CHAPTER (1)

INTRODUCTION

1.1 General Background

Concrete made with Portland cement has been a popular for the past ninety years or more. However, cement concrete have some disadvantages such as delayed hardening, low tensile strength, large drying shrinkage, and low chemical resistance. Also, high-strength concrete (HSC) which acts as the future of the construction industry in Egypt and the Arabian area nowadays is more brittle than ordinary concrete. To reduce these disadvantages, many attempts to use polymers have been made in order to improve the properties of the hardened concrete.

Since few decades, a newer technology of polymers to form a new or to improve the concrete products has been initiated. The wide achievements in the polymer technology applications led the concrete structural technology and designers to consider it [1-14]. There are three main types of polymer concrete family: polymer-modified concrete (PMC), polymer concrete (PC), and polymer-impregnated concrete (PIC). The various applications of the different mentioned types of polymer concrete are: concrete pipes, housing structural, under-water structural, prestressed concrete, flooring coverings, finishing and decoration, thin over layers for pavement and bridge decks, and repairs. When polymers are added to concrete, it improves the chemical and physical properties of the final concrete products. These properties include improving bond strength of concrete, increased flexibility and impact resistance, improved resistance to penetration by water and dissolved salts, and improved resistance to frost action. Consequently, the concrete containing polymer are preferred to use for marine structures and structures under sever environmental conditions.

Polymer-modified concrete are prepared by mixing a polymer or monomer in a dispersed, powdery, or liquid form with fresh cement concrete mixture. As the concrete cures, hardening of the polymer also occurs, forming a continuous matrix of polymer through the concrete. The hydrated cement phase and polymer phase interpenetrated to form monolithic matrix phase. So the aggregate particles are bounded by such co-matrix, resulting in the advanced properties of polymer modified concrete compared to conventional concrete.

Epoxy resins are gradually becoming one of the most important and versatile polymers in the modern civil engineering [1-21]. Because epoxy resins have some unique properties such as toughness, versatility of viscosity and curing conditions, good handling characteristics, high adhesive strength, low shrinkage compared to concrete, high resistance to chemical attack, and high resistance to impact loads. One of the most important application of epoxy resins in civil engineering is as structural adhesives for bonding concrete to concrete (hardened to hardened concrete, and hardened to wet concrete), and concrete to other materials such as bonding steel reinforcement to concrete, anchoring steel bars into concrete, and bonding of fiber reinforced plastics (FRP) to concrete. Also, One of the most important applications of epoxy resins is the using of epoxy as a supplementary cementing material for the producing of epoxy-modified concrete (EMC). The replacing of part of the cement by epoxy resin was found to improve the strength, ductility, chemical resistance, and durability of concrete. It was reported that [14, 15] the improvement of compressive strength of concrete is linearly proportional to epoxy-cement ratio.

The cost of producing polymer-modified concrete is higher than that of ordinary Portland cement concrete. But, the cost of using polymer-modified concrete should not be compared to that of the production of conventional concrete on the short run. Although, polymer-modified concrete has a higher initial production cost, but it should be compared with the sum of the initial production cost of ordinary Portland cement concrete plus the cost associated with the repair work expected during service life of the structure. In other word, the cost of epoxy is higher than that of cement, but it has dropped over the past few years. This trend is expected to continue with the increase of petrochemical plants in different parts of the world. Also, when epoxy is used as a partial replacement of the cement in the mixture, the overall project cost is reduced. It should be also noted that production of cement is more energy-demanding and less environmental friendly compared with the production of polymers. Moreover, epoxy-modified concrete (EMC) sets faster and weighs less than conventional concrete.

1.2 Statement of the Problem

The utilization of polymers in concrete and building industry is inevitable. Polymer concrete and polymer-modified concrete have been found to be much more durable, less permeable, more resistant to chemicals, stronger in compression and tension, faster in hardening, and more ductile than conventional concrete [13, 14, 22-25]. Such concretes also require less curing and posses better bonding properties. The excellent bond strength, freeze-thaw resistance, and resistance to chlorides penetration have made them widely used for producing prefabricated panels and units for industrial floors and pipes and manholes. Epoxy is the most common type of polymer used in structural engineering. Generally, epoxy costs more than cement, but the difference in cost has dropped drastically over the past few years with the increasing number of petrochemical plants in different parts of the world. On the other hand, the production of cement is more energy demanding and less environmental friendly compared with the production of epoxy. Epoxy-modified concrete (EMC) has been widely used in repair works [15-21] and was the subject of extensive research. The addition of resin was found to improve strength, durability, ductility, and chemical resistance of concrete. It was reported [15] that replacing 20% of the cement with epoxy increased the compression, split tension, shear strength, and modulus of rupture of concrete by approximately 3, 8, 4, and 34%, respectively.

