Nouvelles applications pour l'armature composite dans les infrastructures routières

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ABSTRACT

Fiber reinforced polymers (FRP) have emerged as a practical and sustainable material for producing reinforcing bars that provide superior tensile strength and built-in corrosion resistance. Many significant developments from the manufacturer, various researchers and Design Codes along with numerous successful installations have led to a much higher comfort level and exponential use with designers and owners across Canada. After years of investigating, public agencies and regulatory authorities as the MTO has now included GFRP as a premium corrosion resistant reinforcing material in its corrosion protection policy.

1. INTRODUCTION OF GFRP/CFRP REINFORCEMENT

With corrosion being a fundamental issue with governments and owners as they deal with an aging infrastructure and increased traffic volumes, the inherent features and benefits of FRP reinforcement provides cost effective and long-term sustainable performance of concrete structures as shown in Fig.1. Along with its superior tensile properties and built-in corrosion resistance which is impervious to salt ions, chlorides and chemicals, FRP reinforcing bar is electrically/magnetically neutral, provides thermal benefits and is one quarter the weight of steel. Initial bar costs are competitive with epoxy coated rebar, substantially less than stainless steel and the bar of choice when considering life-cycle costing and long-term sustainable performance. In some regions, “cost comparisons have shown that GFRP is actually less costly than epoxy coated reinforcing steel and almost comparable to ‘black’ steel”. (Krisciunas 2009).

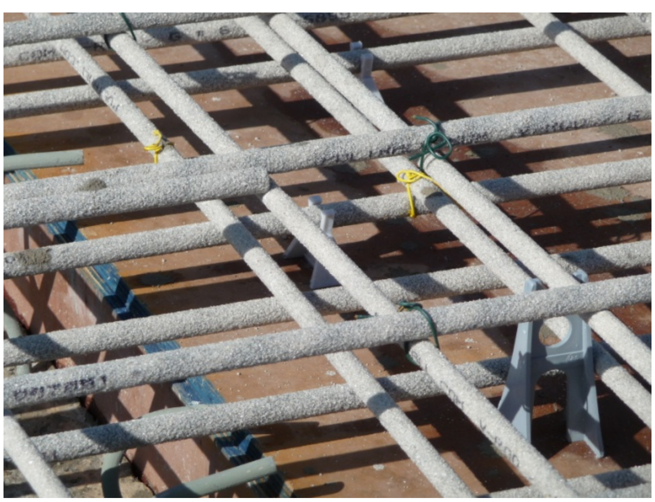

Fig. 1. FRP deck bar ready to cast – Waterloo Region

2. DEVELOPMENTS OF CODES AND GUIDELINES

As mechanical properties of FRP reinforcing bars differ than that of steel, there are a number of design codes and guidelines available. The CSA S-806-02 (world's first full design standard for FRP) and ACI 440.1R-01 are based on the principles of equilibrium and compatibility and the constitutive laws of the materials. The Canadian Bridge Design Code (CHBDC S6-06) is the primary Code for bridge structures along with various ISIS Canada Design Manuals (ISIS Canada Manual No 3 2007). Currently out for comment, a revised CSA S6-06-Section 16 and CSA S-806 is forthcoming later in 2010.

In order to establish stringent guidelines and values for FRP manufacturers and quality control mechanisms for owners to ensure a high comfort level of product supplied, ISIS Canada together with the manufacturer had initiated the "Specifications for Product Certification of FRP's as Internal Reinforcement in Concrete Structures". (ISIS Canada Corporation 2006) This document was the basis for the new FRP specification (CSA S-807-10), which is now available from the CSA website since the end of April 2010. There have been slight revisions to specific values of testing and reporting with three distinct Grades; Grade I (40GPa), Grade II (50GPa) and Grade III (60GPa).

3. BAR PROPERTIES

The mechanical and physical properties of FRP reinforcement are critical in determining the performance and durability of the bar. V-ROD properties and Specifications are available for the various types of FRP rebar and grades, supported by years of research and testing of properties and durability through various researchers, universities and organizations. (Mufti et al. 2005), (Benmokrane et al. 1998, 2005, 2009), (Sparks et al. 2004)

3.1 Glass Fiber Reinforced Polymer (GFRP) Reinforcing Bar

GFRP is the primary type of FRP used in reinforced concrete structures, with the manufacturer currently producing bar that meets the Grade II classification (40GPa) and the Grade 1 (60GPa) based on the "ISIS Certification Guideline". A full test result summary and letter of qualification of the manufacturer are available along with summary of values based on this document as well as the new CSA S-807-10.

