Compressive and Flexural Behavior of Hybrid Use of GFRP Profile with Concrete

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Abstract: Research activities have been taking on place for new construction materials in order to produce more effective constructions. One of the new technological materials is Pultruded Glass Fibre Reinforced Plastic (GFRP) materials. High tensile strength, lightweight and non-corrosive properties allowed GFRP to become a competitive alternative to traditional structural materials. Having resolved fundamental manufacturing constraints through the development of the pultrusion process, the mass adaptation of GFRP sections as primary load bearing elements have been used in a number of civil engineering applications.

In this study; compressive strength and flexural properties of hybrid use of GFRP profile with concrete have been investigated. The tests applied on the specimens including plain concrete, GFRP box profiles and concrete filled GFRP profiles to demonstrate the advantages and importance of GFRP profiles used in civil engineering applications.

Keywords: Glass Fiber Reinforced Plastic, Concrete, Hybrid structure, Compressive properties, Flexural properties

Introduction

The investigations on the technical development have been continuous on the new methodology and construction materials following to the technological development in the world. The limitation of classical construction materials can be overcome by using new technological materials. In the continuing quest for improved performance of structural materials, scientists and engineers strive to improve the traditional natures or produce completely new one. Composite materials are an example of the latter category. Within the past five decades there has been a rapid increase in the development of advanced composites incorporating fine fibres, termed fibre reinforced composites. Due to the high cost of metal and ceramic matrix composite materials, the majority of composites used in the construction industry are based on polymeric matrix materials. Fibre-reinforced polymer (FRP) composites are formed by embedding continuous fibres in a resin matrix which binds the fibres together. Common fibres include carbon, glass, and aramid fibres while common resins are epoxy, polyester, and vinyl ester resins. The most widely used FRP composite is glass fiber reinforced plastic (GFRP) composite which is a new generation of structural materials for civil engineering structures. The GFRP materials have been manufactured using Pultrusion method.

In the Pultrusion method, a continuous E-glass fibre reinforcement in the form of alternate layers of randomly oriented mat and layers of unidirectional roving bundles are pulled through a resin impregnator and then on through a heated die to form continuous prismatic members similar in geometry to those produced by the steel industry as seen Figure 1.

Figure 1. Examples of Pultruded GFRP profiles (www.strongwell.com. 2005)

Pultruded GFRP profiles have great potential as construction materials, presenting several advantages when compared with traditional materials, related to the higher strength to weight ratio, the lower self-weight, the electromagnetic transparency, the possibility of being produced with any cross-section geometry, the easier installation, the lower maintenance requirements and the improved durability under aggressive environments (Karbhari and Seible, 1999, Keller, 2002). The construction industry appears to be gradually recognizing the additional benefits offered by these materials. Having resolved fundamental manufacturing constraints through the development of the pultrusion process, the mass adaptation of GFRP sections as secondary and primary load bearing elements have been used in a number of civil engineering applications (see Figure 2).

Figure 2. Examples of structure constructed using pultruded GFRP profiles (www.strongwell.com. 2005)

GFRP profiles have been used in the buildings that exposed to the negative effect of the sea and chemicals. GFRP materials also used in hybrid bridges and soil improvement systems. GFRP–concrete hybrid elements have also been developed for new structural systems, combining the directional behaviour, the lightness and the high mechanical performance of GFRP pultruded profiles with the concrete compressive strength. The use of concrete-filled fibre reinforced tubes has been used in piles for maritime structures. The concept of hybrid system was first introduced for bridge systems (Seible, 1996). Preliminary studies, however, have shown that the design of concrete filled FRP tube bridge girders is stiffness driven, and that material strength may not be fully utilized. While concrete resists compression and prevents the failure of the tube due to instability phenomena, the FRP element confines the concrete, contributing to a strength and ductility increase, and protection from aggressive environment (Snow, 1999). The results from the tests showed that it is possible to manufacture a fibre reinforced plastic hybrid beam with concrete that can have excellent stiffness and be able to bear heavy loads (Nordin and Taljstena, 2004).

The alternative use of GFRP pultruded profiles in GFRP–concrete hybrid structural elements has a very interesting potential. Compressive strength and flexural properties of hybrid use of GFRP profile with concrete have been investigated to use in construction system to demonstrate the advantages and importance of GFRP profiles used in engineering applications. The study focused on the specimens including plain concrete, GFRP box profiles and concrete filled GFRP profiles.

Compressive Tests

Three different groups (C20, C30 and C40) of concrete using Ordinary Portland Cement washed river sand and crashed aggregate were used in manufacturing the specimens. All specimens were made from the same delivery of materials (sand, aggregate and cement) and similar manufacturing and curing procedures were adopted throughout the test program.