High-strength concrete (HSC) is a brittle material, and as the concrete strength increases, the post-peak portion of the stress-strain diagram almost vanishes or decreased steeply. The increase in concrete strength reduces its ductility, the higher the strength of concrete, the lower is its ductility. This drawback represents significant limitations for its wide range application in modern structural designs. The inverse relation between strength and ductility for high strength concrete can be compromised by the use of epoxy resins. In the literature, several experimental and analytical studies were performed on the behavior of high-strength concrete beams in flexure and shear. Limited research programs [26-28] were only conducted on the shear behavior of normal strength epoxy-modified concrete beams. More work is needed for understanding the flexural and shear behavior of high-strength epoxy-modified concrete beams in terms of the different material, epoxy, and loading parameters.

1.3 Objectives of the Present Research

The present research is concerned with the behavior and performance of epoxy-modified reinforced concrete (EMRC) beams in flexure and shear under monotonic static loading. Comprehensive experimental and analytical studies were performed to study the response of EMRC beams till failure, with different ratios of epoxy. Finally, design equations were proposed for the analysis and design of EMRC beams for flexure and shear. The specific objectives of this research are stated as follows:

1- To present a survey of the experimental investigations of the behavior of high-strength reinforced concrete beams tested for flexure and shear. Also, the behavior of concrete containing polymers including polymer-modified concrete (PMC), polymer concrete (PC), and polymer-impregnated concrete (PIC), has been reviewed too.

2- To perform an experimental program consists of twenty-eight beam specimens on the flexural and shear behavior of EMRC beams till failure in order to study the effects of weight ratio of epoxy as a supplementary cementing material, strength of concrete, ratio of shear span-to-effective depth (a/d), ratio of longitudinal reinforcement and transverse stirrups on the structural response of the beams.

3- To study the effects of epoxy inclusion on the flexural and shear response characteristics of EMRC beams which include load-carrying capacity, resistance, stiffness, deflection, ductility, steel strains, cracking patterns, and failure mechanisms.

4- To evaluate the compressive strength and tensile strength of epoxy-modified concrete based on empirical functions derived from the testing results of mechanical properties of material.

5- To use a nonlinear finite element computer program with simple modification to predict the load-deflection relationships for all the tested beams in flexure and shear. And, compare the numerical with the tested results to emphasize the validity and accuracy of the testing procedure and measured results in the current research program on the structural response of the EMRC beams.

6- To develop analysis and design procedure for EMRC beams under flexure and shear on the basis of the measured experimental data and simple mechanics rules for the beams in the elastic and plastic ranges of loading.

1.4 Thesis Layout

The present study consists of eight chapters described as follows:-

Chapter (1): Introduction

This chapter is concerned with the general background and statement of the problem, the main objectives of the present thesis, and contents of various chapters of thesis.

Chapter (2): Literature Review

The main purpose of this chapter is to present a survey of the experimental investigations of the behavior of high-strength reinforced concrete beams tested for flexure and shear. Also, the behavior of concrete containing polymers including polymer-modified concrete (PMC), polymer concrete (PC), and polymer-impregnated concrete (PIC), has been reviewed too.

Chapter (3): Description of the Experimental Program

The main function of this chapter is to present a comprehensive description of the experimental program carried out in the present research. It describes the dimensions and reinforcing details of the test specimens for flexure and shear and the proportions of mix design of high-strength epoxy-modified concrete which were used herein. In addition, the characteristics of the materials such as cement, mixing water, admixture, coarse and fine aggregates, epoxy resin, and reinforcement were evaluated. Moreover, the loading setup, the measuring apparatus, and the testing procedure were also described in this chapter.