BEHAVIOR OF GFRP AND UHF COMPOSITE GIRDERS WITH FRP BOLTS

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1. INTRODUCTION

In recent years Fiber Reinforced Polymer (FRP) materials have been used in Civil Engineering constructions such as short span road bridges, pedestrian bridges, etc. The application of FRP in Civil Engineering was first introduced in Japan about two decades ago with the development of FRP reinforcement and tendons. Because of their high strength, light weight, high corrosion resistance, etc. these became popular among other construction materials but due to their high initial cost, use of these materials is quite hindered. Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) are the widely used FRP materials. Although CFRP is more expensive over GFRP, its strength is comparatively high compared to GFRP.

An I-beam subjected to bending moment undergoes high flexural stresses in flanges and high shear stresses in web. Therefore the compression flange tends to delaminate before the ultimate compressive strength is achieved. As a result of this, failure of the entire beam occurs and the tension flange is poorly utilized. Ultra High Strength Fiber Reinforced Concrete (UHF) blocks cab be used at top flange in order to increase the effectiveness of the I-beam. Past research shows that the UHF blocks having a small cross sectional area can withstand very high compressive strength and hence the delamination of top flange can be prevented[1)]. Fixing of UHF blocks to the flange was done with steel bolts and epoxy resin. Because of the steel bolts, the durability of the structure may reduce due to corrosion of bolts in severe environments such as marine environment. In this paper, performance of GFRP and UHF composite I-beam with FRP bolts is demonstrated.

2. DETAILS OF EXPERIMENT

Four numbers of GFRP and UHF composite I-beams having dimensions as illustrated in Fig. 1 and Fig. 2 were prepared for the experiment. The test parameters (i.e. bolt diameter, bolt spacing and the availability of bolt head inside the UHF block) of each specimen are given in Table 1. In order to prevent delamination at top flange, UHF blocks having compressive strength and Youngôs modulus of 188MPa and 44GPa respectively were fixed to the top flange using epoxy resin and FRP bolts (see Fig. 2).

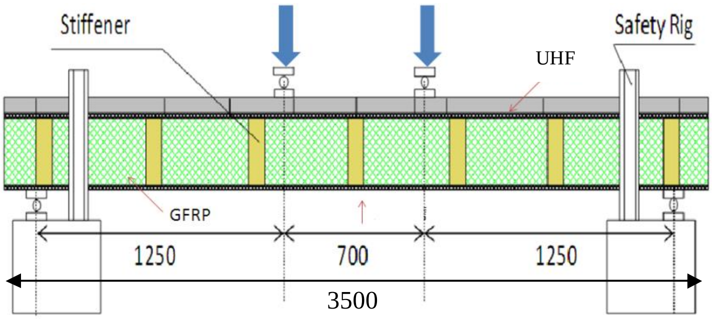

Fig. 1 Test setup (units in mm)

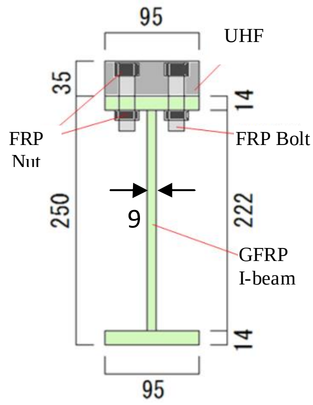

Fig. 2 Cross-section of composite I-beam (units in mm)

A 10 mm gap was maintained between UHF blocks and those were filled with mortar paste having compressive strength and Youngs modulus of 90MPa and 31GPa respectively. In order to avoid lateral buckling, FRP stiffeners were fixed to the both sides of the web using epoxy resin. Four point bending test with roller supports was carried out for all the specimens where the bending span is 700 mm and shear span is 1250 mm. During the test, load was applied from a manually operated hydraulic jack and the deflection at mid span, applied load and strain at mid span were measured until the failure of the beam.

Table 1 Test parameters of specimens

Specimen name	Bolt spacing (mm)	FRP bolt diameter (mm)	Bolt head in the UHF
G10-F16-B4	150	16	No
G10-F10-BN6	100	10	Yes
G10-F16-BN4	150	16	Yes
G10-F16-BN6	100	16	Yes

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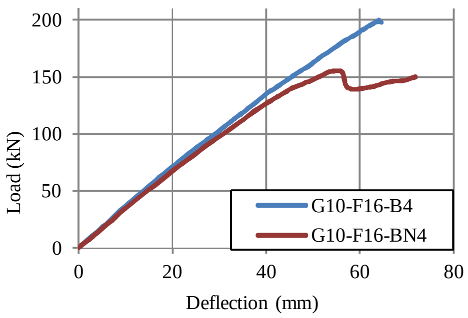
3. RESULTS AND DISCUSSION

