A PROPOSAL OF TENSILE TEST OF PULTRUDED GFRP PLATE

(SC-043)

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ABSTRACT

Recently an attempt that directly applies GFRP plate to structural members is increasing. The researches for investigation of mechanical properties of GFRP plate have been progressed. KS(Korea Standard) M ISO 527(Determination of tensile properties of plastics) based on regulations of ACI 440.3R-04 and ASTM D 3039 is often used for GFRP plate tensile test. However, there is no specific standard for tensile test of GFRP plate. KS M ISO 527, when applied to GFRP plate, causes to sliding failure at the grip in case of rectangular specimen or causes local failure at tapered section of specimen that has dumbbell-shape. So, it is difficult to evaluate the tensile properties of GFRP plate exactly according any current standards. Therefore, this study proposes new standard methodology for tensile test of GFRP plate, through the tests which carried by KS M ISO 527, two methods with different grip and four proposed methods that have different grip and length.

According to experimental results, the proposed tensile test method, which extended length of grip, attached specimen with epoxy and combined grip with hydraulic jack was more effective than existing tensile test method, such as the KS M ISO 527, ACI 440.3R-04 and ASTM D 3039, for applying GFRP plate.

Keywords: GFRP plate, tensile test.

1. INTRODUCTION

FRP (Fiber Reinforced Polymer) due to its superior tensile strength, corrosion resistance and lightweight is increasingly used to replace rebar or strand. As the attempt to apply FRP to the structural material has been increased, it is necessary to investigate the mechanical characteristics of the FRP material. The analysis of tensile strength is more important.

Subsequently, existing tensile strength test has been mostly the standard tensile force test of FRP rod or FRP sheet, which used as reinforcement or supplementary member, and the study on tensile test of FRP plate as structural member has made slow progress. Since of its brittleness and rupture is usually occurred with FRP at early stage, which is attributed to concentrate stress on grip, which requires careful consideration.

Therefore, this study proposes new standard methodology for tensile test of GFRP plate; The tests which carried by KS M ISO 527, two methods with different grip and four methods that have different grip and length, using GFRP has been proposed.

2. GFRP PLATE TENSILE TEST INTERLOCKING PERFORMANCE

2.1. Test summary

FRP plate has smooth surface, unlike rebar and thus, adhesive function of grip depends on adhesive strength between epoxy in grip and GFRP plate and a little friction force. Thus, extended length of adhesion is needed to secure the sufficient adhesion corresponding to the tensile force.

This study is aimed at proposing the certain type of grip and evaluating the performance, taking into account of sliding on grip, failure and separation of the specimen from the support during the tensile strength test.

2.2. Fabrication of the specimen

2.2.1 Properties of the specimen

The material used for specimen was E-glass among the glass fiber and the matrix was polyester resin.

Table 1 Properties of GFRP material

Material	Properties of material		
E-Glass	Specific gravity		2.54
	Tensile strength	22℃	3,448 *MPa*
		371℃	2,620 *MPa*
		538℃	1,424 *MPa*
	Elastic Modulus (22℃)		72.4 *GPa*
	Yield strain		4.8%
Polyester	Specific gravity		1.1 – 1.46
	Tensile strength		40 – 90 *MPa*
	Elastic Modulus		20 – 44 *GPa*
	Elongation		< 5%

2.2.2. Fabrication

The specimen was fabricated using pultrusion method which is the automatic method producing the certain type of section and shape continuously. It's the optimal method for thermosetting resin which is hardened without generating condensation products. Depending on required strength and rigidity, it composes the continuous fiber such as roving or chopped-stand mat.

(a) Roving/mat creel (b) Resinimpregnating (c) Shape performer (d) Heating (e) Puller

Figure 1 GFRP Pultrusion method

Table 2 Variables of specimens

Specimen	Number	Overall Length	Exposure Length	Grip Length	Width	Thickness
KS-1	3 ea	250 mm	50 mm	50 mm	25 mm	3 mm
KS-2	3 ea					
S-1	3 ea					
S-2	3 ea					
SL-1	3 ea	750 mm	150 mm	300 mm		
SL-2	3 ea	1000 mm				
SLE-1	3 ea	750 mm	200 mm	400 mm		
SLE-2	3 ea	1000 mm				

2.2.3. Dimension of the specimen and variables

Among the test variables are KS-1 and KS-2 suggested by KS M ISO 527 and S-1 and S-2 of which grip was modified and SLE-1 and SLE-2 as a result of varying the length of grip on specimen and SLED-1 and SLED-2 of which exposed part was molded in dumbbells, which totaled 8 kinds.

(1) KS-1, KS-2 specimen

KS-1 (Type 2) and KS-2 (type 3) recommended by KS M ISO 527-1 were fabricated.

