Hexagonal Wire Mesh Panel Tensile Behaviour due to Weaving Patterns

Chiwan Hsieh[1], Zhi-Yao Cai[2] and Wen-Shin Shuy[3]
[1]*Professor, National Pingtung University of Science & Technology, Pingtung, Taiwan 91207*
[2]*Graduate Student, National Pingtung University of Science & Technology, Pingtung, Taiwan 91207*
[3]*ssociate Professor, National Pingtung University of Science & Technology, Pingtung, Taiwan 91207*
E-mail: cwh@mail.npust.edu.com

ABSTRACT: The tensile engineering properties of a commonly used wire mesh (120mm x150mm, ψ=4.0mm) with triple-twist (Type A) and fourth-twist (Type B) weaving methods according to the ASTM A975 test standard are studied. Wire mesh panel tensile tests loaded in the longitudinal and transverse directions with and without centre cut wire conditions and panel connection to selvedge tests were evaluated. Generally, the longitudinal tensile strengths were higher than that for the transverse tensile strengths. The Type B panel longitudinal and transverse direction tensile strengths and connection to selvedge strengths were all greater than those for Type A panel. In addition, the Type B panel showed better strength retention rates than the Type A panel with and without centre cut wire condition. The Type B panel showed better tensile behaviour than the Type A panel.

KEYWORDS: Hexagonal wire mesh, Gabion, River bank protection, Slope stabilization, Rock-fall protection.

1. INTROUDUCTION

Steel wire gabions are widely used for river bank protection and slope stabilization applications in Taiwan. However, large stones and tree trunks carried by water damage gabion wire meshes during floods and cause gabion breakage. Currently, more than 15 million square meters of wire mesh gabion have been installed for river bank protection and slope stabilization applications in Taiwan. The annual construction cost for river bank protection is more than 2 billion New Taiwan dollars (approximate 67 million US dollars). Currently, the average wire mesh gabion life-time period for these applications is only about seven years. In considering the failure mechanism, tensile strength, punch strength and wire panel connection to selvedge strength, and panel to panel connection strength are the test items for ASTM A975 standard specification for twisted hexagonal mesh gabion. If a better wire mesh construction pattern can be used in practice, the replacement cost for river bank wire gabion protection would be reduced and the safety of hydraulic structures increased. The objective of this study is to investigate the tensile behaviour of two different hexagonal wire mesh weaving patterns loaded in the longitudinal or transverse direction to provide technical information for engineers for future design applications. The wire mesh connection to selvedge strength is also investigated.

2. RELATED LITERATURES

In old times tree branches, rattan and bamboo were used to construct gabion nets. Gabions were filled with pebbles, boulders, or rock pieces for river bank protection or retaining structures. Due to the improvement in materials, galvanized steel wire is the most common material used to build current gabion structures. The Chinese version of "*Traditional Construction Technique – Introduction and Explanation of Gabions*" was published by the Public Construction Commission (PCC) (2009). Taiwan received permission from the Japanese Gabion Association to translate the design guide into Chinese. The development background, design procedure, construction details, maintenance, case studies, cost and estimation for gabions are discussed in this guide.

Muhunthan et al. (2005) prepared a research report, Analysis and Design of Wire Mesh/Cable Net Slope Protection, for the FHWA, USA. The field performance, test data and design guidelines are covered in this report. Agostini et al. (1988) presented a technical report, *hexagonal wire mesh for rock-fall and slope stabilization,* to discuss the engineering and technical details of hexagonal wire mesh for engineering applications. Bergado & Teerawattanasuk (2001) developed several analytical models for predicting the pullout capacity and interaction between hexagonal wire mesh and silty sand backfill. Sasiharan et al. (2006) conducted a numerical analysis to study the performance of wire mesh and cable net rock fall protection systems. Bertrand et al. (2008) used the discrete element method to model double-twisted hexagonal mesh systems. The engineering behavior of hexagonal mesh systems was studied using laboratory testing and numerical analysis. Lin et al. (2009) performed a laboratory study to evaluate the pull out behavior of two types of hexagonal wire meshes and two kinds of rigid geogrids. Hsieh et al. (2013 and 2015) investigated the engineering behavior of a model and a practical use hexagonal wire meshes (50 mm x 70 mm and 120 mm x 150 mm) with different structural patterns. The hexagonal wire mesh structural pattern influence on engineering behavior using the model size and full scale size specimens and load in the longitudinal or transverse direction were investigated in these studies.

3. TEST MATERIALS AND PROGRAM

Hexagonal steel wire mesh is commonly used to construct steel wire gabions for river bank protection and slope stability applications. Because machine-made hexagonal wire mesh panels are usually woven from more than 15 to 35 strings of steel wires, the length of the steel wire in each production roll is limited. A wire mesh panel would typically consist of one or two wire connections within each panel. Welding or twisting techniques are commonly used to connect the wires for production. These connections are generally the weak points in the wire mesh panel during service life or when conducting tensile or punch tests. A large reaction frame with testing machine and various grips were built to conduct full scale engineering tests of hexagonal wire mesh panels in this study.

Three half-turn (Type A) and four half-turn (Type B) hexagonal twisted wire mesh panels provided by a local wire mesh manufacturer were tested to evaluate the differences in engineering behavior during tensile tests. The mesh was woven using a nominal diameter 4.0 mm galvanized steel wires with a coating weight of 322.4 g/m^2. The tensile strength of the steel wire is 455.9 N/mm^2. The general properties of the test wire are shown in Table 1. One hundred twenty mm by 150 mm mesh opening was used to construct a near perfect hexagonal pattern wire for both type mesh panels. ASTM A975 Standard Specification for Double-Twisted hexagonal Mesh Gabions and Revet Mattresses and A370 Test methods and Definitions for Mechanical Testing of Steel Products were used in these tests. The tensile strengths for hexagonal wire mesh panel parallel to or perpendicular to twist, and connection to selvedges are specified in the ASTM A975 standard as shown in Table 2. However, the punch strength, panel connection strength and wire panel/lacing wire connection strength are also specified but not discussed in this study. Only wire mesh panel tensile tests loaded in the longitudinal or transverse direction with and without a centre cut wire and panel connection to selvedge tests were conducted. In addition, 80 mm by 100 mm and 60 mm by 80 mm are the only two type mesh openings specified in the ASTM A975 standard.

