CHAPTER I

INTRODUCTION

1.1 GENERAL INTRODUCTION

Polymers possess many advantages such as lightness, low cost as well as ease of processing. Some modified polymers exhibit mechanical properties that are either comparable with or superior to those of metals. For this reason, polymers are used so extensively that some have referred the current age as the 'polymer age'; and the growth of polymeric industry has continued to expand at a rate greater than any other industry over the past few decades.

The need for lightweight structural materials has led to a dramatic increase in the use of composite materials because they meet the strength, stiffness, and other mechanical property requirements for high performance applications. Carbon fiber reinforced composites are often utilized where weight reduction and specific strength are required. Recently, they have been applied to strengthen concrete structure and masonry. For matrix, epoxy resin is one of the most important thermoset polymers that have been used as matrix material in carbon fiber-reinforced composites. It has been used and studied more widely than any other thermosets. This is because it can impart many desirable properties such as high strength and modulus, excellent chemical and solvent resistance, thermal stability and bonding properties. Nevertheless, epoxy resin is detrimentally brittle due to its three dimensional cross-linked structure. Modification by incorporating a reinforcing phase such as carbon fiber in the epoxy resin can effectively remedy its low fracture toughness.

Generally, composites are employed in various applications under a variety of environments. They tend to have different service life depending upon the service conditions. Problems such as brittleness and strength reduction are known to have occurred when they are used under certain environmental conditions. Though carbon fiber reinforced epoxy composites display excellent mechanical properties, they are often, in practical applications, exposed to hostile environments where temperature and other climatic conditions, such as relative humidity and the presence of ultraviolet, can seriously affect their long-term performance. Not only does each environmental condition exert an individual effect on the performance of the composites, but combined conditions of two or three hostile factors also jointly play important roles affecting the composites, sometimes more strongly than any one factor alone. Moreover, there is still insufficient information for understanding several effects on the composites at the same time. Previous studies focus on those influences by considering them separately. For example, Truong and Ennis (1991) determined the thermal effect on fracture behavior of epoxy. Maddox and Gillham (1997) also studied the thermal effect on epoxy composites. Lu, Shim and Kim (2001) investigated, in a different approach, the effect of moisture on mechanical properties of epoxy molding compound. Siddaramaiah *et al.* (1999) characterized mechanical, physical and thermal properties of fiber-reinforced composites that are exposed to different aggressive environments consisting of heat aging, humidity, lubricating oil and seawater but analysis was made on individual effect only. Study on long term behavior of properties and characteristics of various polymers are inconvenient because each test is time-consuming. Therefore, an accelerated aging process is applied for solving this inconvenience. Hence, the effect of physical aging induced by exposures to the various environments simultaneously is an area still opened for further study.

In the lifetime of many structures, there are often changes in use. Concrete structure such as road, bridges and buildings often exhibit cracks due to impact and dynamic loading, static overload, creep, thermal gradient or shrinkage. Cracks are aesthetically unpleasant and affect the durability of the structure. In these cases immediate remedial measures should be undertaken to prevent further degradation of the concrete and eventual the condemnation of the entire structure. If the concrete structure is not repaired, the entire structure may become unsuitable and even dangerous. Nowadays, the use of carbon fiber-reinforced composites in repairing concrete structures tends to increase because carbon fiber possesses the strength and modulus higher than those of the glass fiber although carbon fiber costs more. There has also been an apparent increase in the use of carbon fiber and aramid fiber reinforced epoxy composites in the repair and rehabilitation of concrete structures that have become unserviceable for their intended use. However, there is yet lack of studies on the environmental effects and the prediction of the service life of carbon fiber and aramid fiber reinforced composites. These are the important issues in which users of composites often ask and need reply. Prediction of the service life of composites will provide safety precautions and guidelines to the durability and the safety of the concrete structure. For this reason, an investigation on the environmental effects on the carbon fiber reinforced composites and the aramid fiber reinforced composites will be conducted in various environments.

1.2 THE PURPOSES OF THE PRESENT STUDY

There are two objectives in the current research. One is to examine the effects of physical aging on mechanical and thermal properties of two systems of composites namely the carbon fiber-reinforced epoxy composites and the aramid fiber-reinforced epoxy composites. A 2^k factorial design of experiment is performed for designing the aging conditions in the present study. The mechanical properties that will be studied are flexural properties, compressive properties and fracture energy. Fiber reinforced epoxy composites will also be characterized for their glass transition and dynamic mechanical properties. Additionally, microscopic observation will be performed by the use of a scanning electron microscope. After examining the mechanical and thermal properties of composite materials, multiple linear regression models of various mechanical properties will be constructed by applying the principles of statistical analysis such as Yates' algorithm for estimating effect and sum of squares and a single replicate of factorial design to determine each main factor and their interaction. From this technique, significance factors affecting the mechanical properties of composites will be distinguished.

Another purpose of this study is an attempt to predict the service life of carbon fiber reinforced epoxy composites and aramid fiber reinforced epoxy composites based on their mechanical properties after exposure to the designed environments. The concept of time-temperature superposition will be applied. Earlier studies had reported that the temperature dependence of the epoxy's shift factor under various exposure conditions could be represented by WLF equation (Williams, Landel and Ferry, 1955) via the changes in two parameters, namely C_1 and C_2. Thus, the mechanical properties and the service life of the composite systems to be studied can be predicted by an empirical model with the two modified parameters, C_1'' and C_2'' to be found in the present study.