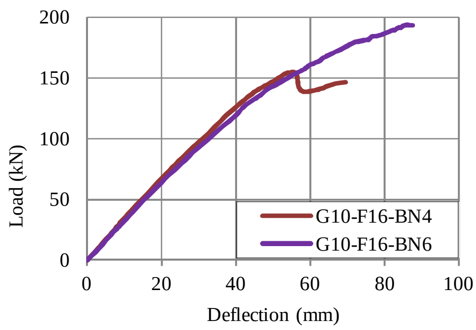
Fig. 3(a), (b), (c) and (d) show the comparison of load vs. deflection relationships at mid span of test specimens. According to the results, Fig. 3(a) shows when the bolts do not have heads inside the UHF blocks, the load carrying capacity is approximately 29% higher than that of when bolts with heads in the UHF block. In the G10-F16-B4 specimen, the area of UHF material in the longitudinal direction in the UHF block is more than that of G10-F16-BN4. Because of the high rigidity of UHF compared to FRP bolt, the ductility is also higher in G10-F16-B4.

Fig. 3(b) illustrates that, when the number of bolts increases the load carrying capacity also significantly increases. This is mainly because of better bonding between FRP beam and UHF blocks due to higher number of bolts. The ultimate load carrying capacity of G10-F16-BN6 is 195kN where that of G10-F16-BN4 is 150kN.

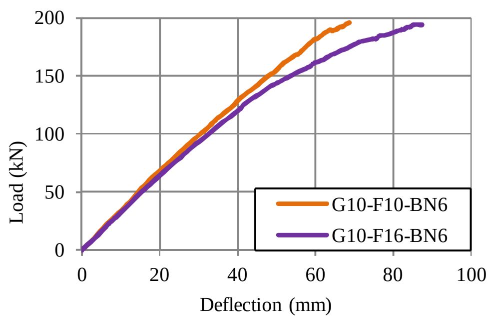
In Fig. 3(c) results indicate that, when the bolt diameter varies the load carrying capacity is approximately remains same but the ductility of the beam has been increased in the specimen which has smaller diameter bolts. This may be due to high rigidity in G10-F10-BN6 specimen, resulted by smaller FRP bolt diameter, which has a higher UHF material area in the longitudinal direction in the UHF block compared to the other specimen. However in this experiment only the 10mm and 16mm diameter bolts considered. Therefore when the bolt diameter is too small, there may be low load carrying capacity due to lack of tensile strength of bolts.



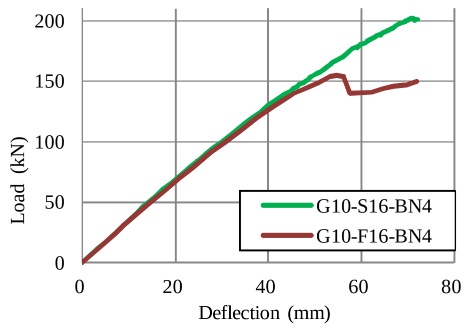
(a) Comparison of bolts having heads inside the UHF block



(b) Comparison of number of bolts



(c) Comparison of bolt diameter



(d) Comparison of bolt type

Fig. 3 Load-deflection curve

A previous research study was carried out with the same GFRP beam and UHF blocks with 16mm steel bolts[2)]. Fig. 3(d) shows the comparison of load vs. deflection between similar beams with steel bolts and FRP bolts. According to that the beam with steel bolts has ultimate load carrying capacity nearly 34% more than beam with FRP bolts. However, the specimen G10-F10-BN6 showed similar performance as composite beam with steel bolts.

4. CONCLUSIONS

In this paper, the behavior of GFRP and UHF composite girders with FRP bolts were discussed and the following conclusions were made according to the results.

- Similar performance as GFRP and UHF composite girder with steel bolts can be achieved with similar beam with FRP bolts. However the number of bots in UHF block and bolt diameters are different.
- When the number of bolts increases, the ultimate load carrying capacity of the composite beam drastically increases.
- When the bolts do not have heads inside the UHF block, the ultimate load carrying capacity of the composite beam increases.

REFERENCES

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2) Perera, S.V.T.J., Mutsuyoshi, H., and Tomoya, A.: Development of Composite Beams Using Ultra-High Performance Fiber Reinforced Concrete and Fiber Reinforced Polymers, 14th International Summer Symposium, JSCE, Nagoya, 2012.