Object: Comparative study between the use of various types of concrete reinforcing materials on the Melbourne (Hwy 55, Easten Townships, Quebec) bridge deck.

Over the past few years now, GFRP (Glass Fiber Reinforced Polymer) concrete reinforcement (rebar) has been gaining in popularity in the construction of structures that are subject to corrosion problems. As a matter of fact, inherent to its nature, GFRP reinforcement has very good corrosion resistance properties and therefore avoids the premature degradation of concrete infrastructures. Proof of the GFRP rebar's technical ef□ciency has been made through many different applications (bridge decks, seawalls, under and above ground multi-storeys parking garages, …) but many concerns still remain regarding the cost of using such a technology. Although the many calculations of Life Cycle Cost (including all maintenance and repair costs over the lifespan of the structure) all conclude that GFRP is the best alternative, we felt compelled to provide some precisions in regards with initial cost.

GFRP reinforcement has mechanical properties that differ from that of steel rebar. Based on those differences, designs will vary, especially in the number of bars to be used, from one material to another. Showing better tensile strength than steel while being less rigid, GFRP reinforcement has advantages and disadvantages. When compared to steel, some works will require more GFRP rebar and some less. Concerned by continuous improvement as well as leadership and to counter, at least partially, the negative impact of the lack of rigidity of its V-ROD product line, Pultrall has developed a new formulation that exhibits greater performances. This brand new composition allowed Pultrall to put together a product line with more rigidity (E≈64 GPa) and more resistance ($f_f \approx 1300$Mpa) called V-ROD HM. Consequently, four designs of the same work, using the four reinforcement material presented (galvanized and Epoxy coated steel, V-ROD and V-ROD HM), were necessary to be able to compare reinforcement's initial buying cost.

Galvanized and Epoxy coated steel's cost has been determined using RFQs sent to three different Canada based steel rebar suppliers. Prices obtained do not include any transportation or installation of the bars. We simply averaged the three different prices given to us and used the result in our calculations presented in Table 1 and 4. The V-ROD and V-ROD HM prices are the very same than the ones Pultrall use in their quotations since October 2008.

Over the past decade or so, Pultrall has focused on bridge decks as one of the most suitable application for GFRP reinforcements. We have then decided to build our economics comparison around a bridge owned by the Quebec's Ministry of Transportation situated close to the city of Melbourne in the Eastern Townships. A thorough description of the structure is given in the attached report titled «Design of Concrete Bridge Deck Slabs Using Different Types And Diameters of GFRP bars». Results of the different designs (reinforcement bars list) are presented in the following Appendix. Tables 1 thru 4 below are respectively the amount and speci□cations of the bars needed for the same work using either galvanized steel, V-ROD, V-ROD HM and Epoxy coated steel.

Governed mainly by the modulus of elasticity (rigidity), the reinforcement design of such a structure requires a greater number of GFRP rebars than steel ones. This shows up very evidently when analysing Tables 1, 2, 3 and4. On the other hand, the volatility of metals prices combined with the productivity improvements of V-ROD's GFRP reinforcement end up tightening the differences between initial purchase costs of the total bars. That being said, we can see that the overall cost of Standard V-ROD reinforcement end up being 3.4% higher than the galvanized steel equivalent. By opposition, if V-ROD HM is used, an overall economy of 2.7% is possible over the total reinforcement cost. If we do the same comparison against Epoxy coated steel, we end up with total bar purchase prices that are 8.3% higher for the standard V-ROD and only 1.8% higher for the V-ROD HM technology. Adding to the equation the fact that V-ROD is ~75% lighter than steel, thus reducing signi□cantly the transportation charges, it makes it more appealing than ever.

This case study is not intended to prove, without a doubt, that using GFRP reinforcement will always offer an economics incentive over the use of galvanized or Epoxy coated steel rebar. Though, it points out very clearly that initial costs are very similar, even if more V-ROD bars need to be used. In conclusion, we are convinced that the Life Cycle Cost advantages, along with a similar initial purchasing cost of the reinforcement, show the relevance of using V-ROD products whenever and as much as possible.

