CHAPTER 1

INTRODUCTION

1.1 GENERAL

In recent years, the construction industry has seen an increasing demand to reinstate, rejuvenate, strengthen and upgrade existing concrete structures. This may be attributed to various causes such as environment degradation, design inadequacies, poor construction practices, lack of regular maintenance, revision of codes of practice, increase in loads and seismic conditions etc. In India, most of the reinforced concrete structures are designed for gravity loading as per IS 456:2000. These structures are susceptible for damage during earthquake. During a severe earthquake, the structure is likely to undergo inelastic deformation and has to depend on ductility and energy dissipation capacity to avoid collapse. Such buildings designed for gravity loading need to be strengthened to increase strength, stiffness and ductility. Jacketing is one of the most frequently used techniques to strengthen Reinforced Concrete (RC) columns. Axial strength, bending strength and stiffness of the original column are increased for the retrofitted columns.

1.2 RETROFITTING

Recent earthquakes have revealed an urgent need to develop retrofit techniques for the existing buildings designed in accordance with old seismic codes so as to meet the requirements of current seismic design standards.

Some of the common problems revealed by earthquakes such as Kobe (Japan 1995), Athens (Greece 1999), Kocaeli (Turkey 1999 and Bhuj (Gujarat 2002) include inadequate confinement of concrete, leading to shear anchorage and splice failures. It is well known and proven that lateral confinement improves the strength and ductility of concrete. Confinement reinforcement is generally applied to compressive members as lateral reinforcement with the aim of increasing their strength and ductility. In addition, lateral confinement prevents slippage and buckling of the longitudinal reinforcement. Lateral reinforcement can be provided by using circular hoops, rectangular ties, jacketing by Steel, Fibre Reinforced Polymer, Ferro cement, etc.

In recent years, repair and seismic retrofit of concrete structures with CFRP sheets has become more common. The strengthening of RC columns with wrapped CFRP sheets to improve seismic performance is one of the major applications of this new strengthening method. The wrapped CFRP sheet around the plastic hinge region of RC columns provides not only enough shear strength which results in a ductile flexure failure mode in accordance with the concept of strong shear and weak flexure, but also confinement of concrete in the plastic hinge region to increase the ductility of the column .Since the total cost of replacement of the vulnerable structures is so overwhelming, the development of innovative rehabilitation and strengthening techniques is required to extend the life expectancy of many existing buildings.

It is known that large inelastic deformation limits of individual members allow entire structures to endorse severe ground motion while dissipating significant levels of seismic energy. Plastic hinge formations associated with lateral displacement excursions is favoured in beams and girders rather than in columns to ensure that the overall structural integrity is not compromised. Plastic hinges can occur in columns, however, particularly at the base of multistory frames where incurred, damage acts to dampen seismic forces considerably. Ductile behaviour is hence essential at these crucial sites to prevent complete structural collapse under sustained loading. The structural response during earthquakes have indicated that the majority of the column failures was caused by high shear stresses, insufficient transverse reinforcement rendering those members ineffective at dissipating seismic energy and inadequate ductility rapidly leading to failure. Typical procedures to compensate for the deficiencies involve external retrofitting of these columns.

The deficiencies in building and structures against earthquake may arise at (i) planning stage with faulty configuration and irregularities, (ii) design stage due to inadequate strength and ductility, and (iii) construction stage due to faulty construction practices. Revision of design codes is a continuing process world over and usually results in up gradation of seismic hazard and increase in design forces. In India also several regions have been upgraded in terms of seismic zones there by renders building unsafe according to upgraded code. All these factors make the retrofitting of existing structures necessary. The retrofitting may also be required if change in usage of a building takes place or there is a major alteration of building.

The level of strengthening of a building depends on the seismic zone in which building is situated and level of performance desired from the building. Important buildings are desired to have a higher performance level during a future earthquake. The seismic zone governs the design earthquake forces and the performance level during a future earthquake. The seismic zone governs the design earthquake forces and the performance level governs the permissible damage or the performance values of member actions due to earthquake forces. Not only the member forces and strength are important, the non linear deformations and ductile capacity of members are also important for seismic safety of building and need to be evaluated and examined.

1.3 NEED FOR STUDY

Damage to columns caused by an earthquake is mainly of two types

1. Damage due to cyclic flexure and low shear under strong axial compression.
2. Damage due to cyclic shear and low flexure under strong axial compression.

The first type of damage manifests itself with failure at the top and bottom of the column. It occurs in columns of moderate to high slenderness ratio. The high bending moment at these points combined with the axial force, leads to the crushing of the compression zone of concrete, successively on both faces of the column. The smaller number of ties in these areas, the higher their vulnerability to this type of damage. The crushing of the compression zone is manifests itself by the spalling of concrete cover to the reinforcement. This phenomenon is usually accompanied by the buckling of bars in compression and by hoop fracture. The fracture of the ties and the disintegration of the concrete lead to shortening of the column under the action of axial force. Therefore this type of damage is very serious because the column not only loses its stiffness, it also loses its ability to carry vertical loads.

The second type of damage is of the shear type and is manifested in the form of X-shaped cracks in the weakest zone of the column. It occurs in columns with moderate to small slenderness ratio. The ultimate form of this type of damage is the explosive cleavage failure of short columns, which usually leads to a spectacular collapse of the building. The frequency of this type of damage is lower than the failure at the top and bottom of the column.

It usually occurs in columns of the ground floor, where, because of the large dimensions of the cross-section of the columns, the slenderness ratio is low.

Hence, it is very important to note that column damage is very dangerous for the structure, because it alters or even destroys the vertical elements of the structural system.

A number of repair and strengthening techniques are currently in use for reinforced concrete structures. Unfortunately, the majority of them is very expensive, time consuming and require the interruption of use of the structure whilst works are carried out. Hence, there is an urgent need for the development of improved, low cost, less disruptive techniques, which will make necessary interventions in many structures economically viable.

Although, the jacketing of columns with new reinforced concrete has been commonly used in some countries, there has been limited output from experimental investigation on effectiveness of such jacketing. The aim of this research is to investigate the effectiveness of various jacketing methodologies on the performance of jacketed columns such as strength, stiffness, ductility and energy dissipation capacity.

1.4 SCOPE AND OBJECTIVE

The hysteretic behaviour of Reinforced Concrete columns and joints depends on the amount of reinforcement. The scope of the work includes a study on the effect on ductile behaviour of Reinforced Concrete columns under lateral cyclic loading with varying percentage of longitudinal reinforcement.

The reinforced concrete frames without seismic provision are often characterized by an unsatisfactory structural behaviour due to low available ductility and lack of strength which in turn induces global failure mechanism. Hence it is very much essential to retrofit the vulnerable building to cope up for the next damaging earthquake. The scope of the work involves experimental investigation to study the structural behaviour of columns strengthened by Glass Fiber Reinforced Polymer (GFRP), Carbon Fibre Reinforced Polymer (CFRP), Reinforced Concrete jacketing (RC), Steel plate, Steel strip, corrugated steel jacketing and Ferro cement jacketing of column footing. It also involves analytical investigation to study the structural behaviour of columns strengthened by Reinforced Concrete jacketing.

The objectives of the present work are:

- To study the behaviour of columns with different percentage of longitudinal reinforcement and to arrive at favorable percentage of longitudinal reinforcement with respect to various parameters such as load carrying capacity, ductility and energy dissipation capacity.
- To study the structural behaviour of columns strengthened by Glass Fiber Reinforced Polymer (GFRP), Carbon Fibre Reinforced Polymer (CFRP), Reinforced Concrete jacketing (RC), Steel plate, Steel strip, Corrugated steel jacketing and Ferro cement jacketing of column footing and to suggest an appropriate method of retrofitting considering strength, stiffness and cost of construction.
- To conduct analytical investigations using Finite element software package ANSYS to validate the experimental performance.

1.5 ORGANISATION OF THE THESIS

The thesis has been organized with six chapters as given below.

- Chapter 1 provides an introductory analysis of the research work. The need for study, scope and objectives of the investigation and the organization of thesis are also presented.
- Chapter 2 describes the literature review highlighting the details of the research work carried out to study the behaviour of columns and jacketing under seismic loading.
- Chapter 3 presents the modeling of the structure which includes the structural configurations, loading and the forces in the structural elements.
- Chapter 4 presents the experimental investigations carried out on columns with varying percentage of longitudinal reinforcement and on columns retrofitted with Fibre Reinforced Polymer jacketing, Reinforced Concrete jacketing, Steel jacketing and Ferro cement jacketing.
- Chapter 5 discusses the Finite element modeling on columns retrofitted with Reinforced Concrete jacketing.
- Chapter 6 summarises the results and discussions on the experimental and analytical investigations done on columns and jacketed columns.
- Chapter 7 presents the conclusions, contributions and scope for work. The list of references is given at the end of the thesis.