3.2 Carbon Fiber Reinforced Polymer (CFRP) Reinforcing Bar

CFRP is used for more specific applications where perhaps larger spans are involved, weight is an issue, extra stiffness is required or for pre-stressing precast structures. With the tensile strength at 1900 MPa and modulus of 144 GPa, Carbon bar has been used to pre-stress several pre-cast bridge decks, girders, sidewalks and curbs such as in Fig.2. Pre-cast companies are utilizing the pre-stressing anchors designed/produced by the University of Waterloo. (Soudki et al. 2008, 2010)

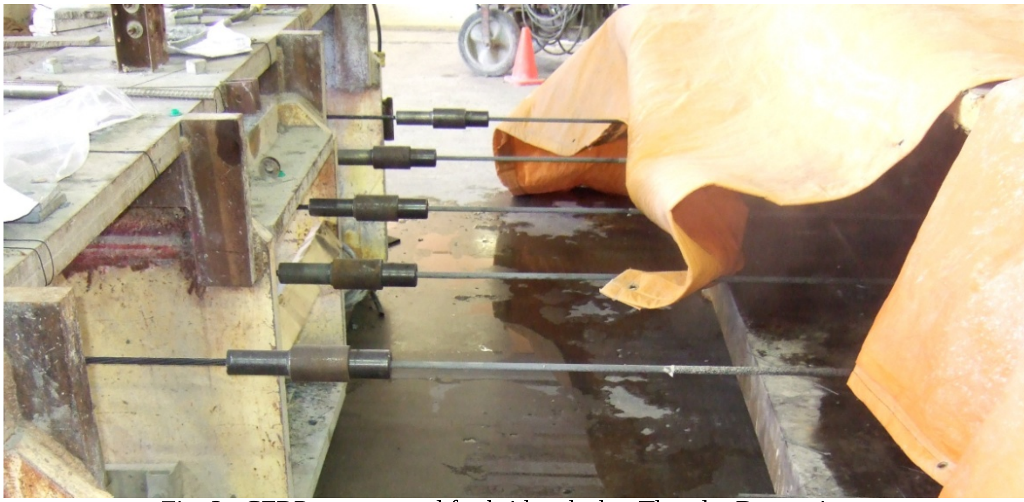

Fig. 2. CFRP pre-stressed for bridge deck – Thunder Bay region

4. PROJECT APPLICATIONS AND EXAMPLES ACROSS CANADA

The number of projects being designed and specified with FRP, types of applications and the overall scope and complexity of the structures has exponentially increased over the past couple of years, with the trend continuing. GFRP is not restricted only to bridge decks. It has also been used to reinforce precast “deck-free” box girders where the tops of the girders form the final bridge deck surface as shown in Fig.3 and Fig.4. (Raymond Krisciunas NW MTO ISIS presentation 2009). Aside from an increasing number of pre-cast bridge projects, FRP continues to be used in more cast-in-place decks, overlays, approach slabs, girders, barriers/parapets, sidewalks and curbs. The following photos provide various examples of a number of project applications across Canada.