Bernard Drouin
General Manager, Ing.
Pultrall Inc.

Appendix

Results

Table 1

Bar List of a bridge deck reinforced with Galvanized Steel.

Configuration of reinforcement	Identification	Length (mm)	Designation	Quantity	Total Length (m)	Price ($/m)	Calculated Total Price ($)
As=833,33 mm^2/m 15M @ 240mm	D1	11485	15M	864	9923,0	3,64 $	36 119,87 $
As=1250 mm^2/m 15M @ 160mm	D2A	10600	15M	465	4929,0	3,64 $	17 941,56 $
As=1250 mm^2/m 15M @ 160mm	D2B	3650	15M	465	1697,3	3,64 $	6 177,99 $
As=1250 mm^2/m 15M @ 160mm	D2E	8865	15M	543	4813,7	3,64 $	17 521,85 $
As=1250 mm^2/m 15M @ 160mm	D2F	5390	15M	543	2926,8	3,64 $	10 653,44 $
As=1250 mm^2/m 15M @ 160mm	D5	2735	15M	1086	2970,2	3,64 $	10 811,56 $
					27259,965m		**99 226,27 $**

Table 2

Bar List of a bridge deck reinforced with V-ROD.

Configuration of reinforcement	Identification	Length (mm)	Designation	Quantity	Total Length (m)	Price ($/m)	Calculated Total Price ($)
A_{frp}=1165 mm^2/m No16 @ 170mm	D1	11485	16	1184	13598,24	2,71 $	36 851,23 $
A_{frp}=1722 mm^2/m No16 @ 115mm	D2A	13655	16	784	10705,52	2,71 $	29 011,96 $
A_{frp}=1722 mm^2/m No16 @ 115mm	D2E	13655	16	784	10705,52	2,71 $	29 011,96 $
A_{frp}=861 mm^2/m No16 @ 230mm	D5	3650	16	784	2861,6	2,71 $	7 754,94 $
					37870,88m		**102 630,08 $**

Table 3

Bar List of a bridge deck reinforced with V-ROD HM.

Configuration of reinforcement	Identification	Length (mm)	Designation	Quantity	Total Length (m)	Price ($/m)	Calculated Total Price ($)
A_{frp}=921 mm^2/m No16 @ 215mm	D1	11485	16	928	10658,08	3,23 $	34 425,60 $
A_{frp}=1366 mm^2/m No16 @ 145mm	D2A	13655	16	621	8479,755	3,23 $	27 389,61 $
A_{frp}=1366 mm^2/m No16 @ 145mm	D2E	13655	16	621	8479,755	3,23 $	27 389,61 $
A_{frp}=683 mm^2/m No16 @ 290mm	D5	3650	16	621	2266,65	3,23 $	7 321,28 $
					29884,24m		96 526,10 $

Table 4

Bar List of a bridge deck reinforced with Epoxy coated steel.

Configuration of reinforcement	Identification	Length (mm)	Designation	Quantity	Total Length (m)	Price ($/m)	Calculated Total Price ($)
As=833,33 mm^2/m 15M @ 240mm	D1	11485	15M	864	9923.0	3.48 $	34 508.84 $
As=1250 mm^2/m 15M @ 160mm	D2A	10600	15M	465	4929.0	3.48 $	17 141.33 $
As=1250 mm^2/m 15M @ 160mm	D2B	3650	15M	465	1697.3	3.48 $	5 902.44 $
As=1250 mm^2/m 15M @ 160mm	D2E	8865	15M	543	4813.7	3.48 $	16 740.34 $
As=1250 mm^2/m 15M @ 160mm	D2F	5390	15M	543	2926.8	3.48 $	10 178.28 $
As=1250 mm^2/m 15M @ 160mm	D5	2735	15M	1086	2970.2	3.48 $	10 329.34 $
					27259,965m		**94 800.56 $**