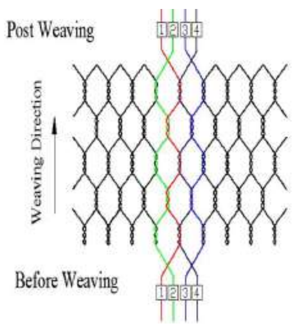
The differences in weaving pattern between three half-turn (Type A) and four half-turn (Type B) twisted hexagonal wire meshes are shown in Figure 1.

Table 1 The general properties of the test wire

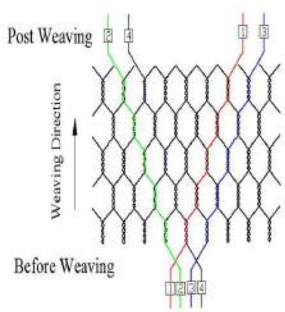
Item	Test method	Results
Wire dimension (mm)	Micrometer	4.0
Zinc coating (g/m^2)	ASTM A90/A90M	322.4
Tensile strength (N/mm^2)	ASTM A370	455.9
Elongation at break (%)	ASTM A370	19.3

Table 2 ASTM A975 Minimum Strength Requirements of Mesh and Connections

Test Description	Gabions, Metallic Coated		Gabion, PVC Coated		Revet Mattress Metallic Coated and PVC Coated	
	kN/m	(lbf/ft)	kN/m	(lbf/ft)	kN/m	(lbf/ft)
Parallel to twist	51.1	(3500)	42.3	(2900)	33.6	(2300)
Perpendicular to twist	26.3	(1800)	20.4	(1400)	13.1	(900)
Connection to selvedges	20.4	(1400)	17.5	(1200)	10.2	(700)
Panel to panel connection using lacing wire or fasteners	20.4	(1400)	17.5	(1200)	10.2	(700)
	kN	(lbf)	kN	(lbf)	kN	(lbf)
Punch Test	26.7	(6000)	23.6	(5300)	17.8	(4000)



(a) Type A weaving pattern



(b) Type B weaving pattern

(c) Type-A wire mesh, mass per unit area = 2.958 kg/m^2

(d) Type-B wire mesh, mass per unit area = 3.182 kg/m^2

Figure 1 Type A and Type B test wire meshes and weaving patterns

As shown, wire top-down (vertical) and diagonal weaving patterns were observed for three half-turn and four half-turn wire meshes, respectively. The top-down or diagonal woven patterns were used for Type A and Type B wire mesh panels, respectively. The mass per unit weight for Type A and Type B wire meshes are 2.958 kg/m^2 and 3.182 kg/m^2, respectively. Different engineering behaviors can be expected due to the differences in weaving structure and load direction in these two meshes. A schematic view of the wire mesh panel tensile test setup is shown in Figure 2. The panel tensile test panel specimen dimension was 1000 mm by 700 mm. In addition, schematic views of the wire mesh panel tensile tests with and without a centre cut wire for Type A and Type B in parallel to or perpendicular to the twist are shown in Figure 3. A schematic view of the panel connection to selvedges tensile test is shown in Figure 4. The test panel dimensions are 1000 mm by 425 mm.

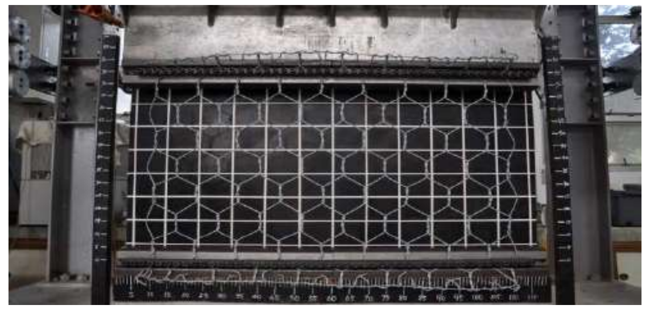
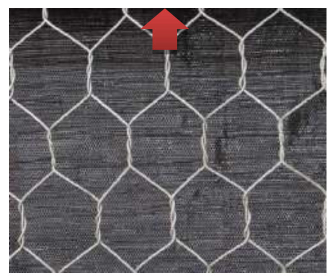
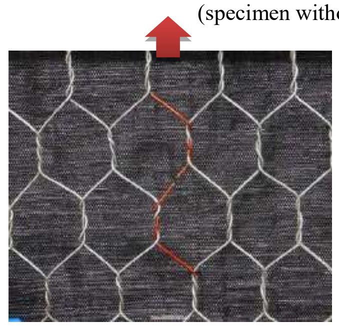


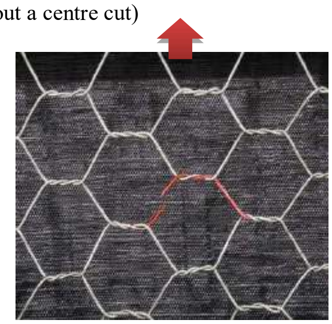
Figure 2 Schematic view of wire mesh panel tensile test setup

(Parallel to twist) (Perpendicular to twist)



