CHAPTER I
INTRODUCTION

1.1: Background

1.1.1: Material Properties

Bridges are vital components of any transportation system. They are the most expensive elements of the system on a per mile basis, and require the most time to construct. As such, researchers and practitioners have made many strides in extending the service life of bridges, thereby reducing the overall lifecycle costs. One area of focus in extending the service life is reducing the deterioration of bridge reinforcement due to chloride exposure. This is a big problem in bridge decks, which receive high concentrations of chloride exposure from deicing salts. One very promising way to prevent deterioration in bridge decks due to chloride exposure is by using an alternative material to mild steel reinforcement. One such material that has been offered as an alternative to mild steel reinforcement is Fiber Reinforced Polymer (FRP) bars, in particular Glass Fiber Reinforced Polymer (GFRP) bars.

These bars have several advantages over steel reinforcement, but the one most important with regards to bridge decks is that they are non-reactive to chlorides. However, the stress-strain behavior of FRP bars is linear elastic to failure with no yield plateau. Due to this, there is much concern for using FRP reinforcement as the sole reinforcing in a bridge deck. To maximize the advantages of both types of reinforcing, it has been proposed to use FRP bars as the top mat of reinforcing in a bridge deck while using plain or epoxy coated mild steel bars as the bottom mat. Using FRP bars as the top mat of reinforcing significantly increases the cover depth over the steel bars and requires that the chlorides penetrate and additional 75 – 100 mm (3 – 4 in.) to the bottom mat of reinforcement before causing any deck deterioration. Forcing the chlorides to penetrate further will cause an increase in the service life, and thereby reduce the life cycle costs of the bridge.

Much information about the behavior of FRP is needed to safely design a bridge deck with FRP bars. This project is the first in a series of three projects sponsored by the Virginia Department of Transportation with the eventual overall goal of building a bridge with FRP as the top mat of reinforcement. This scope of this project is to determine how different properties of FRP bars from different manufacturers affect the design of a bridge deck. Each manufacturer of FRP bars produces their own literature with the physical, and bond characteristics of the bar. As yet, however, there is no uniform set of standards, as with steel, that sets minimum criteria, which all manufacturers must adhere to. As a result, independent tests should be performed to verify the properties presented in the manufacturers' literature. In addition, an evaluation should be made as to how the physical, and bond characteristics, of a certain type bar affect the design of a bridge deck using FRP bars as the top mat of reinforcement in a bridge deck.

1.1.2: Bond Test Comparison

The American Concrete Institute (ACI) produces a document entitled the 440K, which specifies the standard test methods for FRP rod and sheet. In this specification there is a provision for the standard bond test method to determine the bond strength of FRP bars. The ACI 440K (1999) document specifies the use of direct pullout tests. In this test an FRP bar is embedded a certain length into a concrete cylinder. After curing, the cylinder is placed in a universal testing machine (UTM), and the bar is pulled out. Testing an FRP bar in this manner results in the concrete around the bar being in compression. This is antipodal to what is happening in a flexural member, where the concrete around a bar will be in tension. The compression field around the bar is commonly known to prevent cracks that would normally form if the concrete was in tension, and as a result, the direct pullout test delivers higher than actual bond stresses. Due to the inaccurate results of the direct pullout test, an alternative test method should be investigated, and comparisons of results should be made.

Beam end bond tests are an alternative test method to direct pullout tests. In a beam end bond test the concrete around the bar is in tension (Johnston and Zia, 1982). This more accurately depicts flexural behavior. Unfortunately, this method of testing requires more construction time, and a more elaborate test setup. The FRP bars used in a beam end bond test are cast in a block representing one half of a beam. For this, formwork must be built, and shear force considerations must be taken into account. Also, the test cannot be performed in a UTM and a separate test frame and setup must be built to accommodate the loading. So, there is a need for an investigation into the difference in results between direct pullout tests and beam end bond tests, to see if the disparity is great enough to warrant consideration of a change or an addition to the specification set forth by the ACI 440K (1999).

1.2: Objectives of the Thesis

1.2.1: Objective One

The first objective of the thesis is to acquire and quantify material and bond properties of three different types of FRP bar and determine their effect on the design of a bridge deck. The material properties of focus are ultimate tensile strength, and modulus of elasticity. The bond properties include characterizing the bond behavior (load vs. slip), and determining the maximum bond stress.

To accomplish this objective first FRP bars were procured from three manufacturers. The three manufactures in the study are Hughes Brothers Inc., Marshall Industries, and Pultrall. The material properties of tensile strength, and modulus of elasticity were obtained through tensile testing of the different FRP bars. Each bar was tested in a UTM, and all load and strain data were recorded for each test. Stress-strain diagrams were constructed for each test from which the modulus was obtained. The ultimate tensile strength was recorded directly from each test. The bond tests were conducted by first constructing the specimens, which included form design, and construction as well as reinforcing bar cage design and assembly. Then a test frame was designed and constructed to accommodate and load the specimens after they had cured. Data that was recorded during testing included load data, slip data, and strain data. Load vs. slip graphs were constructed for the live or loaded end, as well as the free or unloaded end, for each test. The load vs. slip graphs allowed for the determination of the bond behavior as well as yielding the maximum bond stress. Stress-strain diagrams were constructed for all of the bond tests to provide modulus information, which was used for analysis of live end slip data. All of the gathered results were compared to literature provided by the manufacturer. Finally the tested results were used in conjunction with the ACI 440.1 (2001) design guide to determine the effect of the various material properties on the design of a bridge deck.

1.2.2: Objective Two

The second objective of the thesis is to compare the direct pullout test method with the beam end bond test method to determine if there is significant disparity in the results of the two methods

The second objective was accomplished by comparing the results from the bond tests, which are explained in 1.2.1, with previous literature to quantify the difference in the results of beam end and direct pullout bond stress tests. After the results have been quantified, a determination will be made as to the significance of the difference.