Fig. 3. CFRP stirrups in girders – MTO NW region

Fig. 4. Finished precast girders – MTO NW region

Fig. 5. Top & bottom FRP in decks and barriers – Quebec 2004

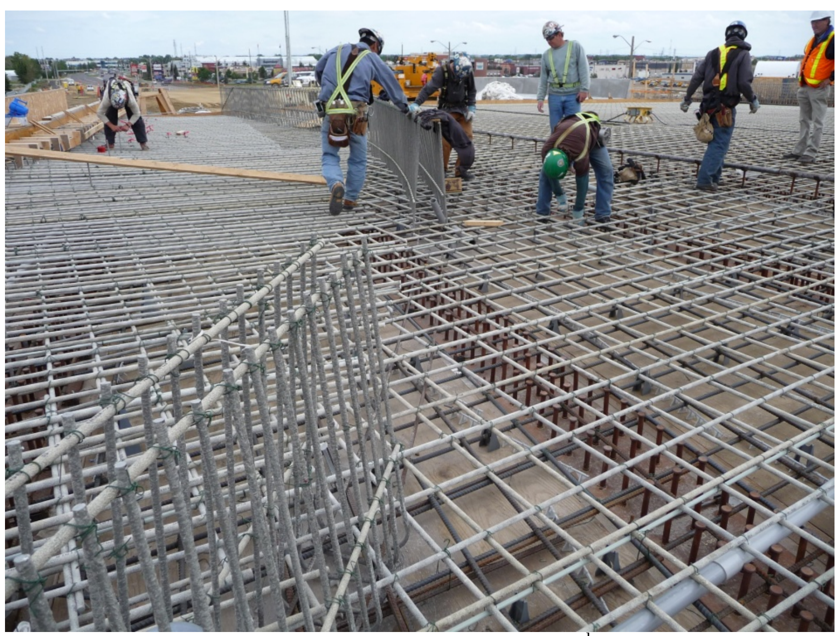

Fig. 6. FRP decks and barriers – Gateway Blvd/23rd Ave – Alberta 2009

Fig. 7. FRP decks/app slabs/ barriers – Skagit River – BC MOT 2009

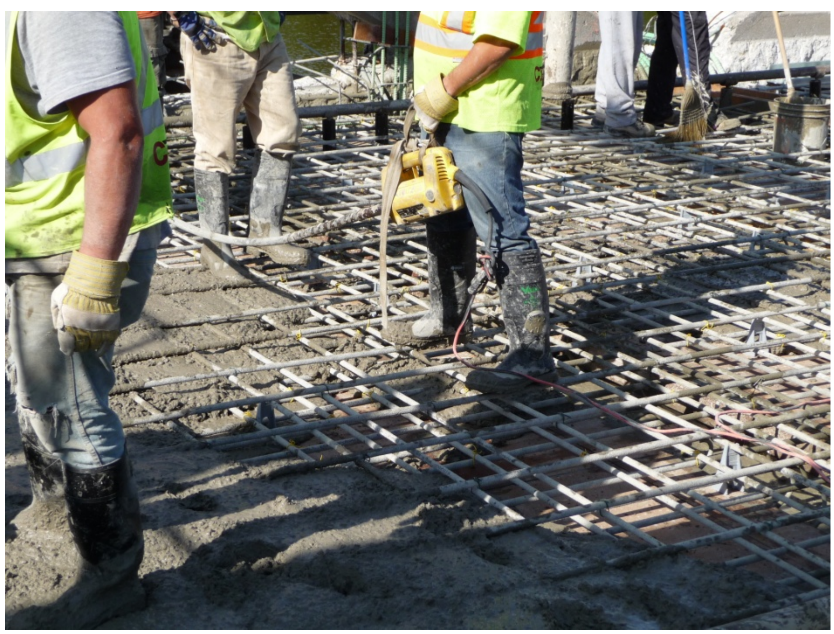