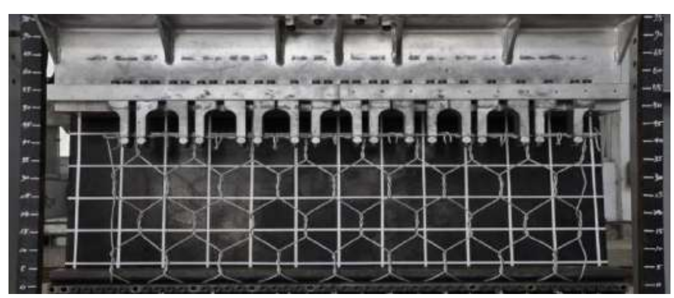
(specimen without a centre cut)





(specimen with a centre cut)

Figure 3 Schematic view of a wire mesh panel specimen without and with a centre cut

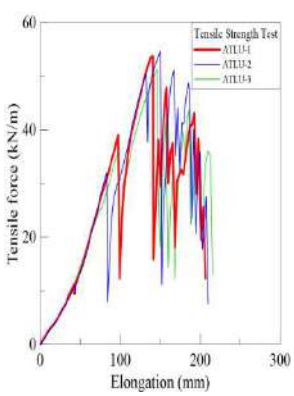


4 Schematic view of wire mesh panel connection to selvedges tensile test setup

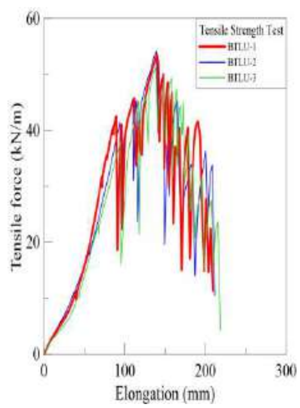
4. RESULTS AND DISCUSSIONS

A series of wide width tensile tests were conducted according to the ASTM D975 test method. The test panel sample dimensions were 1000 mm by 700 mm for the wide width tensile tests. Tensile tests for Type A and Type B twisted hexagonal wire mesh panels loaded in the longitudinal (parallel to twist) or transverse (perpendicular to twist) direction with and without one centre cut wire were conducted. A minimum of three tests were conducted for each test condition to prove the repeatability of the engineering behavior. A high degree of repeatability for the tensile tests for Type A and Type B twisted hexagonal wire mesh panels loaded in the longitudinal direction with or without a centre cut wire was achieved, as shown in Figure 5.

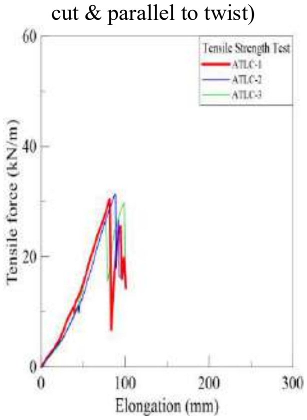
The research test condition results are discussed below. The material and test conditions are represented using four letters. The first letter indicates the test material, A for Type A wire mesh panel, or B for Type B mesh panel. The second letter T or P indicates the tensile test or punch test. The punch test results are not discussed in this paper. The third letter L or T represents the load direction either the longitudinal or transverse direction. The fourth letter U or C indicates uncut or cut center wire panel used in the test.



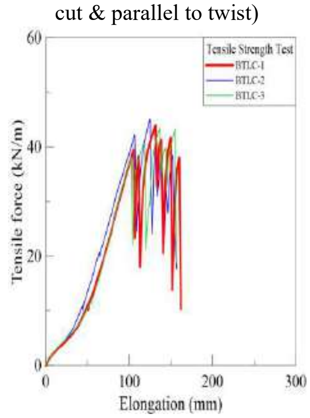
ATLU (Type A without a centre cut & parallel to twist)



BTLU (Type B without a centre cut & parallel to twist)



ATLC (Type A with a centre cut & parallel to twist)



BTLC (Type B with a centre cut & parallel to twist)

Figure 5 Repeatability of Type-A and Type-B wire mesh panel tensile tests in Longitudinal direction without and with a centre cut wire

4.1 Tensile tests loaded in the longitudinal direction without a center cut wire

The tensile test results loaded in the longitudinal direction for three half-turn (Type A) and four half-turn (Type B) hexagonal wire mesh panels without and with a centre cut wire are shown in Figure 5. Excellent repeatability was observed for both types of wire mesh panels. A drop in tensile stress was observed associated with wire breakage during the test. The typical tensile test results for both type wire mesh panels without a centre cut wire are shown in Figure 6 and Figure 3. As shown, the tensile stress versus elongation curves can be divided into three stages. The initial tensile stress versus elongation curves (stage-1) for both mesh types are quite similar to each other. Tensile forces were distributed to panel wires and transferred from the panel boundaries to the center. Wire elongation and panel necking were observed for both mesh types during the stage-1 and stage-2 loading process. Some initial elongations during stage-1 were related to the adjustment of samples between the clamps at the beginning of load stage-1. Based on observation, the elongations were contributed by both the straight and twisted wire sections of the hexagonal wire mesh during the stage-1 and stage-2 loading processes. The first peak and the ultimate tensile strength are marked as No. (1) and No. (2) as shown in Table 3.

