Study on static mechanical properties of gabion specimen

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Abstract: In order to study the static mechanical properties of gabion specimen. The experiments of unconfined compressive strength test of gabion specimens under different conditions with different parameters were conducted, including the shape of gabion specimen (Cube and Cylinder), the size (Height diameter ratio) and the specifications of wire mesh. The experimental results display as follows: 1) Gabion specimens go through four phases: elastic compression, deformation cracking, rockfill compression and rockfill crushing during the unconfined compressive strength test; 2) The contrast of cube specimens and cylinder specimens show that the vertical load of the former general appears as several alternate crests and troughs before peak appears during the vertical loading, while the latter general shows that the first crest is the peak; 3) The contrast of the cylinder specimens with different heights show that the height of the specimens have a obvious impact on post-peak strength, circumference deformation and fractures of the wire mesh. While there is no remarkable effect on peak force of unconfined compassion test by changing the height of specimens. The experimental results can provide some theoretical support for the academic study and engineering design in the future.

1. Introduction

Two thousand years ago, Li Bing took the pebble-filled bamboo cage into Dujiangyan water conservancy project to ensure the control of inundation, which made the conceptual model of gabion cage start to board the stage of history. Due to its advantages\textsuperscript{[1]-[4]}, European engineers began to use the soil-filled wicker baskets to strengthen military forts and river levees in the 16th century. On the contrary, the current research on the mechanical properties of the gabion stone cage is not enough, greatly far behind the practice.

Jiangyang\textsuperscript{[5]} performed four unconfined compression tests on gabion cages. The experimental results show that the maximum deformation occurred in the middle of the cages and the axial stress-axial strain curve was ladder-like, different in each stage. Fudan\textsuperscript{[6]} found that the gabion cage has elastic properties with large elastic modulus in the initial stage of the unconfined compression tests. As the axial strain increased, the stress rose volatility. Increasing the diameter of the metal wire plays a great role in improving the compressive strength of the gabion cage. The confined and unconfined compression tests carried out by Bertrand\textsuperscript{[7]} indicate that the layout of the filler has a distinct effect on the load capacity of the gabion cage, which leads to the difference in axial strain-stress curve of gabion cage with the same porosity. However, the specimens in the above experiments do not have a unified standard and the size and sharp of these specimens on the macro-mechanic response of gabion cage are...
not involved in these researches.
This paper aims to study the mechanic evolution and failure modes of the gabion cage under unconfined compression tests. As well as rock specimens \[8\], the shape and the size of the tested specimens were changed to investigate the influence of these factors on the macro-mechanical properties of gabion cage. The results can provide certain theory support for its engineering application.

2. **Unconfined Compression Test**

2.1. **Experimental Apparatus and Test process**
All the tests were performed on the micro-control electronic universal testing machine, WDW-100, which has an axial load capacity of 100kN and a displacement resolution of 0.01 mm, as shown in Figure 1. The axial load and axial displacement of the test machine are automatically recorded, and the axial load-axial displacement curve is drawn in real time during the test.

Specimen was put on the center of the platen, as shown in Figure 2. The experimental control mode was displacement control, and the loading rate was set at 5 mm / min. The end condition of loading was set as the axial deformation is equal to 50% of the height of the test specimen.

2.2. **Specimens**
The filler used in the gabion specimen in the sample were pebble stone and the wire mesh of the gabion cage is made of spot welding galvanized wire, square in shape. This uniaxial compression test used three cubic specimens, as shown in Figure 3. For each type of test, three groups of parallel tests were set up for each group of comparative test conditions, as shown in Table 1.

Figure 1. Experimental apparatus
Figure 2. The specimen on the testing machine

Figure 3. Gabion specimen in different shape and size
Table 1. Test conditions

| Conditions | Shape       | Size                     | Mesh Size (mm) | Wire Diameter (mm) |
|------------|-------------|--------------------------|----------------|-------------------|
| 1          | Cube        | Length 10 cm             | 6×6            | 0.8               |
| 2          |             |                          | 9×9            | 0.8               |
| 3          |             |                          | 13×13          | 0.8               |
| 4          | Cylinder    | Diameter 10cm, height 10cm, height diameter ratio 1:1 | 6×6            | 0.8               |
| 5          |             |                          | 9×9            | 0.8               |
| 6          |             |                          | 13×13          | 0.8               |
| 7          | Cylinder    | Diameter 10cm, height 20cm, height diameter ratio 1:2 | 6×6            | 0.8               |
| 8          |             |                          | 9×9            | 0.8               |
| 9          |             |                          | 13×13          | 0.8               |

3. Analysis of experiment results

3.1. The characteristics of the force-displacement curve in the whole process of uniaxial compression

In order to study the mechanical properties of gabion specimens under uniaxial compression, a group of typical curves is selected from the experiments for analysis.

Figure 4 shows the unconfined compression force-displacement curve of the cylindrical gabion specimens. The images in Figure 4 shows the corresponding pictures of each stage.

