TENSILE BEHAVIOR OF NANO-GFRP BARS

Yi-Na Yoon[1], Su-Jin Lee[1], Byung-Tak Hong[1], Tei-Joon Choi[1], Jong-Pil Won[1], Wan-Young Kim[2]

[1]Department of Civil & Environmental System Engineering, Konkuk University, Seoul, 143-701, Republic of Korea.
[2]Dam Engineering Research Center, Korea Institute of Water and Environment, Daejeon, Republic of Korea

Introduction

Given that fiber-reinforced polymer (FRP) bars have high strength, excellent corrosion and fatigue resistance, and a very high strength-to-weight ratio, much research is currently examining their use a reinforcing material to replace reinforcing bars in concrete structures.[2] However, despite a hardness-to-weight ratio that is 10~15 times higher than that of reinforcing bars, FRP bars have disadvantages, including brittle properties that behave like linear-elastic stress-strain until failure and smaller elasticity coefficients than reinforcing bars. In particular, the mechanical properties of FRP bars are affected not only by the kinds of fiber and matrix used in their manufacture, the volume fraction of the fiber and matrix, and stress transfer from the bar surface to the interior but also by the fact that these properties can be changed by the manufacturing process or curing ratio and quality control of the resin.[2][5]

Nanoparticles not only have a high surface area but, in addition, their strong interaction with the matrix and lighter weight dimensional stability, due to the high aspect ratio, further improve their strength, hardness, heat-resistance and barrier properties, as compared with standard fillers.**[1][**3] In addition, we can expect synergistic effects between an inorganic nanomaterial and organic matrix. [4]

Therefore, we manufactured glass fiber-reinforced polymer (GFRP) bars by adding nano-clay and nano-silica to improve the performance over existing GFRP bars and analyzed their performance.

Experimental

Materials

The GFRP bars used in this study were composed of glass fiber and vinyl ester resin. The GFRP bars were manufactured using a pultrusion method and the ratio of glass fiber to vinyl ester resin was 80:20 by volume.

The nanomaterials used were nano-clay and nano-silica and 1wt.% of vinyl ester resin was added to each.

Specimen Preparation and Test Method

The tensile test was performed according to the test standards suggested by the ACI 440 committee. It was measured using a displacement-adjustable universal testing machine (UTM) with a capacity of 25 tons. The specimen of GFRP rebar tested had a diameter of 4 mm and a total length of 800 mm. To both ends of the GFRP rebar, an anchor was installed with a 250-mm-long steel pipe filled with epoxy. Fig. 1 shows a picture of the tensile test of the GFRP rebar.

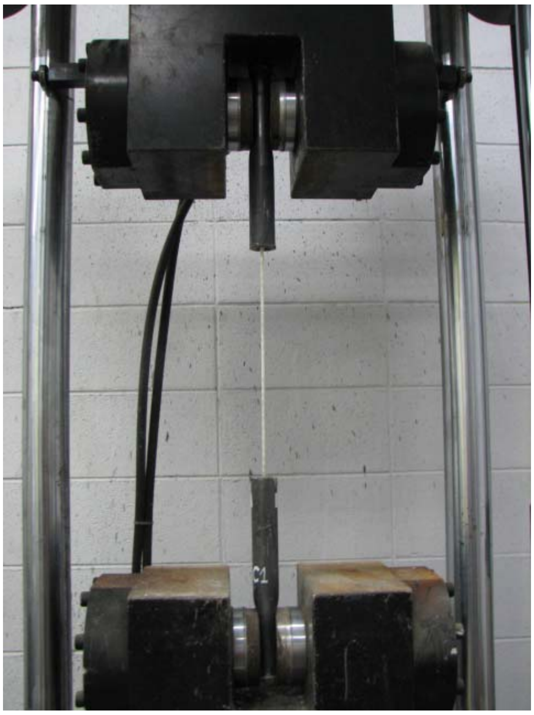

Fig. 1 Tensile test of the GFRP rebar

Results and Discussion

Fig. 2 shows the results of the tensile strength test of the GFRP bar with added nanomaterials. The tensile strength of the plain GFRP rebar was the highest, followed by the GFRP rebar with added nano-silica, and then that with added nano-clay. However, as seen in Fig. 4, in terms of the elasticity coefficient, the bar with added nano-silica had the highest elasticity coefficient and the GFRP rebar without added nanomaterial had the lowest. This implies that the hardness is greater with nanomaterial because the nano-clay and nano-silica particles are harder than the matrix.[3] Hard particles have short strain because they cannot elongate sufficiently, as in Fig. 3, and stress concentration can be demonstrated as hard particles have elasticity properties that are different from those of the resin. This stress concentration reduces the tensile strength, due to the reduction in the surface area of the filler and reduced interaction with the matrix.[1][3] In addition, the mechanical dispersion of nanoparticles with high-speed stirring can cause the re-agglomeration of nanoparticles within the resin, as the correct dispersion of particles is not established and the nanoparticles exist in a mass with a high viscosity. This reduces the tensile strength because pores exist within the resin.[3] In addition, in nanocomposites, different results occur because of defects already within the nanocomposites, such as weak boundaries between particles and bubbles [3] or the surface treatment of the nanomaterials.

