CHAPTER-1

INTRODUCTION

1.1. GENERAL

Reinforced concrete is one of the most abundantly used construction material not only in the developed world, but also in the remotest parts of the developing world due to its property of achieving high compression strength. In the rural areas of the developing world; due to transference of expertise and technology knowhow to urban areas; reinforced concrete poses threat due to its abuse rather than use. The transformation of non-engineered construction into an engineered one needs to be such that it could be sustain worst combination of loads. The methodology should be simple in execution, offer better performance even when handled by less experienced workers, must comprise materials, which are readily available, and yet durable, strong and cost-effective.

The major problem that exists in today's Construction Industry is that most of the structures fail to serve its intended purpose up to its designed life span. Many such structures start showing sign of distress much earlier than the end of their design life due to deterioration of structural material caused by environmental factors, ageing or due to an increase in applied loads.

This deterioration of bridge decks, beams, girders, columns, buildings, and others may be attributed to ageing, environmentally induced degradation, poor initial design and / or construction, lack of maintenance, and to accidental events such as earthquakes. The deterioration as well as up gradation of codes make these structures structurally deficient and functionally obsolete, and so, necessitates retrofitting.

Furthermore, the deterioration of a reinforced cementitious materials or elements is a complex problem. Hence, even a minor damage should not be ignored since it carries the potential to cause damage and cause failure either leading to a wide scale loss of life and property, or halting some revenue earning activity or both. It is this possibility which calls for inspection of structures on a regular basis or in other words Structural Health Monitoring (SHM).

The SHM helps in identifying the damage easily and provides warning of the unsafe condition of the structure. SHM aims to give, at every moment during the life of structure, a diagnosis of state of constituent materials, of the different parts and of the full assembly of these parts constituting the structure as a whole (Sharifi and Banan 2008). SHM can provide sufficient warning before serious damage or failure of structures. SHM allows the optimal use of structure and the avoidance of catastrophic failures. Information on damage may be utilised to make decisions on maintenance and structural safety of an existing building, rapid evaluation of condition of damaged structure, estimation of residual life of structures, feasibility of repair and retrofitting of structures, demolition of structure and financial planning for renovation and rehabilitation.

It has become necessary to take a decision whether to demolish a distressed structure or to restore the same. The issue of upgrading the existing civil engineering infrastructure has been receiving great importance for over a decade (Bracci et al. 1997). Reconstruction involves lot of economic interference as compared to retrofitting. The retrofitting of structures damaged due to various natural or artificial reasons like blasts, fires, earthquakes, is a matter of concern these days. A retrofitting programme starts with a diagnosis and progresses through selection of methods employed for meeting the demands of deficient area.

A slab is a most widely used as a load supporting member which receives load directly. Its main function is to transfer the load to the members below like beams, columns, walls and finally to the substructure. The surface area of the slab is large and it can be viewed as a member comprising of closely spaced grid-beams. Also, the slab is highly sensitive to the supporting system and its layout. These thick plates are highly redundant and the design is remunerated by sufficient cracking and deflections without disturbing the load carrying capacity.

1.2. PROBLEM FORMULATION

1.2.1. Need and Significance of Present Research Work

The infrastructure's growing decay is often pooled with the need for upgrading so that structures can meet more rigorous design requirements. Hence the damage identification and retrofitting of civil engineering infrastructure has attracted significant attention over the past few years throughout the world.

Structural health monitoring helps to identify damage detection of structures. The need for SHM is growing to maintain existing civil infrastructure. Important infrastructure may include multi-storey buildings, bridges etc. Their safe performance is necessary for ensuring safety to human and economic activities. So it has become important to monitor the damage for its existence, location and extent.

The review of literature in *Chapter-2* indicates that in the past, the researchers have extensively studied on retrofitting techniques and their suitability on structural elements like beams, columns etc. Relatively, very little research attention has been made in case of slabs. The primary purpose of the research envisaged was concerned with the monitoring of reinforced concrete slabs and their retrofitting using laminates. Glass Fibre Reinforced Polymer (GFRP), Ferrocement and Mild Steel (MS) sheet were used to strengthen the damaged slabs.