Fig. 8. FRP top & bottom layers of decks – Bridgeport Bridge – Waterloo, ON 2009

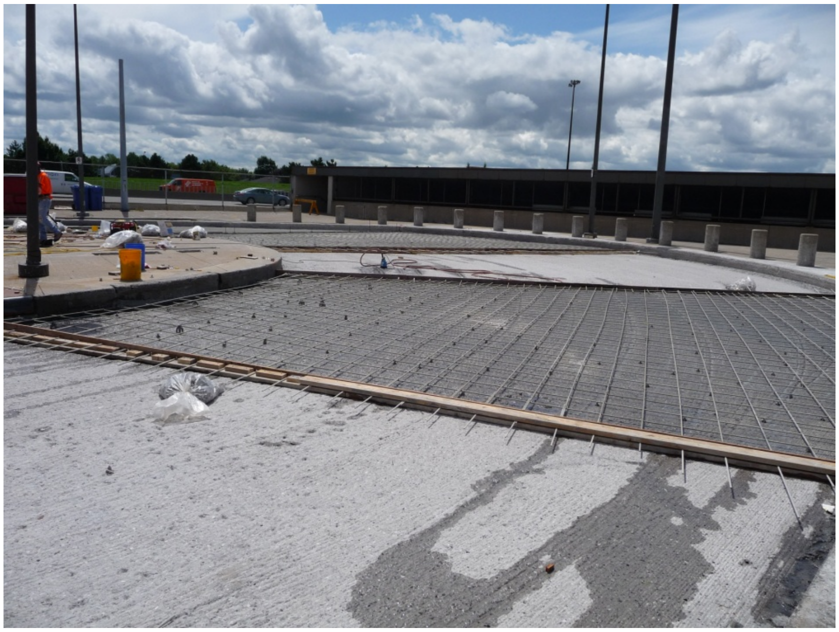

Fig. 9. FRP mat each way – East Transitway, Ottawa, ON 2009

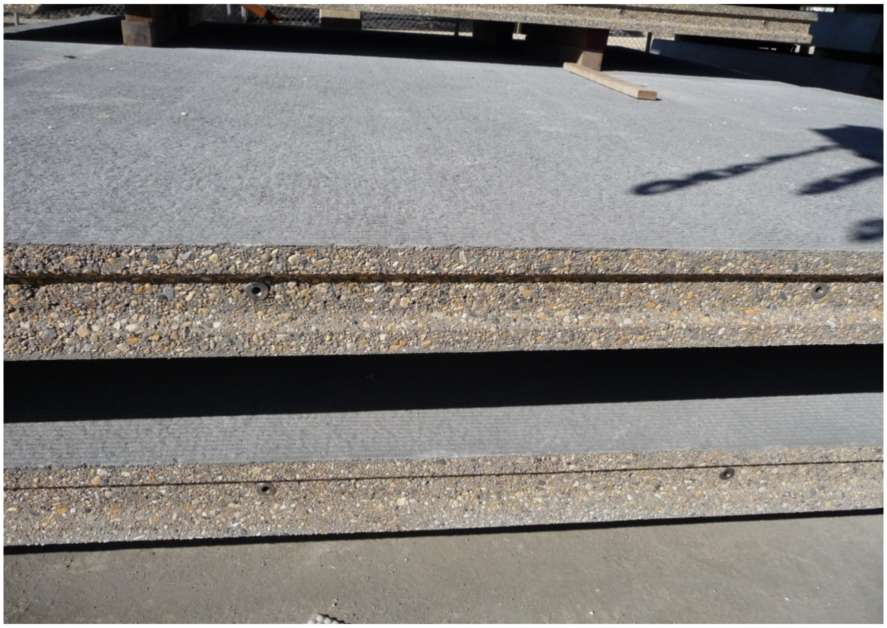

Fig. 10. Top & bottom bar in precast, CFRP prestressed– Noden Causeway ON 2008

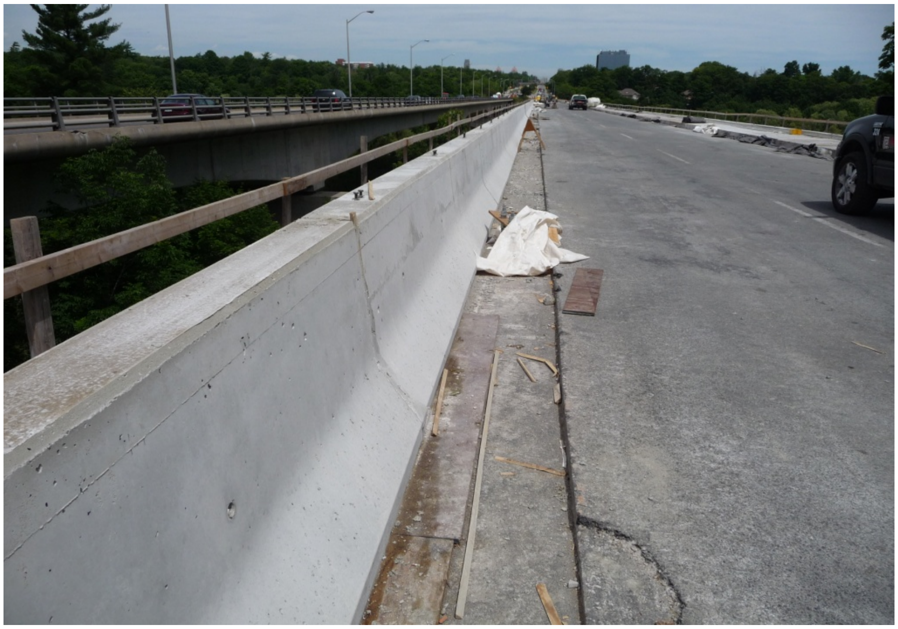
Fig. 11. FRP in barriers – Burnhamthorpe bridges, Mississauga, ON 2009

