Title: Use of Fiber Reinforced Polymer (FRP) in Retrofitting and Strengthening of Bridge Girders.

Name: Chakrapan Tuakta

Introduction

More than 50% of bridges in the U.S. were built before 1940, and half of these bridges have become structurally deficient due to exceeding service load and environmental deterioration. Strengthening and retrofit are among the alternatives to deal with this problem. The desirable strength of structurally deficient bridges can be achieved by several techniques, including increasing the size of deficient member, introducing additional beams to the structure, adding externally post-tensioned cables, and employing traffic management to relieve life load. In recent years, as research and development of fibers and matrix materials and fabrication process related to construction industry have grown rapidly, using fiber reinforced polymer (FRP) in retrofit of bridge girder is gaining attention in both research and application. Because of its superior mechanical properties, high corrosion resistance, and ease of handling, FRP is gradually replacing steel plate in strengthening deficient structural member. This paper will first investigate the nature of FRP and its mechanical behaviors. Then, examine its application and design practice in strengthening bridge girder through several case studies from literature.

Facts and Findings (in brief)

Fiber reinforced polymer is two-phased material, consisting of fiber and matrix of polymer. Three major fibers used in construction industry are glass (GFRP), carbon (CFRP), and aramid fibers. To achieve desirable functionality, they are required to have high modulus of elasticity, high ultimate strength, low variation of strength between each fiber, high stability and retention of their strength during handling, and high uniformity of diameter and surface dimensions. Matrices widely used are thermoplastic and thermosetting polymers, such as polyester, epoxy, vinylester, etc. Between fibers and matrix is interface, which is assumed to perfect bonding. The mechanical properties of FRP composites depend on: 1.) relative proportion of fiber and matrix materials; 2.) the method of manufacture; 3.) the mechanical properties of component parts; and 4.) fiber orientation within the polymer matrix.

In structural and civil engineering, FRP is used in both new constructions and strengthening existing infrastructures. In bridge structure, FRP composite can be used in externally strengthening of deficient girders, increasing their flexural and shear strength. The disadvantages of using steel plate instead of FRP are the possibility of corrosion, which can adversely affect bond strength, and the difficulty in transport, handling, and installation.

To increase flexural strength, FRP composite is bonded longitudinally to the tension surface of bridge girder by using epoxy or resin. The dimensions of FRP required for flexure can be calculated using strain compatibility method and the MBT M-Brace Design Guidelines. To increase shear strength, FRP composite is bonded vertically to the sides of bridge girder. Similarly, the required dimensions of external FRP stirrups can be calculated using strain compatibility method and the following equation:

$$\Phi V_n = \Phi A_{vf} f_{FRP} \mu$$

where A_{vf} = area of FRP stirrups needed per m; f_{FRP} = stress in FRP stirrups; Φ = strength reduction factor, 0.85; and μ = friction coefficient.

From experiments conducted by the authors of several papers listed in reference section, the flexural capacity of repaired girder can be increased as much as 25%, while the shear capacity can be increased as much as 16%. However, as the strength is increased, the ductility of repaired girder is decreased, which should be taken into account in the design process.

Future Work

There are many things to be done in the future. First, I have to study in more detail the M-Brace Design Guideline for flexural strengthening design. Second, it would be nice, if I have comparison of costs incurred from using FRP and steel plate. Third, if this possible, I will have to do more research on the performance of repaired bridge after strengthening.

Reference

1. Hollaway, L. C., & Leeming M. B., eds. Strengthening of Reinforced Concrete Structures: Using Externally-bonded FRP Composites in Structural and Civil Engineering. 1999.
2. Hollaway, L. C. & Head, P. R. "Composite Material and Structure in Civil Engineering"
3. Spadea, G., Swamy, R. N., & Bencardino F. Strength and Ductility of RC Beams Repaired with Bonded CFRP Laminates. Journal of Bridge Engineering, September/October 2001, 349-355.
4. Reed, C. E., & Peterman, R. J. Evaluation of Prestressed Concrete Girders Strengthened with Carbon Fiber Reinforced Polymer Sheets. Journal of Bridge Engineering, March/April 2004, 185-192.
5. Stallings, J. M., Tedesco, J. W., El-Mihimy, M., & McCauley, M. Field Performance of FRP Bridge Repairs. Journal of Bridge Engineering, May 2000, 107-113.
6. Ross, S., Boyd, A., Johnson, M., Sexsmith, R., & Banthia, N. Potential Retrofit Methods for Concrete Channel Beam Bridges Using Glass Fiber Reinforced Polymer. Journal of Bridge Engineering, January/February 2004, 66-74.