Concrete and concrete filled GFRP cube specimens in three groups with six specimens in each groups, concrete classes were prepared according to the Turkish Standard (TSE 802, 1985). Wall thickness of 4 mm and cross-section of 100x100 mm GFRP box profile were used to produce concrete filled specimens (see Figure 3). Portions of fresh mixed concrete were filled in cube mould and the remainder was filled in GFRP profiles. The specimens were kept in the water for 28 days and then tested to determine compressive strength according to the Turkish Standard (TS EN 12390-3, 2002). Average compressive strength and unit weight values are presented in Table 1.

Figure 3: Samples of Compressive Tests

Sample	Concrete Class	Unit Weight (gr/cm^3)	Ultimate Load (N)	Compressive Strength
Plain Concrete	C 20	2.33	272383	27
Concrete filled GFRP Profiles	C 20	2.21	328450	33
Plain Concrete	C 30	2.37	393250	39
Concrete filled GFRP Profiles	C 30	2.27	430480	43
Plain Concrete	C 40	2.41	479816	48
Concrete filled GFRP Profiles	C 40	2.19	532817	53

Table 1: Results of Compression Tests

Compressive tests outcomes of C20 class specimens showed that the strength of concrete-filled GFRP has about 22% higher strength when compared with plain concrete. Comparisons between plain concrete and concrete- filled GFRP profiles average values are given in Figure 4. However; compressive tests outcomes of C30 and C40 class's specimens showed that the strength of concrete-filled GFRP has about 10% higher strength when compared with plain concrete as seen in Figures 5 and 6. Unit weight of concrete was reduced about 10% as seen in Table 1. The results showed that the hybrid use of GFRP with concrete increased the compressive strength in three different concrete classes. The outcomes showed that increases of concrete quality reduce the effect of GFRP profiles. In addition; failure patterns of concrete filled GFRP profile were examined. Test results showed that all samples were broken from the corner as seen in Figure 7.