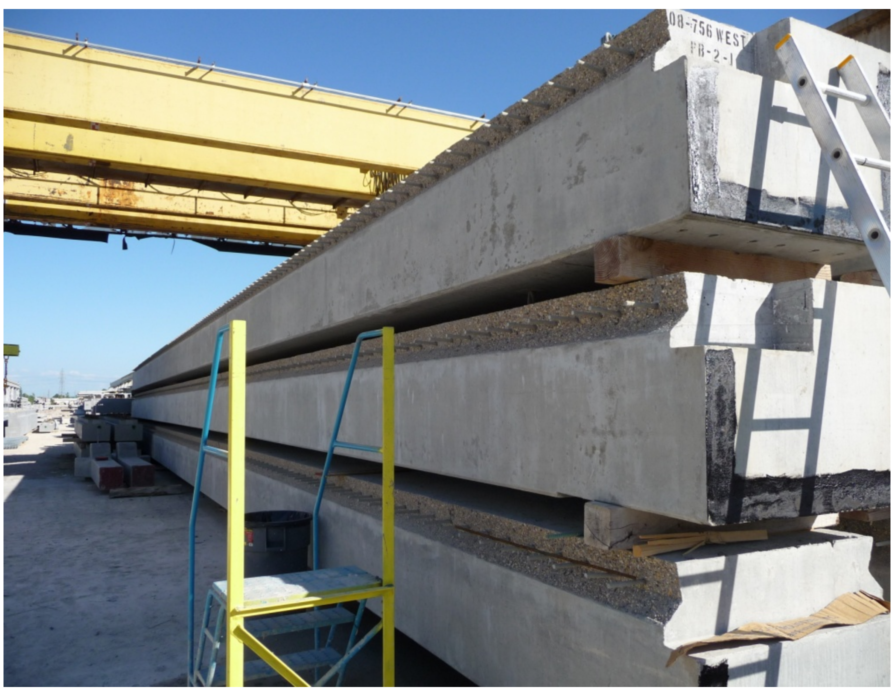

Fig. 12. FRP precast structure Hawk Lake bridge, MTO NW, ON 2008

5. FRP ACCESSORIES AND CONTINUING R&D

As the use of FRP reinforcing continues to increase dramatically, the manufacturer continues investing in R&D to improve bar properties, expand its product range and develop accessories to compliment the bar.

5.1 Bar Connectors

As certain stage construction projects require bar connectors where there is no room for lapping reinforcing bar, it became imperative to produce a FRP to FRP connector, similar to connectors used for steel reinforcement except designed not to damage the fibers. A lower performance “crimped” on connector tested to 345 MPa is available for certain applications where it can for example have steel bar threaded into it as shown in Fig.12. For higher performance, a 316 stainless steel connector has been developed as a male/female assembly as shown in Fig.13.

