiometers control the variation of the global circumferential length at different height levels; the volume variation of the cell is then monitored, and
- one linear wire potentiometer measures the length variation along a vertical line on the surface of the sample.

Furthermore, strain gauges will be also used to monitor the strain of some internal ties for relevant specimens. A schematic view of both layouts is presented in Fig. 2a and Fig. 2b.

4.2. Direct shear tests

Both load and displacement values will be monitored during direct shear tests. Two load cells will be used to monitor the horizontal shear load and the vertical pre-compression load respectively. About displacements, three LVDTs will be placed to control the vertical displacement of the steel plate used to transfer the vertical load. Furthermore, an additional LVDT will be used to record the horizontal relative displacement between upper and lower part of the test rig. A schematic view of the instrumental setup for direct shear tests is shown in Fig. 2c.

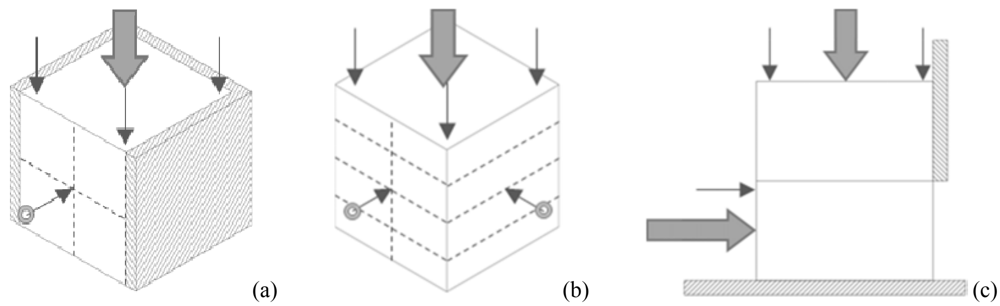

Fig. 2. Setup of instruments for confined compression (a), unconfined compression (b) and shear (c) tests. Indication of load cells (large arrows), LVDTs (small arrows), rotational sensors (circles) and linear wire potentiometers (dot lines) positions.

5. Conclusion and future developments

The paper outlines the design of a large experimental campaign aiming at improving the understanding on the overall mechanical behaviour of gabion elements. The main parameters governing their overall behaviour are identified and discussed.

Both compression and direct shear tests are planned in order to reach a comprehensive understanding of the performance of the samples. The compression tests will consider different boundary conditions, namely unconfined and confined on three sides to simulate the real field application. The setup of instruments and the related measures are also presented.

The forthcoming laboratory tests will allow an in-depth understanding of the overall mechanical behaviour of gabion elements. The influence of the relevant identified variables will be also assessed.

Future studies based on the experimental results will deal with numerical models aiming at an improved understanding of the internal mechanisms governing the overall behaviour of tested samples.

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