The OA segment in the curve indicates that the gabion specimens presented elastic property at the initial stage of loading, and the axial force increased approximately linearly. At this time, the pebble stone was compacted internally, and the wire mesh expands outwards without breaking. Point A indicates the first break of the wire mesh. After that, the AB segment exhibits a jagged fluctuation, in which the sharp rise and drop were caused by the sequential breakage of the wire mesh, continuous dislocation, rearrangement of the filler, and the partial crushed. The curve at point B reached a local trough, at which point the broken wire mesh forms one or several fracture zones. Due to the formation of the fracture zone, the occurrence of wire mesh fracture after the BC segment was rare and the axial force had a small increase. The wire mesh-pebble stone pressure-bearing system was gradually transformed into a stone-based pressure-bearing system. Due to the continuous compression in the CD segment, the internal stone crushed phenomenon was intensified, and the test force has been maintained at a dynamic and stable level until the end.

Figure 4. Typical Force-displacement curve of gabion cage under unconfined compression test
3.2. The influence of specimen’s shape on test results

The test results of the cube specimen and the cylinder specimen are shown in Figure 5. It can be seen from the figure that the cubic specimen had a relatively small slope compared with the cylindrical specimen in the initial rise phase of the curve.

Except for the initial rise phase, both types of loading curves of test pieces exhibited a continuous fluctuation. Both types of test pieces showed good adaptability to large deformation, and they still had high compressive capacity when the axial deformation reaches 50% of the height. Before the peak stress, there will be many obvious alternations of crest and trough in the load curve of cube specimen, that is, the first crest does not reach the peak value of the whole process.

In general, the peak compressive strength of the cylinder specimen is slightly larger than that of the cube specimen. The differences in the fracture mode of the wire mesh after the tests between cylinder specimen and the cube specimen are shown in Figure 8. The fracture of the cube specimen’s wire mesh mainly occurred at the side edges. Compared with the cylindrical specimen, the splitting opening caused by the rupture and the lateral deformation after compression of the square wire mesh were larger.

![Graphs showing test results](image_url)

(a) Mesh size 6mm × 6mm; wire diameter 0.8mm  (b) Mesh size 9mm × 9mm; wire diameter 0.8mm  (c) Mesh size 13mm × 13mm; wire diameter 0.8mm

Figure 5. Comparison of test results for cube and cylindrical specimens with the standard height

3.3. The influence of specimen’s ratio of height to diameter (D/H) on test results

In contrast, two kinds of cylinder specimens with different heights were involved in the test, and their loading curve is shown in Figure 6.

It can be seen from the Figure 7 and Figure 8 that the height of the specimen has little effect on the initial stage of the loading curve. The peak force of the cylindrical specimen with a larger ratio of height to diameter (D/H=1:2) was slightly higher than that of a standard specimen (D/H=1:1). The post-peak curve generally indicates that the load level of specimen with higher peak strength drop faster after they reached their peak strength. The residual strength of specimen with a higher ratio of height to diameter was lower than the standard specimen, in terms of both absolute deformation 50mm and relative deformation 50%. From the aspect of the failure mode, the largest deformation of the standard specimen occurred in the middle, and the fracture zone formed after the rupture of the wire mesh was small and evenly distributed.
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(a) Mesh size 6mm × 6mm; wire diameter 0.8mm  
(b) Mesh size 9mm × 9mm; wire diameter 0.8mm

(c) Mesh size 13mm × 13mm; wire diameter 0.8mm

Figure 6. Comparison of test results of cylindrical specimens with different ratios of height to diameter

(a) Cube specimens  
(D=10cm, H=10cm)  
(b) Cylindrical specimens  
(D=10cm, H=10cm)  
(c) Cylindrical specimens  
(D=10cm, H=20cm)

Figure 7. The lateral view of the broken wire cage (mesh 9mm×9mm, wire diameter 0.8mm)

(a) Cube specimens  
(D=10cm, H=10cm)  
(b) Cylindrical specimens  
(D=10cm, H=10cm)  
(c) Cylindrical specimens  
(D=10cm, H=20cm)

Figure 8. The vertical view of the broken wire cage (mesh 9mm×9mm, wire diameter 0.8mm)
4. Conclusions

The whole load curve of the gabion cage under unconfined compression test can be divided into four stages: elastic compaction, deformation and cracking of the wire mesh, stone-based pressure-bearing system, and filler crushed.

There will be many obvious alternations of crest and trough in the load curve of cube specimen during the unconfined compression test and the fracture of the cube specimen’s wire mesh mainly occurred at the side edges, while the first crest of the cylinder specimen is the ultimate strength of the whole process.

The height of the specimen has little effect on the peak strength of the gabion cage. From the aspect of the failure mode, the largest deformation of the standard specimen occurred in the middle, and the fracture zone formed after the rupture of the wire mesh was small and evenly distributed, while the largest deformation of the specimen with a higher ratio of height to diameter occurred at the upper part. The fracture zone formed after the rupture of the steel cage was large and concentrated. The crushed small pebble stone in the standard specimen was more than that in the gabion cage with a higher ratio of height to diameter.

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