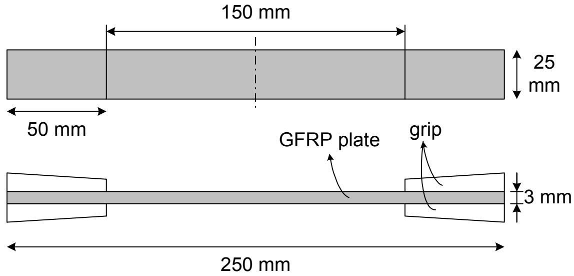

Figure 2 Scheme of KS-1

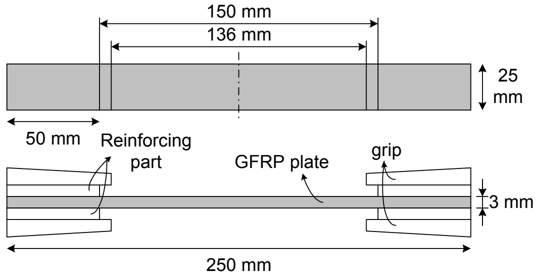

Figure 3 Scheme of KS-2

(2) S-1, S-2 specimen

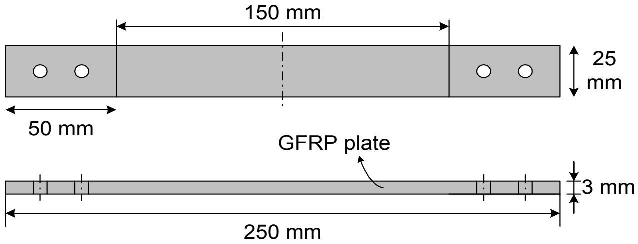

Figure 4 Scheme of S-1

Figure 5 Grip of S-1 specimen

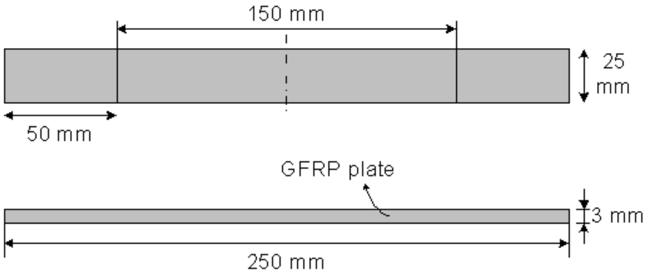

Figure 6 Scheme of S-2

Figure 7 Grip of S-2 specimen

S-1 and S-2 have same dimension as KS specimen but different type of grip. S-1 has a grip which can be tightened with bolt while S-2 has grip in box shape in which epoxy can be injected.

(3) SLE-1, SLE-2 specimen

Referring to ACI 440.3R-04 FRP bar test standard, the length of grip was designed to be longer than KS-1 and the ratio of length is 1: 2(exposed(*L*) and grip(*La*) part). For grip, SLE-1 has box-shaped in which epoxy was injected, while SLE-2 was designed to add volting process to SLE-1.

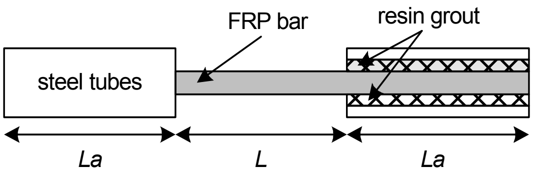

Figure 8 FRP bar tensile test (ACI 440.3R-04)

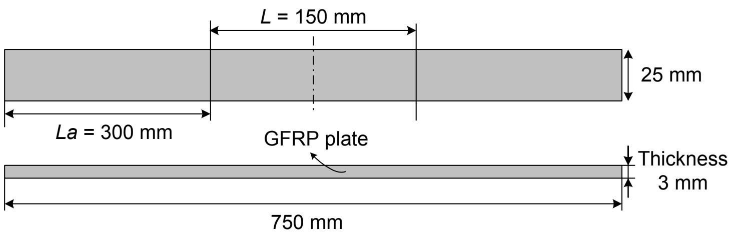

Figure 9 Scheme of SLE-1

Figure 10 Grip of SLE-1 & SLED-1

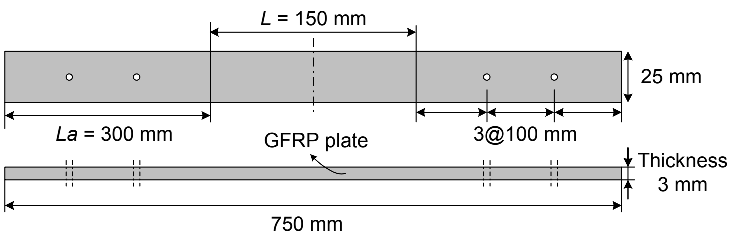

Figure 11 Scheme of SLE-2

Figure 12 Grip of SLE-2 & SLED-2

(4) SLED-1, SLED-2 specimen

SLED series were same as SLE series in size of specimen and type of grip, but the exposed part was molded in shape of dumbbells.

