Influence of Washers on Mechanical Behavior of Single Lap Connection in GFRP Plates using Tapping Screws

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1. Introduction

Fiber reinforced polymer (FRP) has currently been widely used in the fields of vehicles, aircraft, because of their have many good characteristics when comparison with other materials such as light weight, high strength, high corrosion resistance, good freedom of molding, etc. In addition, these characteristics lead to high seismic resistance, long life, and ease in construction; therefore, FRPs have also been used in architecture and civil engineering field. For example, in the architecture sector, it has been used in the large space of the roof frames, indoor swimming pools, etc. In the civil engineering sector, it has been used in pedestrian bridge, floodgate, etc. At present, because the connection behavior of FRP connection is relatively complex, it is impossible to construct freely like wood, concrete, steel. If that problem is solved, FRP will be a material which can change significantly the construction structure. Unlike steel, the connection of FRP is difficult to welding, so mechanical connection, adhesive connection, or both have been used. However, the mechanical properties of connection, which are indispensable for constructing structures by FRP material, are not clarified sufficiently. Therefore, accumulation of research results to improve design method are necessary. There have been many researches about mechanical connection for FRP by steel bolts/rivet. This connection requires drilling to create the holes in FRP material first and bearing strength is lower than the material strength due to the influence of connection clearance. Hence, solving this problem to improve initial stiffness of connection and bearing strength by tapping screw should be considered carefully. Furthermore, the screw has a drill at the tip, so there don't need hole processing, increasing construction speed. In this study, we shows on the screw connection strength and influence of washers using in tapping screw on connection strength in FRP plates by experimental single-lapped tensile-shear loading test.

2. Experimental Method

In this study, GFRP which was used in the test is pultruded GFRP (AGC Matex manufactured “Plalloy” C100B), fiber is mainly roving, resin use unsaturated polyeste. The mechanical properties of specimen (FRP materials) are shown in Table 1.

Table 1 Mechanical properties of specimen

FRP materials	Value
Tensile strength(MPa)	408
Longitudinal elastic modulus (GPa)	28
Glass content rate (weight %)	54

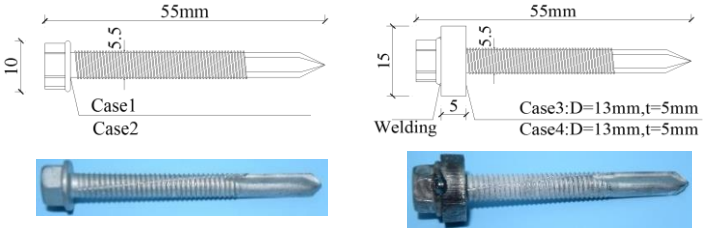

Figure 1 Tapping screws

Tapping screws (Japan Power Fastening manufactured “MB TEKS” HEX#5), which were used in the experimental tests, are shown in Figure 1; tapping screws were made by stainless steel. The experiment was conducted with 4 different case about the influent of washer on the connection strength. While case 1 is tapping screws without washer. Case 2, 3, 4 include washer diameter with 10mm, 13mm, and 15mm respectively. Tightening torque of the screw was controlled as 15N·m in order to prevent the damage to the specimen material. Figure 2 shows the experimental methods. Figure 3 shows experimental setup. In case 1, in order to release the effect of washer on FRP plate, the distance between washer and FRP plate is 5mm. The connection strength of FRP plate was investigated through single-lapped tensile-shear loading test.

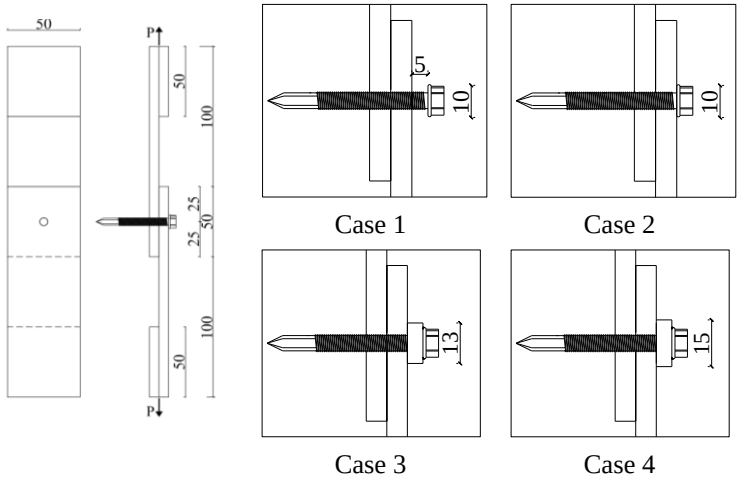

Figure 2 Experimental method

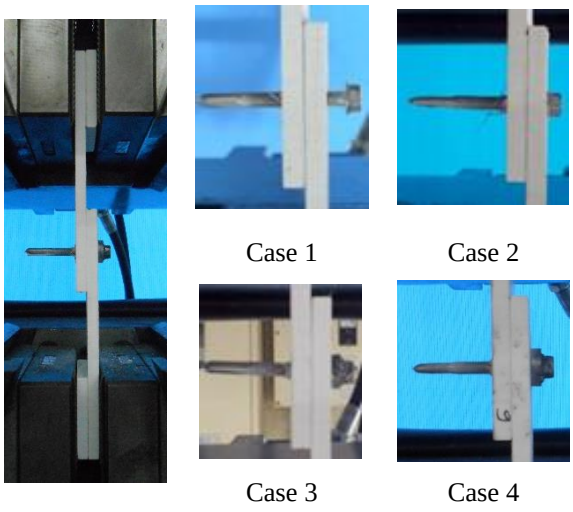

Figure 3 Experimental setup

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3. Experimental Result and Discussion

Figure 4 shows load-displacement relations, Figure 5 shows the maximum load, average of maximum load, and variation coefficient of maximum load, Table 2 shows the load capacity per unit thickness and average bearing strength of the experiment results for case 1, 2, 3, 4. The impact modes of washer on FRP plate are shown in Figure 6, the typical failure modes of the hole and FRP plates are shown in Figure 7, the deformation modes are shown in Figure 8, the rotation restriction by washer is shown in Figure 9.