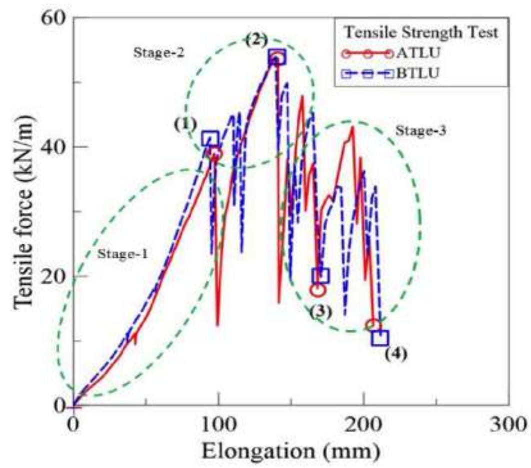


Figure 6 Typical tensile test results of Type A and Type B panel specimen loaded in longitudinal direction without a center cut wire (ATLU vs. BTLU)

Table 3 Comparison of the typical tensile test results between Type A and Type B loaded in longitudinal direction without a center cut wire (ATLU vs. BTLU)

Type or Item	mark (1)	mark (2) *	mark (3)	mark (4)
ATLU	F = 38.97 kN △= 97 mm	F = 53.67 kN △= 141 mm	F = 18.09 kN △= 168 mm	F = 12.31 kN △= 206 mm
BTLU	F = 41.47 kN △= 94 mm	F = 54.13 kN △= 139 mm	F = 19.91 kN △= 171 mm	F = 10.49 kN △= 212 mm
Strength difference (%)	+ 6.4 %	+ 0.8 %	+ 10.7 %	- 14.7 %
Elongation difference (%)	- 3.1 %	- 1.4 %	+ 1.8 %	+ 2.9 %

Notes: △ and * represent the elongation and tensile strength. Difference (%) = (BTLU-ATLU)/ATLU.

Linear stress-elongation curves were observed for both type mesh panels within the stage-2 loading process. Necking behavior was observed up to the tensile load reaching 75% of the ultimate strength (mark 1) for both Type A and Type B panel tests. The associated elongations were 97 mm and 94 mm for the Type A and the Type B wire meshes, respectively. After the first peak breakage, the tensile forces were transferred from both sides to the central region of the test specimen for both type mesh panels. Due to the straight top-down weaving pattern for the Type A panel, wire de-twisting behavior was observed near the broken wires after wire breakage. A larger opening was also observed for Type A wire panel. In addition, de-twisting behavior was not clear for Type B mesh panel after wire breakage due to the diagonal weaving pattern. However, the ultimate tensile strength (mark 2) and the associated elongation are quite similar to each other for the Type A and Type B mesh panels.

Several similar consecutive peak tensile forces were observed after the first peak tensile force occurred as the elongation continued for both wire mesh panels. In general, one peak stress is associated with breaking one steel wire. The elongation after the ultimate peak represented stage-3 elongation. A larger amount of elongation between each consecutive break was observed for the Type A mesh panel. This implied that the Type A mesh panel elongated more and quicker than the Type B mesh panel. The consecutive peak tensile forces for the Type B wire mesh panel decreased as the elongation increased. However, the elongation between each consecutive break was significantly less than that for the Type A wire mesh. This implied that the Type B wire mesh deformed less when subjected to tensile loads.

4.2 Tensile test of panels loaded in the longitudinal direction with a centre cut wire

During in-situ applications, steel wires in a panel could be broken by stones or other objects during panel service life. Therefore, it is necessary to study the engineering behavior of steel wire mesh with a broken (cut) steel wire to simulate this condition. A series of tensile tests for the Type A and the Type B hexagonal wire mesh panels loaded in the longitudinal direction with one centre wire cut was performed. The typical tensile stress versus elongation curves for Type A and Type B panels loaded in the longitudinal direction with a center cut wire are shown in Figure 7 and Table 4. The peak strength for the Type A mesh panel with a pre-cut wire was about 30.4 kN/m and the peak elongation was about 82 mm. The test panel was divided into two parts with a large vertical hole. Low load resistance and steel wire de-twisting around the pre-cut wire were observed for the Type A mesh panel. Conversely, the peak tensile strength for the Type B mesh panel was about 43.9 kN/m and the peak elongation was about 131 mm. This implies that more energy was required to cause failure in a pre-cut type B mesh panel than for the Type A mesh panel. A diagonal hole with consecutive wire breakages near the pre-cut wire was also observed for the Type B wire panel.

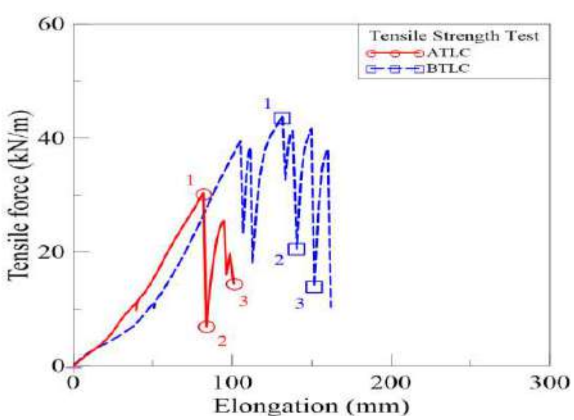


Figure 7 Typical tensile test results of Type A (ATLC) and Type B (BTLC) panel specimen loaded in the longitudinal direction with a centre cut wire

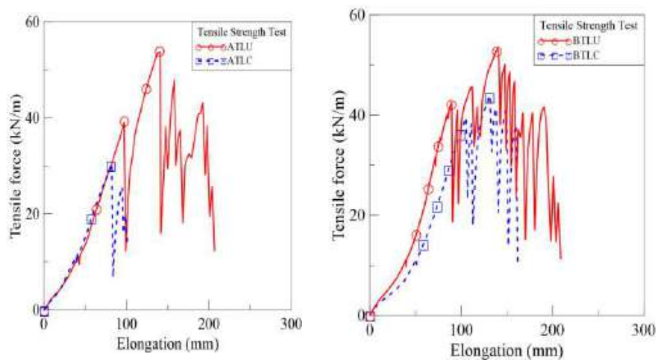
Table 4 Comparison of the typical tensile test results between Type A and Type B loaded in longitudinal direction with a center cut wire (ATLC vs. BTLC)

Type or Item	mark 1*	mark 2	mark 3
ATLC	F = 30.37 kN △= 82 mm	F = 6.82 kN △= 84 mm	F = 14.34 kN △= 100 mm
BTLC	F = 43.93 kN △= 131 mm	F = 20.54 kN △= 141 mm	F = 13.86 kN △= 152 mm
Strength difference (%)	+ 44.6 %	+ 66.7 %	-
Elongation difference (%)	+59.8 %	+ 67.9 %	-

Notes: △ and * represent the elongation and tensile strength. Difference (%) = (BTLC-ATLC)/ATLC.