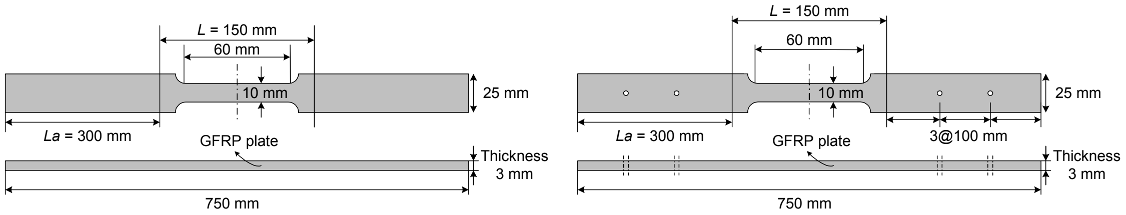

Figure 13 Scheme of SLED-1(left) & SLED-2(right)

2.3. Test method

Tensile load at 2mm/min was imposed on GFRP plate using hydraulic UTM(Universal Testing Machine) with max capacity of 100ton. For KS-1 and KS-2, grip was fixed using hydraulic jack, while grip and hydraulic were unified for tensioning for other specimens. To measure the strain of GFRP plate, a strain gauge was set on the center and the points 25mm up and down.

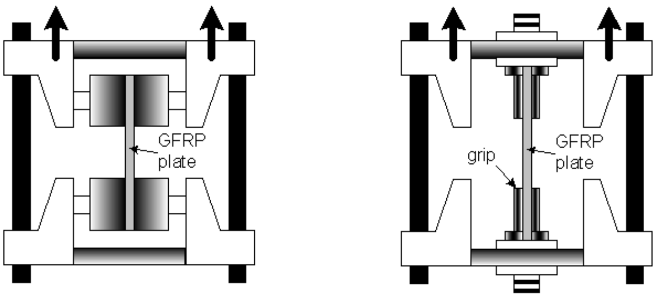

Figure 14 Scheme of loading system (Left : conventional grip, Right : proposed grip)

