# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL INTRODUCTION

This research project was undertaken to investigate the potential of using composite piles for load bearing applications, specifically bridge substructures. Composite piles refer to alternative pile foundations composed of fiber reinforced polymers (FRP's), recycled plastics, or hybrid materials that are placed in the ground to support axial and/or lateral loads. Traditionally, piles are made of materials such as steel, concrete, and timber. These pile materials have limited service life and high maintenance costs when used in harsh marine environments (Lampo et al. 1998). Degradation problems of conventional piles include chloride attack on concrete, steel corrosion, and marine borer attack on timber piles. It has been estimated that repair and replacement of piling systems costs the U.S. over $1 billion annually (Lampo et al. 1997). High repair and replacement costs drive the need to investigate the feasibility of using FRP composite materials for pile foundations (Lampo et al. 1998, Iskander and Hassan 1998). FRP composite materials are considered an attractive alternative for marine and other harsh environments because they are resistant to the degradation mechanisms mentioned above.

Composite piles have been available in the North American market since the late 1980's, but to date their use has been limited mainly to marine fender piles, load bearing piles for light structures, and experimental test piles (Iskander et al. 2001). Composite piles have not yet gained wide acceptance in the civil engineering industry, primarily due to the lack of a long track record of performance, and the scarcity of well-documented field load tests. However, FRP composite piles may exhibit longer life cycle and improved durability in harsh marine environments, thereby presenting the potential for substantially reduced costs. Potential disadvantages with using composite piles are related to cost and performance. At present, composite piles are generally more expensive than traditional piles (Hoy 1995, Iskander and Hassan 1998). Driveability may be less efficient with these piles. Structural properties, including low bending and axial stiffness, could result in large deformations. Piles with composite exteriors may have low surface friction. The scope and extent of potential problems with composite piles is uncertain due to the lack of a long-term track record of their use.

Some of these potential disadvantages may be relative. The apparent higher cost is expected to decrease as composite pilings gain wider penetration in the civil engineering industry (Iskander and Hassan 1998). Ballinger (1994) pointed out that although the cost of FRP composite materials may be higher, the cost of labor and use of equipment necessary for construction work may be lower due to their lighter weight. Furthermore, the author suggested not only to compare costs on a total installed first-cost basis, but preferably on a reasonable total life cycle cost basis. Most composite piling manufacturers believe their products may be competitive when compared to the life-cycle cost of traditional piles in some applications (Ballinger 1994). Some manufacturers claim their composite piles may last twice as long as treated wooden piles (Iskander and Hassan 1998). However, in order to confidently design facilities using composite piles, engineers need more information about composite piles.

## 1.2 OBJECTIVES

The main focus of this research project is to determine the potential of composite piles for use in load-bearing applications, such as bridge substructures. In order to confidently establish the feasibility of using composite piles for load-bearing structures, more information and performance data was gathered in critical areas, such as: long-term durability and geotechnical behavior including driveability and soil-pile load transfer interactions.

The overall objective of this research project is to establish the feasibility of using composite piles in bridge substructures. More specific objectives are to:

1. Evaluate the long-term durability of concrete-filled FRP composite pipe piles.
2. Perform laboratory tests to evaluate the soil-pile interface behavior of concrete-filled FRP composite pipe piles and compare them with tests carried out on conventional prestressed concrete piles.
3. Design and perform a field test pile program to evaluate the driveability and axial and lateral behavior and capacity of a concrete-filled FRP composite pile, and a steel reinforced recycled plastic composite pile, and to compare them to a conventional prestressed concrete pile.
4. Design and perform a production pile testing and monitoring program in a real bridge project to compare long-term performance, load-transfer, and durability of concrete-filled FRP composite piles and conventional prestressed concrete piles.

## 1.3 ORGANIZATION OF THESIS

This thesis is organized into eleven chapters and three appendices. Chapter 2 presents background information on composite piles in general, and a literature review with specific focus on the two composite piles investigated in this research, i.e., concrete-filled FRP composite piles, and steel reinforced recycled plastic composite piles.

Chapter 3 presents the results of the experimental study on interface behavior between composite piles and two sands. A summary of the interface shear test results is given for seven pile material types (5 composite pile materials, and 2 conventional pile materials) against two types of sands. The soil materials, pile materials, and test procedures employed are also described in Chapter 3.

Chapter 4 presents the methods and results of the experimental durability study of FRP composite piles. Overview and background information related to durability of FRP composite materials is also presented in this chapter.

Chapters 5 and 6 present the findings from the field load tests at the Route 40 and Route 351 bridges, respectively. For each field load test program, information is provided pertaining to the description of the bridges, the description of the test piles, the soil conditions at the test sites, pile fabrication, instrumentation, and installation. The results of axial and lateral load tests are presented and discussed for each field load test program. Chapter 5 also presents details of the finished Route 40 bridge including description of Pier No. 2 of the bridge which is solely supported by concrete-filled FRP composite piles.

The results from axial and lateral analyses for the field load tests carried out at the Route 351 Bridge are presented in Chapters 7 and 8, respectively.

In Chapter 9, the long term monitoring program implemented for two production piles at the Route 351 Bridge is described. Only preliminary load transfer instrumentation data is presented since the bridge is still under construction. The long term monitoring will be carried out by the Virginia Department of Transportation.

Chapter 10 provides cost information for the composite piles and prestressed concrete piles used in this research project.

Summary, conclusions, and recommendations for future work are presented in the Chapter 11.

The results of the laboratory tests performed for the interface behavior study are presented in Appendix A. The solution for the moisture diffusion into a cylindrical FRP composite is presented in Appendix B. The results of the structural tests carried out on pile cutoff pieces from Route 40 are presented in Appendix C. These tests included a creep bending test and pushout tests to investigate the bond strength between the concrete core and FRP shell of the composite piles. Appendix D includes the results of geotechnical field investigations carried out at the test site at the Route 351 bridge project.