1.2.2. Programme / Technical Work / Methodology / Equipment Required / Laboratory Work Facility

Looking at the importance of the problem and keeping in mind, the availability of limited information regarding health monitoring and retrofitting of slabs; one is prompted to work in this direction which is of significant importance in present scenario keeping in view the elaborate scope of applications of retrofitting materials in the civil engineering construction. Therefore, the present investigation has been planned to carry out in-depth study on the Structural Health Monitoring and Retrofitting of slabs with different retrofitting options. Eighteen specimens of slabs with two different aspect ratios were casted. The monitoring of the slabs was done by visual inspection, rebound hammer test and ultrasonic pulse velocity test. Then the slabs were damaged by applying external load. Thereafter retrofitting of the damaged slabs was done by Glass Fibre Reinforced Polymer (GFRP), ferrocement and Mild Steel (MS) sheet. The performance of the two slabs like deflection, crack pattern, ultimate load and any other unexpected structural behaviour was compared. After comparing their performances, results were interpreted. The finite element modelling of the slabs was done using Atena 3D software. The experimental and analytical results were compared and conclusions drawn.

1.2.3. Objectives of the Present Investigation

In the present study, it was intended

1) To study the available retrofit technique / solution for the reinforced concrete slabs that can be used, on-site, effectively for restoring the strength and stiffness based upon their study.

2) Monitoring of the slabs by non-destructive testing methods.

3) Experimental validation of retrofit materials employed on model slabs.

4) Numerical validation of retrofit techniques employed on model and prototype slabs.

5) To develop design-aids / charts for design of retrofit system.

1.2.4. Scope of Study

The slab specimens were designed using the guidelines of IS 456: 2000 to achieve the objectives set in *1.2.3*.

Firstly, the nondestructive testing of the structural slab element was carried out. Then the slab specimens were damaged under uniformly distributed load. These slab specimens were then retrofitted suitably by employing Glass Fibre Reinforced Polymer, Mild Steel plate and Ferrocement so that strength of the damaged slab can be restored.

Then available retrofitting materials were used to determine the best possible solution out of ferrocement, glass fibres and MS.

The model slabs were then numerically validated to check the deviation from the experimental behaviour and any other unexpected / unnoticed behaviour during loading.

Interpretation of results was carried out to find the economical solution and extent of restoration of strength.

1.2.5. Methodology

To achieve above objectives, it was proposed to take two-way slabs supported over a rigid boundary. The slabs were cured for 28 days and monitored for their health by applying nondestructive testing methods. Then the slabs were damaged under uniformly distributed load. Thereafter the slabs were again monitored for their health by applying nondestructive testing methods. Their degree of deterioration was assessed. Subsequently, the slabs were retrofitted using ferro cement laminates, glass fibre reinforced polymer, and mild steel sheet. These were then again tested for uniformly distributed load for experimental verification.

Thereafter, the slabs were modelled using ATENA software for slabs without retrofitting and slabs retrofitted with GFRP, Ferrocement, and MS sheet. The experimental results were compared with the finite element method using ATENA software.

1.3. ORGANIZATION OF THE THESIS

The thesis is organized as per detail given below:

The *Chapter-1* presents brief introduction to Structural Health Monitoring and Retrofitting phenomenon. The Research Significance, Objectives, Scope of the study and Outline of the Thesis are also given in this Chapter.

The *Chapter-2* reviews the available literature on the subject to establish the need of present study.

The *Chapter-3* describes the detail of the experimental programme. The properties of the various materials used in this investigation are given. The health checkup of slabs before and after loading tests is discussed. The details of various non-destructive tests such as Rebound Hammer test and Ultrasonic Pulse Velocity Test have been presented. The various retrofitting options and the procedure of their application on slabs for validation of results are also presented.

The *Chapter-4* deals with the Introduction to the Finite Element Modelling on the model slabs using Atena 3D software.

The *Chapter 5* presents the Results and Discussion of the present study. The data incorporated from research is represented in the form of tables and graphs. The description is also presented in the form of images.

The *Chapter 6* describes the Conclusions of the present investigation.