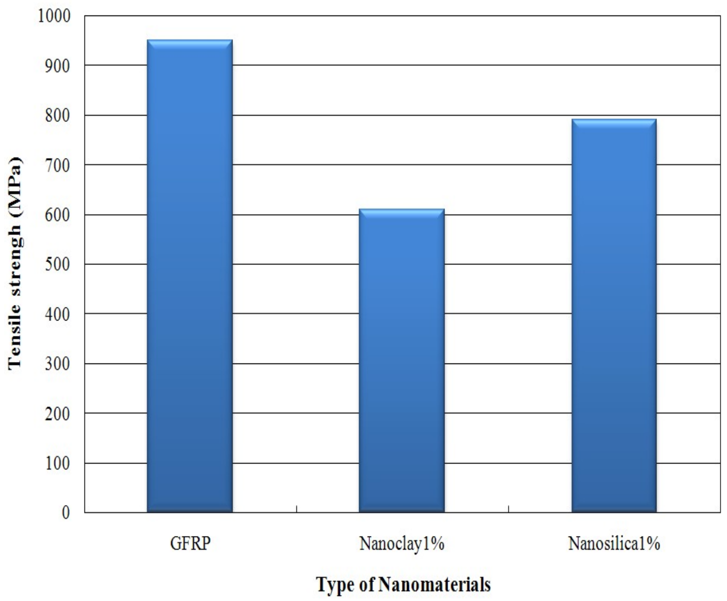

Fig. 2 Tensile strength of the nano-GFRP bars

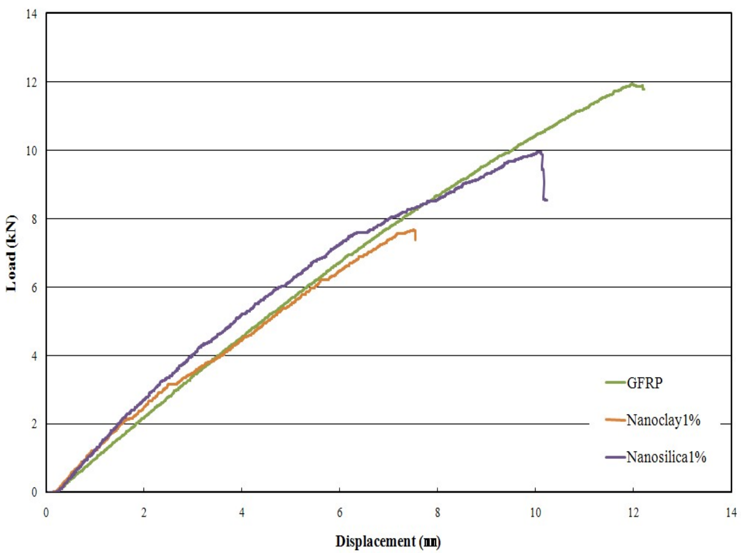

Fig. 3 Load-displacement curves of the nano-GFRP bars

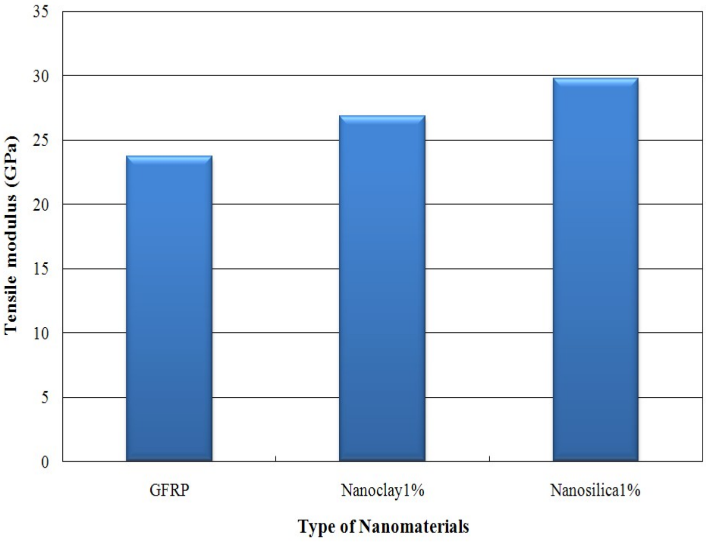

Fig. 4 Tensile modulus of the nano-GFRP bars

Conclusion

This study analyzed the tensile properties of GFRP bars with 1wt% added nano-clay or nano-silica. The results showed that the bars containing the nanoparticles were weaker because of agglomeration and stress concentration, as compared to the pure GFRP rebar. However, the elasticity coefficient was higher because of the properties of the hard nanoparticles, as compared with the pure GFRP rebar, and the strain until failure was smaller.

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