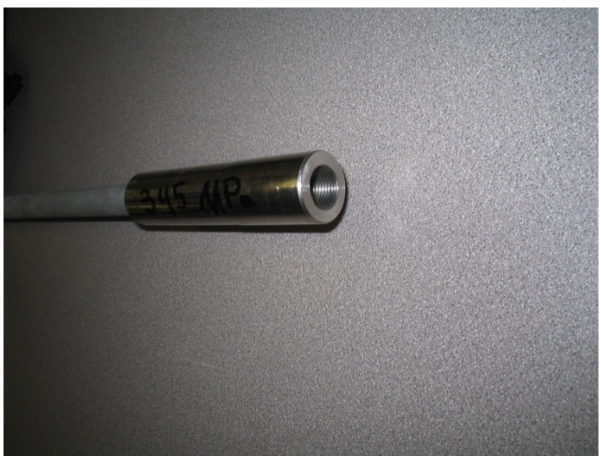

Fig. 12. Stainless steel crimped on connector

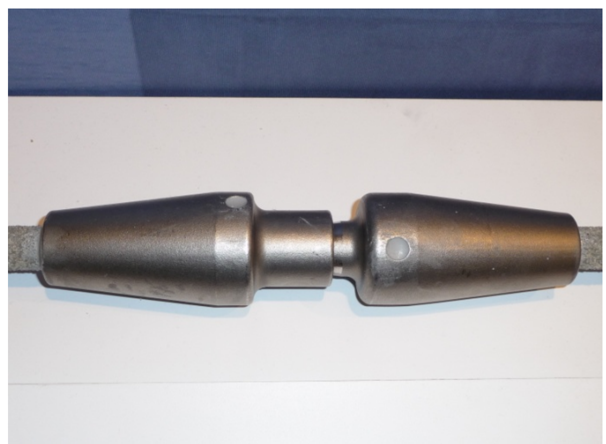

Fig. 13. 316 Stainless steel male/female connector

5.2 Headed Reinforcement

As with steel reinforcement, FRP bars are produced to accommodate various types of bends, stirrups and ties required for development. As there are some limitations to FRP bends, there is the option of utilizing “headed” reinforcement to achieve the required development as shown in Fig.14. This may be for example in congested reinforcement areas, long lengths of bars that cannot be produced in FRP as one piece or as a design option for barriers for example. The headed reinforcement would typically be used on the High Modulus (60GPa) bar where maximum spacing can be achieved and bends eliminated. It must be noted however that heads secured on straight reinforcing bar will not address all reinforcement requirements. This will be dependent on the types of structures being designed for example where continuity is required and bends will be required.

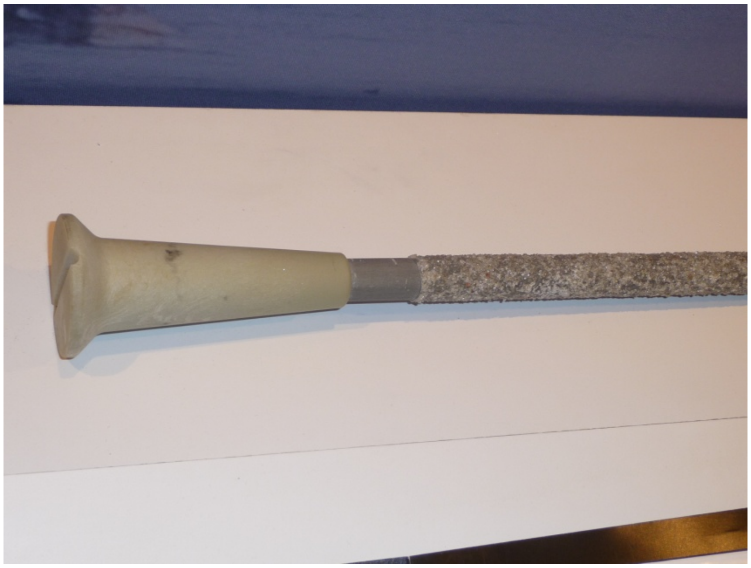

Fig. 14. Thermoplastic head secured on FRP bar

6. CONCLUDING REMARKS

As the manufacturing process, accessories and properties of the FRP reinforcing bar continues to improve while various codes and guidelines provide owners and consultants with the tools for specifying and designing, the use of FRP reinforcement continues to increase exponentially. The scope of work on various project applications continues to grow wider and more complex as the long-term benefits of this non-corrosive and non-conductive composite reinforcement is providing a sustainable solution for our structures.

7. ACKNOWLEDGMENTS

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The author also acknowledges figure credits for the attached photos. Figures 3 and 4 are courtesy of Ray Krisciunas of MTO NW 2009 and Figure 7 is courtesy of BC MOT 2009. All other photos are courtesy of Gene Latour of Trancels-Pultrall Canada Inc.

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