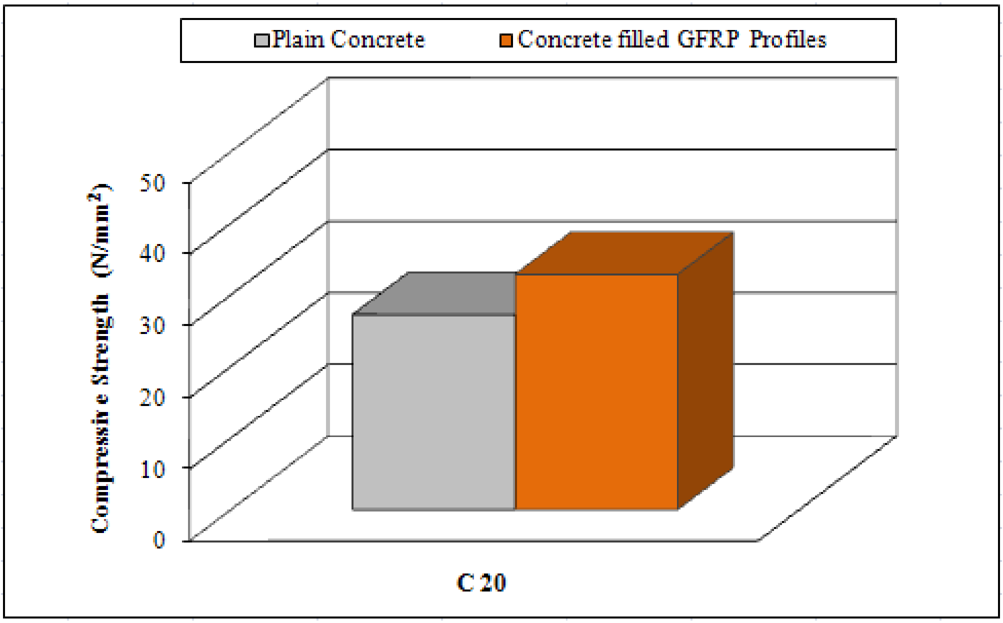

Figure 4: Compression results of C20 concrete samples

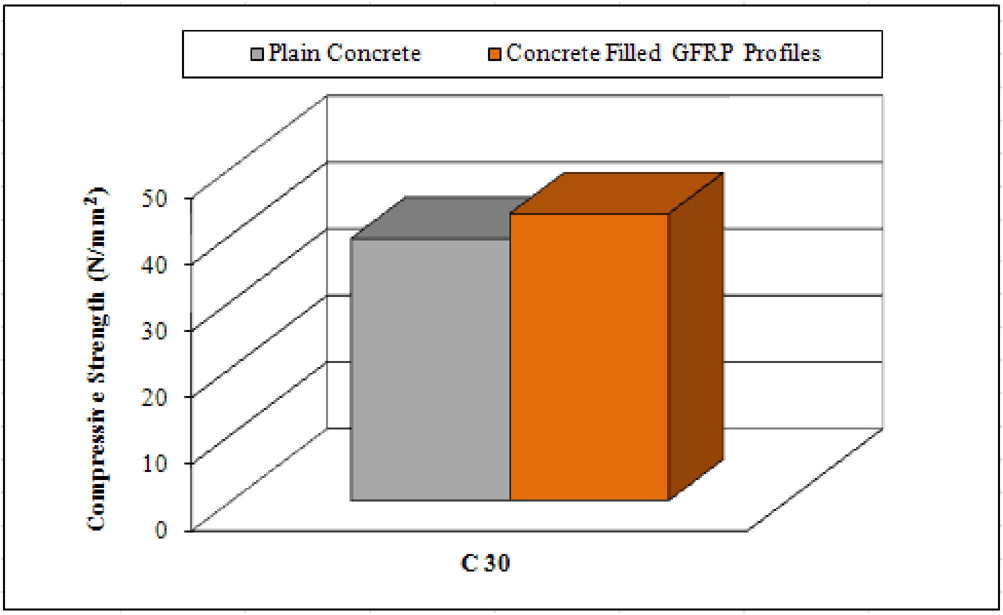

Figure 5: Compression results of C30 concrete samples

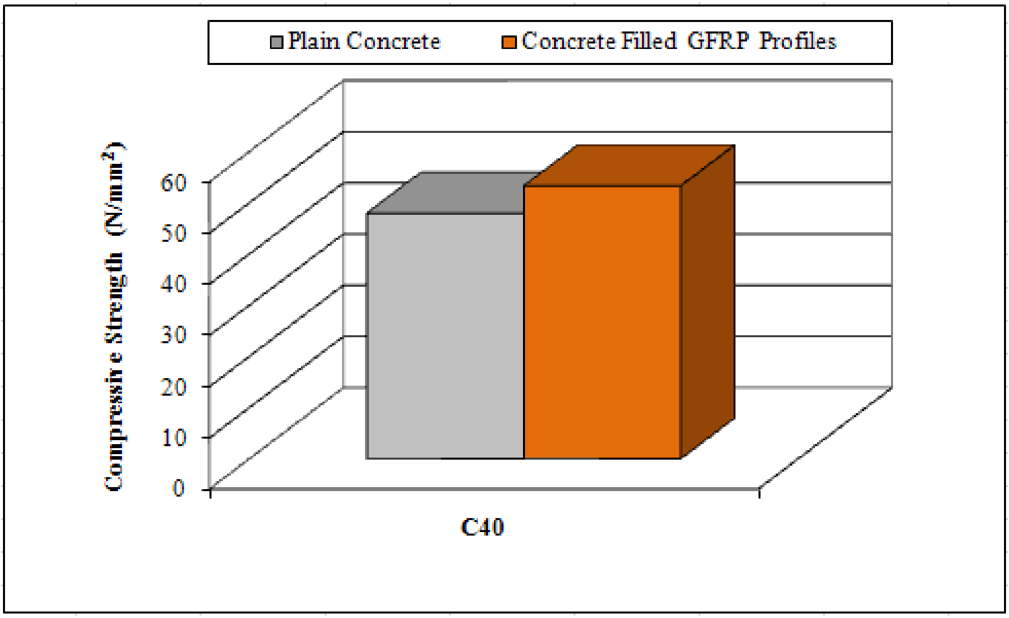

Figure 6: Compression results of C40 concrete samples

Figure 7: Concrete filled GFRP samples failure pattern

Flexure Tests

Concrete and concrete filled GFRP bending specimens in three groups (C20, C30 and C40) concrete classes were prepared according to the Turkish Standard (TSE 802, 1985). Wall thickness of 4 mm and cross-section of 74x74 mm length of 500 mm (beam's span 400 mm) GFRP box profile were used to produce concrete filled bending specimens (see Figure 8). Portions of fresh mixed concrete were filled in GFRP box section and remainder was filled in same size of mould. The specimens were kept in the water for 28 days and then tested to determine bending strength according to the Turkish Standard (TS EN 12390-5, 2002). Three point bending tests were performed using universal tensile test machine as shown in Figure 9. Deflection of plain concrete, plain GFRP box section and concrete filled GFRP profile were recorded to determine the relative bending of the specimens. The load cell and LVDTs were connected to a PC via a signal conditioning unit. Measurements were taken at five intervals giving approximately 150 sets of measurements per test.

Figure 8: Samples of Flexure Tests

Figure 9: Flexure Test with Concrete Filled GFRP Box Profile

After experiments in the load-deflection graphs are formed and the bending strength values of all samples were calculated by the equation 1. The obtained results have been compared to each with others. Average bending load and bending strength values are presented in Table 2.

$$\sigma = \frac{M \times y}{I} \qquad (1)$$

Where; σ is bending strength, M is bending moment, I is moment of inertia and y is neutral axis distance.

Sample	Ultimate Load (kN)	Bending Strength (N/mm^2)
Plain Concrete	4.84	7.17
Box Profile	11.70	47.17
Concrete Filled GFRP Profiles (C 20)	19.45	28.79
Concrete Filled GFRP Profiles (C 30)	19.07	28.23
Concrete Filled GFRP Profiles (C 40)	21.15	31.31

Table 2: Results of Flexure Tests

Tests outcomes of specimens showed that the bending load of concrete-filled GFRP has about four times and two times higher values when compared with plain concrete and plain GFRP box section respectively. Comparisons between plain concrete, plain GFRP and concrete- filled GFRP profiles load-deflection graphs are given in Figure 10-12. The results showed that the hybrid use of GFRP with concrete increased the bending load capacity in three different concrete classes. In addition; the GFRP box section protects the concrete and the filled concrete defends the local failure of GFRP profile. Test results showed that all samples were broken from the corner as similar as compressive samples as seen in Figure 13.

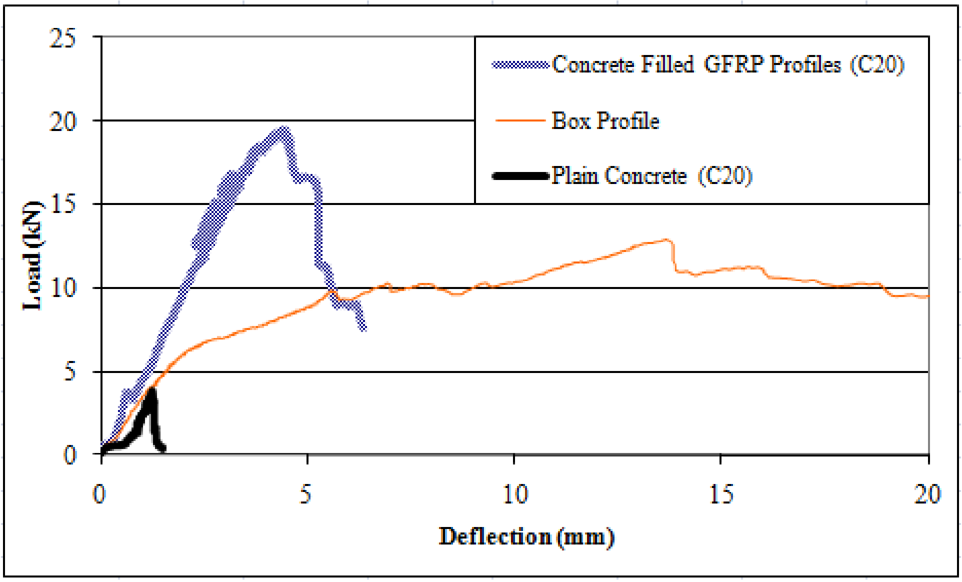

Figure 10: Comparison between beam samples in C20 compressive strength

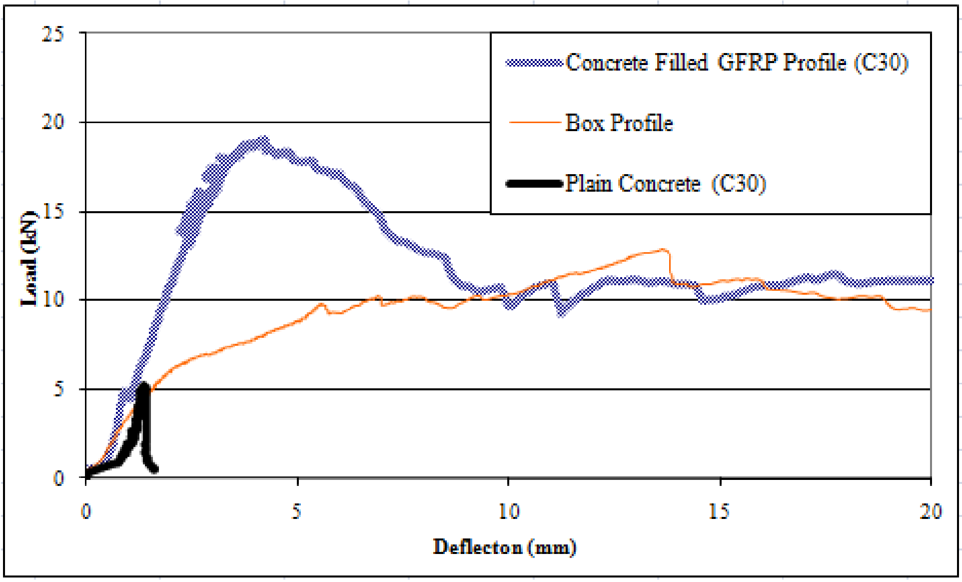

Figure 11: Comparison between beam samples in C30 compressive strength

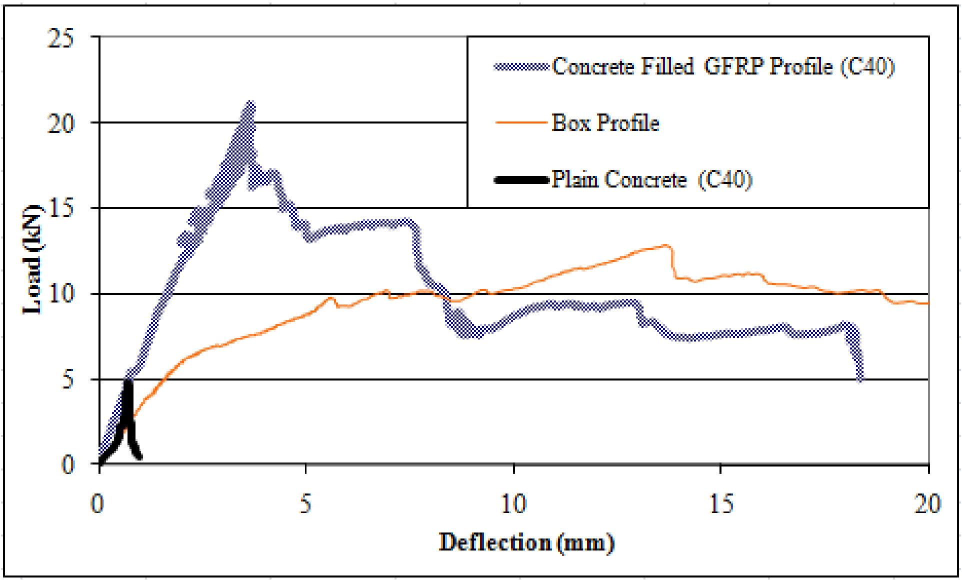

Figure 12: Comparison between beam samples in C40 compressive strength

Figure 13: Beam Sample after Flexure Test

Conclusions

High tensile strength, lightweight and non-corrosive properties allowed GFRP to become a competitive alternative to traditional structural materials. Research activities have been taken in order to produce more effective constructions materials using hybrid use of pultruded GFRP and concrete. Compressive strength and flexural properties of hybrid use of GFRP profile with concrete have been investigated. The tests applied on the specimens including plain concrete, GFRP box profiles and concrete filled GFRP profiles. The outcomes demonstrate the advantages and importance of GFRP profiles will be used engineering applications. With respect to the experimental behaviour, the following conclusions have been drawn:

- Compressive tests outcomes of C20 class specimens showed that the strength of concrete-filled GFRP has about 22% higher strength when compared with plain concrete. The tests outcomes of C30 and

C40 class's specimens showed that the strength of concrete-filled GFRP has about 10% higher when compared with plain concrete. The results showed that the hybrid use of GFRP with concrete increased the compressive strength.

- Bending tests outcomes of specimens showed that the bending load of concrete-filled GFRP has about four times higher values when compared with plain concrete and two times higher than plain GFRP box section. The results showed that the hybrid use of GFRP with concrete increased the bending load capacity in all concrete classes. GFRP box section protects the concrete and the filled concrete protects the local failure of GFRP profile.

- Compressive and bending test results showed that all samples were broken from the corner of pultruded GFRP box profiles.

- There are several structural advantages of hybrid use of pultruded GFRP profiles with concrete, including the increase of the flexural stiffness, reducing the structures deformability, and the increase of the structures strength capacity, and preventing the local failure of the GFRP profiles.

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