4.3 Tensile tests in longitudinal direction summary

Comparing the typical tensile stress versus elongation curve for the Type A mesh panel loaded in the longitudinal direction with and without one centre cut wire is shown in Figure 8. A significant difference in mesh panel elongation occurred between the two test conditions. In addition, the typical tensile test curves for the Type B mesh panel loaded in the longitudinal direction with and without one centre cut wire were quite similar to each other. This implies that the presence of one centre cut wire in the Type B mesh panel has only a minimal effect on the tensile behaviour when loaded in the longitudinal direction. However, the Type A mesh panel showed a larger displacement and less tensile resistance after one wire was cut at the centre of the panel when loaded in the longitudinal direction. The ultimate tensile strength and associated elongation for these conditions are summarized in Table 5. As shown in the table, the retained tensile strength after a centre cut wire for Type B panel is 81.2%, which was significantly higher than the retained strength (56.6%) for Type A.



(a) ATLU vs. ATLC (Type A) (b) BTLU vs. BTLC (Type B)

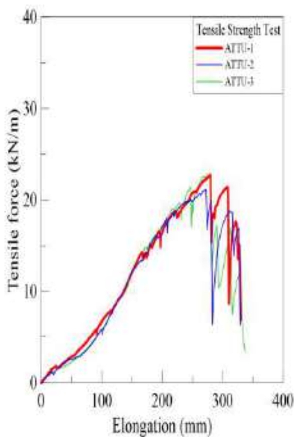
Figure 8 Comparison the tensile test results for test specimen without and with a centre cut wire for Type-A or Type-B mesh panels loaded in the longitudinal direction.

Table 5 Comparison of ultimate tensile strength for Type-A and Type-B without and with a center cut wire loaded in longitudinal direction

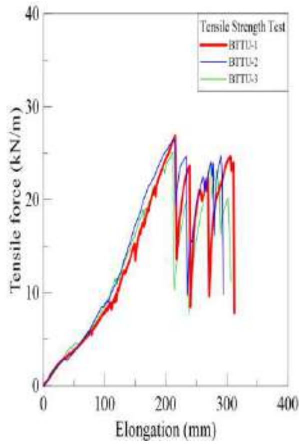
center cut wire condition	Test condition	Tensile strength (kN/m)	Test condition	Tensile strength (kN/m)	Strength difference (%)
without	ATLU	53.67	BTLU	54.13	+ 4.4%
with	ATLC	30.37	BTLC	43.93	+ 44.6%
Cut retained strength (%)	-	56.6%	-	81.2%	-

4.4 Tensile tests loaded in the transverse direction without a centre cut wire

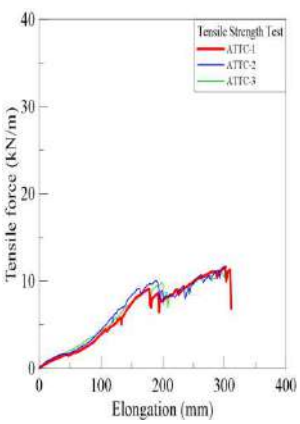
Because a wire mesh panel could be placed in a direction parallel or perpendicular to the load direction, the minimum tensile strength of hexagonal wire mesh loaded in the transverse direction is also an important material property in the ASTM A975 standard specification. Therefore, a series of tensile tests loaded in the transverse direction for three half-turn (Type A) and four half-turn (Type B) hexagonal wire mesh panels without a centre cut wire were also conducted. Three repeated tensile test results for the Type A and the Type B twisted hexagonal wire mesh panels loaded in the transverse direction are shown in Figure 9. A high degree of tensile test result repeatability is also shown in the figure.



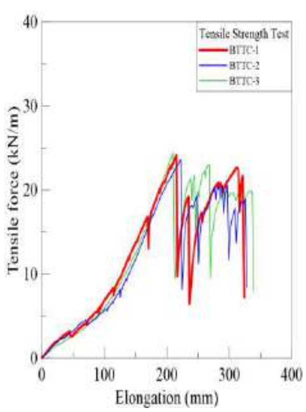
ATTU (Type A without a centre cut & perpendicular to twist)



BTTU (Type B without a centre cut & perpendicular to twist)



ATTC (Type A with a centre cut & perpendicular to twist)



BTTC (Type B with a centre cut & perpendicular to twist)

Figure 9 Repeatability of Type-A and Type-B wire mesh panel tensile tests in the Transverse direction with and without a centre cut wire

The typical tensile test results loaded in the transverse direction for three half-turn (Type A) and four half-turn (Type B) hexagonal wire mesh panels without a centre cut wire are shown in Figure 10 and Table 6. The tensile stress versus elongation curves can be divided into two stages. The initial tensile stress versus elongation curves (stage-1) for both mesh types are quite similar to each other. The tensile load was uniformly transferred through the panel steel wires and induced necking in the central region of the panels. The peak tensile strength for the Type B panel (26.9 kN/m) is slightly higher than that for the Type A panel (22.7 kN/m). In addition, the associated elongation at peak for the Type B panel (215 mm) is slightly less than that for the Type A panel (280 mm).