2.4. Test result and analysis

2.4.1. Failure mode

(1) KS-1, KS-2

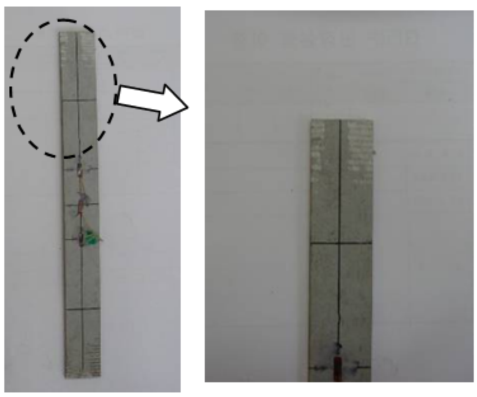

Figure 15 KS-1: specimen slided on grip

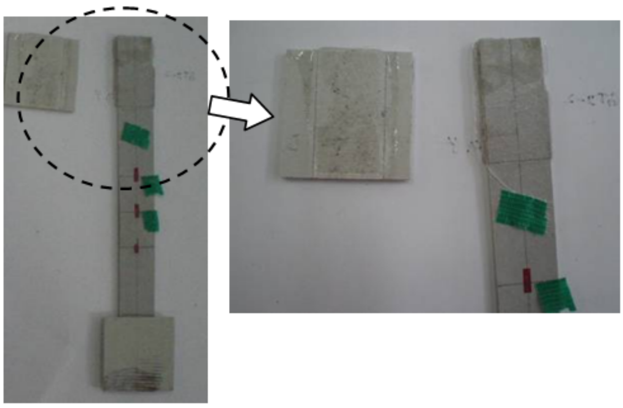

Figure 16 KS-2: specimen was split up due to fracture of epoxy in grip

(2) S-1, S-2

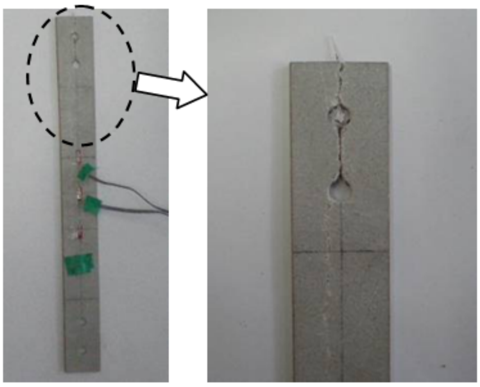

Figure 17 S-1: specimen was torn at part of grip

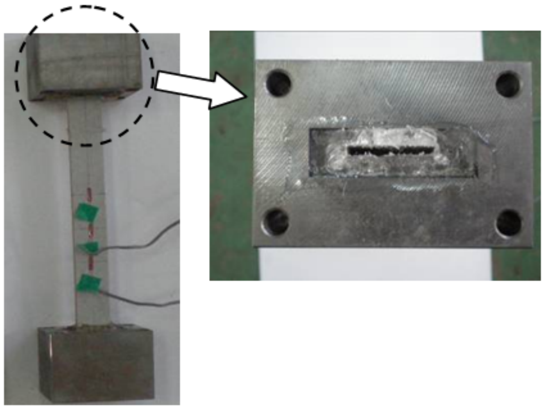

Figure 18 S-2: epoxy on grip was ruptured

(3) SLE-1, SLE-2

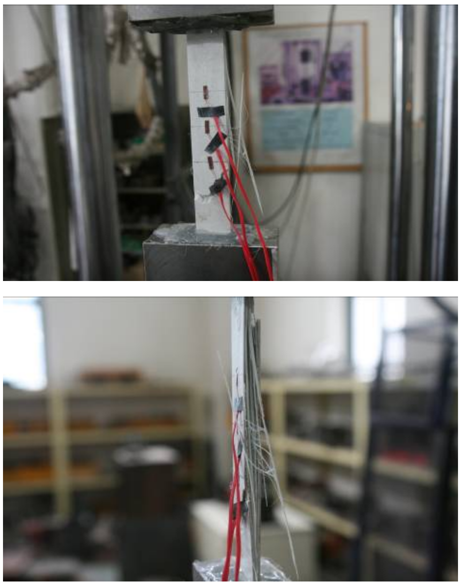

Figure 19 SLE-1 & SLE-2 : Typical tensile failure

(4) SLED-1, SLED-2

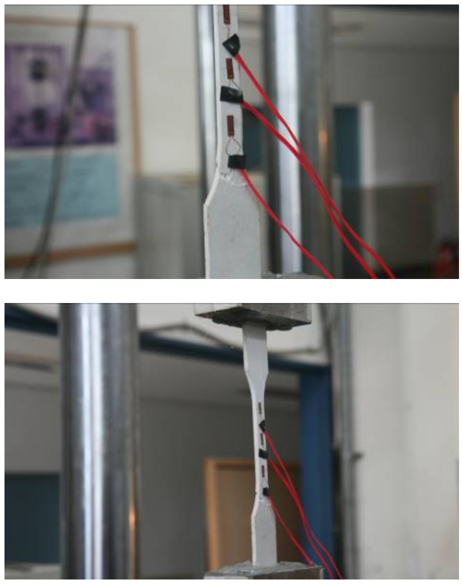

Figure 20 Partial failure on transitional section

2.4.2. Result and analysis

As a result of the test, KS series and S series occurred sliding and epoxy rupture, making it difficult to evaluate tensile strength, while SLE series and SLED series had tensile failure and fiber pullout, making it possible to investigate the tensile performance of GFRP plate. A mean tensile strength of SLE series was 334 MPa and modulus of elasticity was 23 GPa and a mean tensile strength of SLED series was 242 MPa and modulus of elasticity was 24 GPa. The modulus of elasticity of GFRP plate appeared to be similar at the section with the strain of 0~0.003. Comparing SLE and SLED series, SLED in which the stress was concentrated at the transition section was ruptured by smaller tensile strength than SLE series.

Table 3 Result of tensile tests

Specimen	***L* : *La***	**Tensile strength** (*MPa*)	**Elastic modulus** (*GPa*)	**Failure mode**
KS-1	3:1	-	-	Sliding
KS-2		-	-	Sliding/ rupture
S-1	3:1	-	-	Tearing
S-2		-	-	Splitting
SL-1	1:2	325	24	Tensile failure
SL-2		343	22	Tensile failure
SLE-1	1:2	233	25	Partial failure
SLE-2		250	23	Partial failure

3. CONCLUSION

1) SLE series without stress concentration, sliding of grip and epoxy rupture was found to be optimal as material tensile strength test method for GFRP plate, and SLE-1 was more efficient because it's simpler than SLE-2 in fabrication process.
2) When it comes to grip, tensioning method after unifying the grip and hydraulic jack is more efficient than direct fixing.

4. REFERENCES

[1] Plastics Determination of tensile properties – Part 4: Test conditions for isotropic and orthotropic fibre – reinforced plastic (KS M ISO 527-4)

[2] ACI 440.3R-04 Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures

[3] ASTM D 3039/D 3039M-08 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials