CHAPTER 1
INTRODUCTION

1.1 GENERAL

Concrete, steel and masonry materials are the common materials used for housing, office buildings, bridges, power plant structures and these structures are being deteriorated with age. The deterioration of the structures is due to the design deficiency, materials deficiency, poor workmanship and extreme loads. As long as the structural integrity of the building exists, the deterioration of the structure can be rectified. Structures are designed to withstand safely a particular predetermined load during their life period. Generally Reinforced Concrete (RC) structures can suffer varying degrees of damage due to several reasons including material deterioration, construction technique adopted, poor workmanship, overloading, aggressive environments, fatigue and corrosion of steel reinforcement embedded in concrete.

1.2 DAMAGE ASSESSMENT OF STRUCTURES

Damage assessment survey is conducted to understand the nature of deterioration occurred in the structure. The details such as location of the structure, type of foundation, geometry of the structure, function of the building, design standards adopted, will help to identify the scope for further investigations. Deterioration due to structural inadequacy may require detailed analysis and deterioration due to material deficiency requires few investigations in the laboratory and in the field.

The performance and safety of reinforced concrete structures can be assessed initially by visual inspection. Crack width measurements can indicate the level of damage. The distribution and pattern of the cracks measure the extent of damage present in the structure. Non Destructive Test (NDT) can be effectively employed to evaluate the degree of damage in the structures. The strength and life depend on damage level of the structures. The extent of damage in structures should be effectively assessed in order to ensure safety and serviceability of structures. Non destructive testing methods such as Schmidt rebound hammer, ultrasonic pulse velocity, acoustic emission and Windsor probe test can be conducted to assess the quality of concrete.
1.3 REPAIR, REHABILITATION AND RETROFITTING OF STRUCTURES

Repair and rehabilitation mean restoring the damaged structures to make them fit for serviceability condition whereas retrofitting means strengthening of undamaged and new structures. Durable repair can be done only by matching the properties of the base concrete with those of the repair material intended for use (Neelamegam, 2001). Rehabilitation of structurally deteriorated RC structures is one of the major tasks for the construction industries worldwide. Use of properly selected materials can solve this tough task. Retrofitting, upgraded the structural elements for its load carrying capacity by using techniques like plate bonding. The selection of repair materials is based on their properties and some of them are listed below:

i) Dimensional stability
ii) Modulus of elasticity
iii) Permeability
iv) Chemical resistance
v) Adhesion with parent concrete
vi) Coefficient of thermal expansion
vii) Easy to use

1.3.1 Patch Repairing

Once damage occurs, repair is an important factor in extending the life span of structures. Patch repair consists of removal of the damaged concrete, cleaning of rust, and restitution of the original geometry with a patch material. Patch repairing is one of the common concrete repair technologies, especially when a localized corrosion occurs. The three types of patch materials available in the market are plain cement mortar, epoxy - resin mortar and cement - polymer mortar. The plain cement mortar repairing is not suitable for structural repair works because of their dimensional instability, weak adhesion, and durability. The resin mortars including acrylics, polyurethanes, polyesters, and epoxies have superior properties as repair mortars. But the use of these mortars is restricted because of their cost and incompatibility with most of the substrate concretes. The cement - polymer mortar has better adhesive properties, crack resistibility and compatibility. Styrene Butadiene Rubber (SBR) latex is being effectively used to modify cement mortar to
be used as a repair system in practical application (Ali et al., 1998). Some additional reinforcements are added partially or totally to restore the original area of bars (Rio et al., 2005).

1.3.2 Flexural Strengthening

The flexural capacity of member need to be enhanced either to withstand the additional increments of load beyond those for which the structures were originally designed or to compensate the loss of capacity due to corrosion of the embedded steel reinforcement. Historically, RC members have been repaired by post -tensioning or jacking with new concrete in conjunction with a surface adhesive. Since mid -1960s epoxy – bonded steel plates are being used to retrofit the flexural members. But corrosion may occur along the adhesive interface and affects the bond at the steel plate – concrete interface. In the 1980s, Fibre Reinforced Polymers (FRP) were developed and used in the form of thin laminates. They are constructed of high performance fibres such as carbon, aramid or glass, which are placed in a resin matrix. Selecting these fibres for particular application can alter the mechanical and durability properties (Hsu et al., 2003).

The FRP laminates are being widely used for flexural strengthening because of their excellent properties including the following:

i) High strength – to – weight ratio
ii) Low weight (making them much easier to handle on site)
iii) Immunity to corrosion
iv) Excellent mechanical strength and stiffness
v) Unlimited availability in length
vi) Easy fabrication
vii) Possibility of bonding to non - flat surfaces
viii) Durability in adverse environments
ix) High fatigue strength

Moreover, bonding of FRP plating does not need expensive scaffolding. Many researchers have done experiments on RC beams strengthened with externally bonded FRP laminates to the tension face to exhibit ultimate flexural strength
greater than their original/damaged beams. They indicated that the ductility of RC beams using externally bonded Glass Fibre Reinforced Polymer (GFRP) and Carbon Fibre Reinforced Polymer (CFRP) laminates gets reduced and the extent of reduction in ductility is dependent upon the characteristics of original beams (Grace et al. 1999; Kurtz and Balaguru 2001; Kim et al. 2002; Lamanna et al. 2004; Malek and Patel 2002; Micelli et al. 2002; Saadamanesh et al. 1991; Sharif et al. 1994; Spadea et al. 1998; Thomsen et al. 2004).

1.4 GFRP AND CFRP STRENGTHENING OF MEMBERS

Fibre reinforced polymers are continuous or non-continuous strong fibres surrounded by a matrix material. The matrix serves to distribute the fibers and transmit the load to the fibres. The bonding between the fibres and the matrix is created during the manufacturing phase and becomes a composite material in the final stages of fabrication when the matrix is hardened. The characteristics of composite materials depend on proportions of reinforcements and matrix, the form of reinforcement, and the fabrication processes. These are a combination of fibre reinforcement and a resin matrix. The resin system holds fibers together and transfers the loads through the fibres to the rest of the structure. In addition to binding the composite structure together, it protects from impact, abrasion, corrosion, other environmental factors and rough handling. The most common resins of the thermoset family are Polyester (orthophthalic and isophthalic), vinyl ester, epoxy, and phenolic.

Epoxy resins are a broadly used in FRP materials. Epoxy resin systems are extremely high three dimensional crosslink density which results to the best mechanical performance characteristics of all the resins. It can resist high amount of strength and hardness, very good resistance to heat and electricity. The disadvantages of this epoxy is higher cost and processing difficulty. Epoxy systems are effectively used in various applications such as aerospace, defence, marine, sports equipment, adhesives, sealants, coatings, architectural, flooring and many other areas.
1.4.1 GFRP Strengthening

GFRP material possesses high strength, light weight, good resistance to salt water, chemical environment and durable. It can be moulded in any complex shape and it has low maintenance. GFRP can be used for both interior and exterior application with fixtures in a variety of shapes, styles, and textures for the construction of domes, fountains, columns, balustrade, panels, sculpture, facades, cornice, porticos and roofs. The different type of application of GFRP are shown in Figures 1.1 to 1.4.

Figure 1.1 Flexural Strengthening of Existing Beams

Figure 1.2 Flexural Strengthening of Existing Slab
1.4.2 CFRP Strengthening

CFRP is made by weaving carbon fibre into a textile material and on the top of it, epoxy resin or any other resin is applied. Then it is allowed to cure and the resulting material is very strong. It has the best strength to weight ratio of all construction materials. It is an improved version of GFRP material and it is more expensive when compared to GFRP. The CFRP can be used effectively in strengthening of RC structures. The CFRP can also be used in the manufacture of expensive sports cars where strong and light materials are required. The competition bicycles and motorbikes are made up of CFRP and it helps to keep the weight to a minimum and at the same time it is retaining its load carrying capacity. It is also be used in the manufacture of aeroplane. The different type of application of CFRP are shown in Figures 1.5 to 1.8.
Figure 1.5 Flexural Strengthening of Existing Beams

Figure 1.6 Strengthening of Existing Column

Figure 1.7 Strengthening of Existing Pipe

Figure 1.8 Flexural Strengthening of Existing Slab
1.5 NEED FOR STUDY

Most of the investigation reports on strengthening of damaged RC structures are based on patch repairing and using FRP sheets for flexural, shear and compressive strengthening of members. This research work is mainly focused on retrofitting of RC beams using GFRP and CFRP sheets. It aims at studying the effect of multiple layers of GFRP and CFRP sheets used as strengthening materials by adopting plate bonding technique on RC beams made of various grades of concrete. Most of the experimental studies are carried out in foreign countries and this retrofitting work is carried out with locally available GFRP and CFRP sheets. This study is helpful to understand the retrofitting of RC beams strengthened with GFRP and CFRP sheets according to the Indian environment. It also deals with FEM modelling of beams using ANSYS software to predict load carrying capacity and deflection of control and retrofitted beams.

1.6 ORGANISATION OF THE THESIS

The first chapter gives an introduction to various strengthening techniques adopted for repair, rehabilitation and retrofitting of structures. The second chapter reviews the relevant literature in the areas of strengthening of various methods adopted for RC beams. The third chapter narrates the purpose of this research work and the usefulness of retrofitting methods. The fourth chapter explains the experiments conducted for this research work. The fifth chapter deals with FEM modelling using ANSYS software for assessing the flexural behavior of control and retrofitted beams. The sixth chapter describes the results and discussion of this research work. The seventh chapter summarizes the results obtained from this research.