Several similar consecutive peak tensile forces were observed after the highest peak tensile force occurred as the elongation continued for both mesh panels. Wire breakage normally occurred initially near two sides of the panel. The elongation after the first peak represented stage-2 elongation. A larger amount of elongation in conjunction with wire de-twisting around the broken wires between each consecutive break was also observed for the test Type A mesh. This indicated that the Type A mesh panel elongated more and quicker than the Type B mesh panel. The consecutive peak tensile forces for the Type B wire mesh panel decreased as the elongation increased. However, the elongation between each consecutive break was significantly less than that for the Type A wire mesh. This implied that the Type B wire mesh would deform less than the Type A wire mesh when subjected to tensile loads.

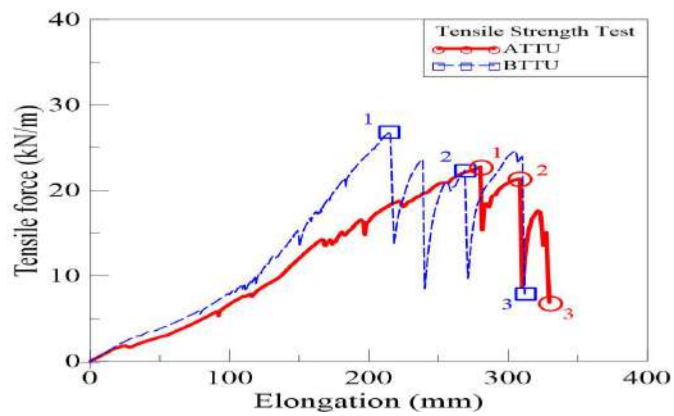


Figure 10 Typical tensile test results for Type A and Type B mesh panels loaded in the transverse direction without one cut wire (ATTU vs. BTTU)

Table 6 Comparison of the typical tensile test results between Type A and Type B loaded in transverse direction without a center cut wire (ATTU vs. BTTU)

Type or difference	mark 1*	mark 2	mark 3
ATTU	F = 22.74 kN ∆= 280 mm	F = 21.33 kN ∆= 308 mm	F = 6.85 kN ∆= 330 mm
BTTU	F = 26.86 kN ∆= 215 mm	F = 22.34 kN ∆= 269 mm	F = 7.85 kN ∆= 312 mm
Strength difference (%)	+18.1%	+4.7%	+14.6%
Elongation difference (%)	-23.2%	-12.7	-18.0

Notes: ∆ and * represent the elongation and tensile strength.
Difference (%) = (BTTU-ATTU)/ATTU.

4.5 Tensile test of panel loaded in the transverse direction with a centre cut wire

A series of tensile tests for the Type A and the Type B hexagonal wire mesh panels loaded in the transverse direction with one centre wire cut was also performed. The typical tensile stress versus elongation curves are shown in Figure 11 and Table 7. Due to the presence of one pre-cut wire, the ultimate strength was only about 11.6 kN/m and the peak elongation was greater than 300 mm for the Type A wire mesh panel. Low tensile load resistance and steel wire de-twisting around the pre-cut wire were observed for the Type A mesh panel. Typically, a large hole would be observed in the centre of the test panel.

The first peak tensile stress for the Type B mesh panel was 24.1 kN/m. The tensile load was uniformly distributed to all steel wires in the panel. The presence of one pre-cut wire showed a minimum influence on the tensile test results. In addition, consecutive wire breakages near the pre-cut wire were observed for the Type B wire mesh panel.

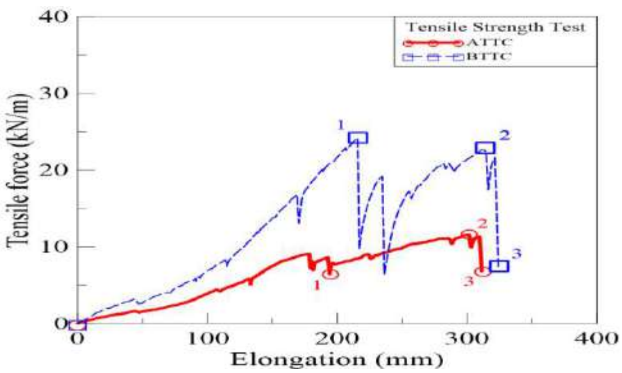


Figure 11 Typical tensile test results for Type A and Type B mesh panels loaded in the transverse direction with one cut wire (ATTC vs. BTTC).

Table 7 Comparison of the typical tensile test results between Type A and Type B loaded in transverse direction with a center cut wire (ATTC vs. BTTC)

Type or difference	mark 1	mark 2	mark 3
ATTC	F = 6.45 kN △= 195 mm	**F = 11.61 kN *** △= 301 mm	F = 6.82 kN △= 311 mm
BTTC	**F = 24.14 kN *** △= 216 mm	F = 22.62 kN △= 311 mm	F = 7.23 kN △= 324 mm
Strength difference (%)	+274.3%	+94.8%	-6.0%
Elongation difference (%)	+10.7%	+3.3%	+4.2%

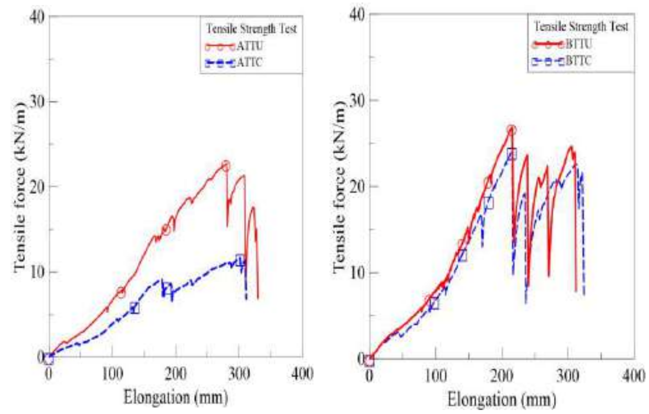
Notes: △ and * represent the elongation and tensile strength. Difference (%) = (BTTC-ATTC)/ATTC.