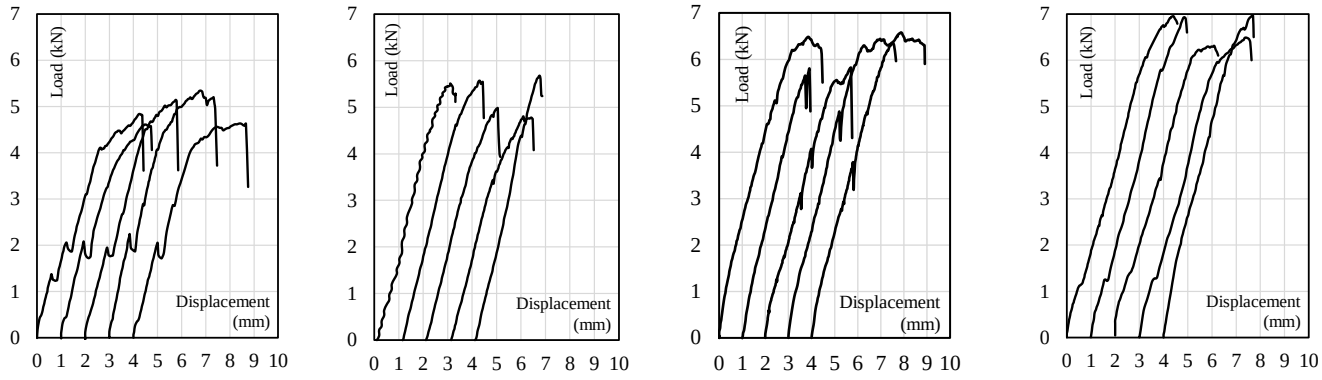

Figure 4: Load-displacement relations

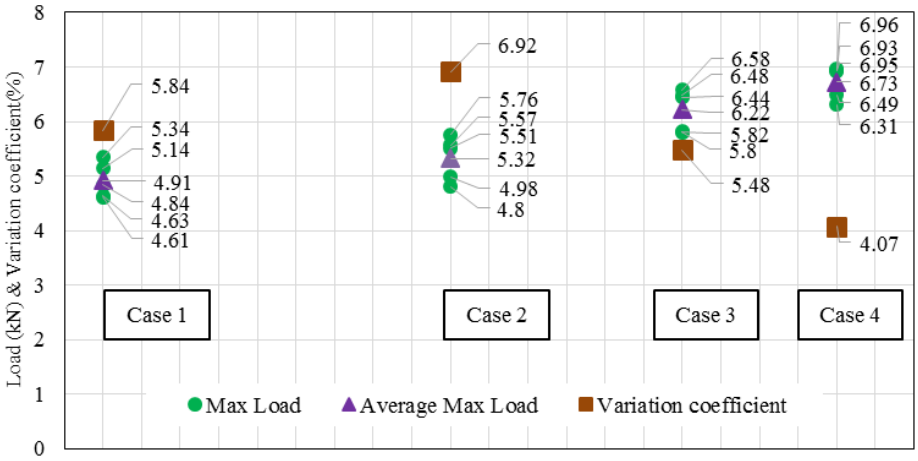

Figure 5: Experimental result

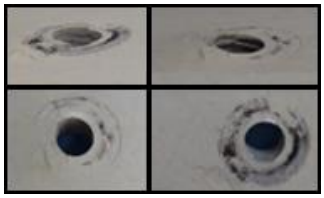

Figure 6 Impact modes of washer on FRP plate (case 3)

Figure 7 Typical failure modes of the hole and FRP plate

Table 2: Load capacity per unit thickness, average bearing strength

	Case 1	Case 2	Case 3	Case 4
Average thickness (mm)	6.58	6.46	6.53	6.53
Load capacity per unit thickness (kN/mm)	0.75	0.82	0.95	1.03
Average bearing strength (MPa)	135.84	149.77	173.41	187.33

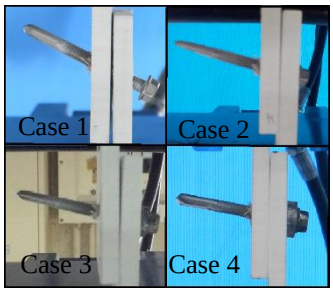

Figure 8 Deformation modes

Figure 9 Rotation restriction by washer (case 3)

The load gradually decreased after reaching the maximum load in all specimens as shown in Figure 4, because tapping screw is rotated by shear loading as shown in Figure 8. The max load increased when increasing the diameter of the washer, because rotation was restrained by washer as shown in Figure 9; the stiffness of steel washer is higher than FRP plate, rotation restriction by washer lead to the deformation of FRP plate at the contact position between FRP plate and washer as shown in Figure 6. In case of specimens having washer, load linearly increased and variation coefficient of maximum load decreased depend on washer's diameter as shown in Figure 5.

4. Conclusion

In this study, the connection strength and effect of washer diameter on the connection strength in FRP plates was investigated through single-lapped tensile-shear loading test. The connection bearing strength in GFRP plates depends on washer's diameter; when, increasing washer's diameter, the connection bearing strength stably increased. Hence increasing washer's diameter in a reasonable level is effective method to increase the load carrying capability for tapping screws connection in GFRP plate.

REFERENCES:

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