4.6 Tensile tests in transverse direction summary

The typical tensile stress versus elongation curve comparison for the Type A wire mesh loaded in the transverse direction with and without one cut centre wire are shown in Figure 12(a) and Table 8. A significant difference in wire mesh elongation occurred between the two test conditions. Typical tensile test curve comparison for the Type B wire mesh loaded in the transverse direction with and without one cut centre wire was quite similar to each other; results shown in Figure 12(b) and Table 8. This implies that the presence of one centre cut wire in the Type B mesh panel has a very minimal effect on the tensile behaviour when loaded in the transverse direction. However, the Type A mesh panel showed a larger displacement and less tensile resistance after one wire was cut in the panel centre when loaded in the transverse direction.

4.7 Summary of the tensile strengths for all test conditions

The tensile strengths and associated elongation for these eight test conditions are summarized in Figure 13. In general, the test tensile strengths for Type A and Type B wire mesh panels with 120 mm by 150 mm opening satisfy the values shown in the ASTM specification. The tensile strengths for the test panels loaded in the transverse direction were only less (only 40% to 60%) than those values for panels loaded in the longitudinal direction. In addition, the tensile strengths for test panels with one centre cut wire were less than the tensile strengths for the test panels without one centre cut wire condition. Therefore, it would be better to design the panel loaded in the direction parallel to the twist with any damage to the panel. However, the retained strength rates for Type B panels were generally higher than those for Type A panels. The presence of one centre cut wire in the Type B mesh panel has a very minimal effect on the tensile behaviour when loaded in the longitudinal and transverse directions.



(a) ATTU vs. ATTC (Type A) (b) BTTU vs. BTTC (Type B)

Figure 12 Comparison the tensile test results for test specimen without and with a centre cut wire for Type-A or Type-B mesh panels loaded in the transverse direction

Table 8 Comparison of ultimate tensile strength for Type-A and Type-B without and with a center cut wire loaded in transverse direction

Center cut wire condition	Test condition	Tensile strength (kN/m)	Test condition	Tensile strength (kN/m)	Strength difference (%)
without	ATTU	22.74	BTTU	26.86	+ 18.1%
with	ATTC	11.61	BTTC	24.14	+107.9%
Cut retained strength(%)	-	51.1%	-	89.9%	-

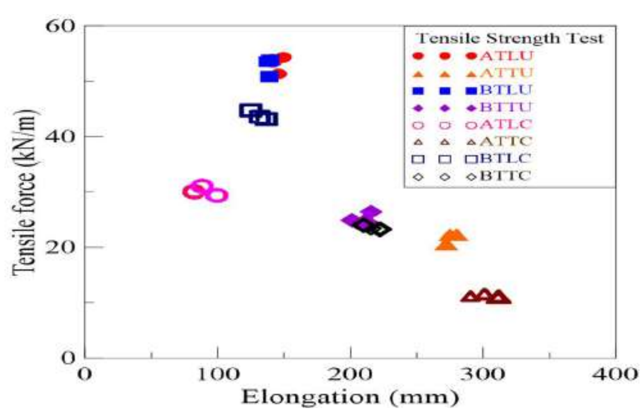
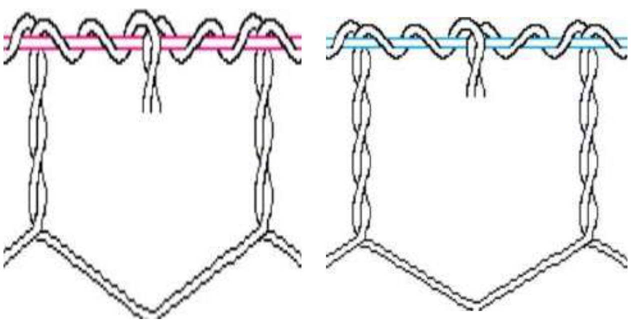


Figure 13 Summary of the tensile strength test results for all test conditions for Type-A and Type-B panels

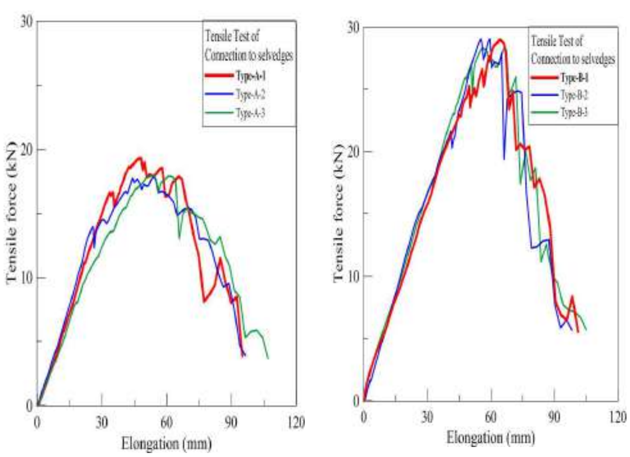
4.8 Connection to selvedge tensile test

Selvedge wires are commonly used to as the wire mesh panel edges. These selvedge wires are perpendicular to the double twist wires by mechanically wrapping the mesh wires around it at least 2.5 times or by inserting it throughout the twists and folding one mesh length. Furthermore, lacing wires or fasteners can be used for binding various wire mesh panels sizes to form gabions or revet mattresses. Therefore, the connection strength of the mesh panel to selvedge wire is also an important engineering property of gabions or revet mattresses. A schematic view of the Type A and Type B mesh wires wrapping around selvedge wire is shown in Figure 14. Several mesh panel connection to selvedge wire tensile test results for Type A and Type B hexagonal wire mesh panels are shown in Figure 15. Excellent repeatability was observed for both types of wire mesh panels. Typical overviews of the Type A and Type B test panels during load conditions are shown in Figure 16. Similar to the tensile tests, the applied tensile forces were distributed to panel wires and transferred from the panel boundary wires to the centre panel wires. The loads were more uniformly distributed over the entire Type B specimen by observing the hexagonal shape of the panel wires, as shown in Figure 16(b), than that shown in Figure 16(a). In addition, comparisons of the typical connection to selvedge test results for Type A and Type B panels are shown in Figure 17 and Table 9. Several peak strengths were associated the de-twisting of mesh wires from selvedge wire. Due to the vertical or diagonal weaving pattern effect for Type A or Type B panel, more uniform load distribution and higher connection strength was observed for Type B mesh panel. The results also imply that Type B panel structure could provide a better load distribution.



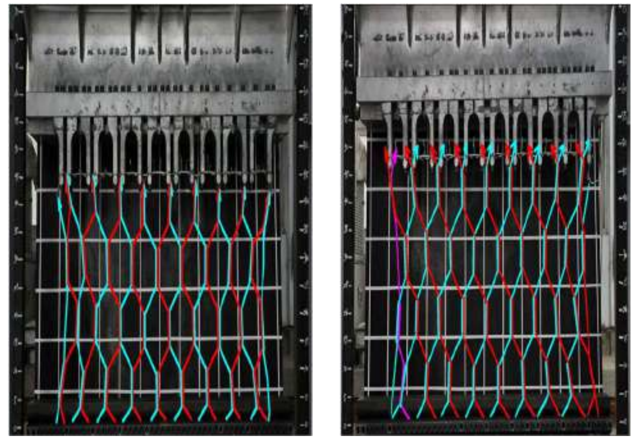
(a) Type-A wire mesh (b) Type-B wire mesh

Figure 14 Schematic view of panel wires connected to selvedge wire for Type A and Type B mesh panel



(a) Type-A wire mesh (b) Type-B wire mesh

Figure 15 Repeatability of connection to selvedge wire tensile tests for Type-A and Type-B panels



(a) Type-A wire mesh (b) Type-B wire mesh

Figure 16 Overviews of the connection to selvedge wire tensile tests for Type-A and Type-B panels

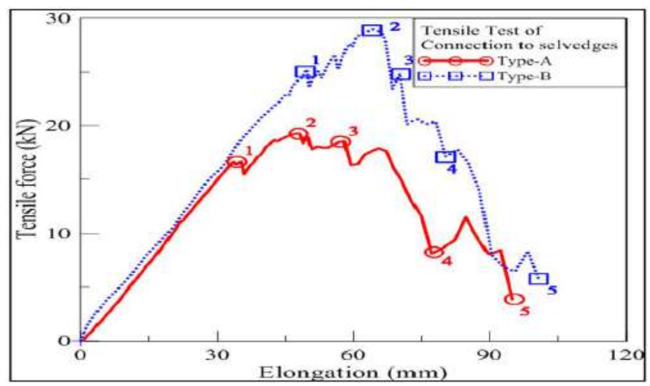


Figure 17 Comparison the typical connection to selvedge wire tensile tests for Type-A and Type-B panels

Table 9 Comparison of typical connection to selvedges tensile test results between Type A and Type B panels (See Figure 17)

Type or difference	mark 1	mark 2 *	mark 3	mark 4	mark 5
Type A	F = 16.66 kN △= 36 mm	F = 19.26 kN △= 48 mm	F = 18.55 kN △= 58 mm	F = 8.13 kN △= 80 mm	F = 3.87 kN △= 95 mm
Type B	F = 25.24 kN △= 50 mm	F = 28.98 kN △= 64 mm	F = 24.84 kN △= 70 mm	F = 17.12 kN △= 80 mm	F = 6.47 kN △= 96 mm
Strength difference (%)	+51.5%	+50.5%	+33.9%	+111%	+67.2%
Elongation difference (%)	+38.9%	+33.3%	+20.7%	0%	+1.1%

Notes: △ and * represent the elongation and tensile strength. Difference (%) = (Type B – Type A)/Type A.

5. SUMMARY AND CONCLUSIONS

The average replacement time for wire mesh gabions for river bank protection and slope stabilization applications is about seven years in Taiwan. The annual construction cost for these applications is more than 2 billion New Taiwan dollars (approximate 66 million US dollars). This study investigated the engineering behavior of three half-turn (Type A) and four half-turn (Type B) hexagonal wire meshes (120mm x150mm, ψ=4.0mm) using tensile tests loaded in the longitudinal or transverse directions without and with a center cut wire. The Type A and Type B panel connection to selvedges tensile tests were also conducted. ASTM A975 test standard was used in this study.

In general, the tensile strength for a panel loaded in the longitudinal direction is about double that compared to a panel loaded in the transverse direction for both types of mesh panels. The results indicated that the ultimate tensile strengths for Type A or Type B hexagonal wire mesh panels loaded in the longitudinal or transverse directions without one centre cut wire were similar to each other. However, the Type B panels showed better tensile resistance after one wire was cut at the panel center to simulate mesh damage that could occur during typical field situations. This implies that the presence of broken wires within the four half-turn (Type B) hexagonal wire mesh would have less effect on the panel tensile strength. In addition, the Type B panel connection strength was also higher than that for the Type A panel. The tensile strengths in the longitudinal and transverse directions and panel connection to selvedges strengths for Type A and Type B generally satisfied the ASTM A975 materials specifications.

The Type B wire mesh is a more robust and durable weaving pattern than Type A wire mesh. It is suggested that the placement of twisted section wire mesh be parallel to the load direction. These results provide important technical information that, if implemented, could extend the service life and, thus, reduce the life cycle cost of wire gabion installations when used for river bank and slope protection applications.

6. REFERENCES

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