Structural strengthening methods

INTRODUCTION

GENERAL

Strengthening or upgrading of a structure may be required quite often due to several reasons. Many a times, loads due to seismic forces or wind forces are not taken into account while designing the structure or sometimes a higher load carrying capacity is required in case the use of the structure changes. In such cases, strengthening of a structure may be required. Strengthening may also be required in case of any deficiency in the ability of a structure to carry the expected design loads. There may be several reasons for such deficiencies in a structure. These include structural damage, loss of concrete section, corrosion of steel rebars, error while construction or flaws in the design. Several techniques can be employed to overcome such problems. Arriving at a best and optimum strengthening solution for each project depends on various factors like increase in strength required, constructability restrictions, size and importance of project, accessibility, time availability, and availability of skilled/unskilled labour, availability of raw material and other equipments, environmental conditions, cost or many such other issues.

Out of the available strengthening techniques, the most wonderful feature of strengthening by FRP laminates is its non-corrosive nature. It is due to corrosion of rebars that billions of capital of a country is wasted every year. Replacing steel reinforcement by the non-corrosive FRP reinforcement is an effective alternative that obviates the problem of loss of strength of a structural element due to corrosion.

Thus, investigation of the behaviour or response of such strengthening techniques is very crucial before it is adopted in actual structures.

Experimental based testing has been carried out by researchers for long. This method of investigation is both time-consuming and expensive. Thus, analytical and numerical methods of investigation are in vogue. Finite Element Method (FEM) is one of the numerical methods of analysis. With the advancement in computer and technology, FEM softwares like ANSYS are reliable along with being less time-consuming and cost-effective. In the present research, numerical investigation of RC beams strengthened with FRP laminates is carried out.

STRENGTHENING USING FRP COMPOSITES

There are several reasons for which strengthening of a structure may be required. And for this purpose several conventional techniques like use of steel plates have been used since ages. But in the recent years, use of Fibre reinforced polymers for structural strengthening has come into existence. Fibre Reinforce Polymers or FRPs exhibit several improved properties, like non-corrosiveness, high stiffness-weight ratio, high strength-weight ratio, high fatigue strength, flexibility and ease of application due to its light weight.

In recent years, several researchers have been studying the use of FRP sheets or laminates to strengthen concrete structural members. Using FRPs for strengthening have turned out be an effective technique suitable for several structural elements such as beams, columns, walls, and slab. For strengthening of existing structures externally, FRP materials are considered most suitable as it is non-corrosive, resistant to chemicals and non-magnetic.

From the past research, it has been found that Glass Fibre Reinforced Polymers or GFRP is very effective in increasing flexural as well as shear strength of the reinforced concrete structures when bonded externally.

FRP laminates is one of the emerging material for strengthening of RC beams. It can be used for strengthening the beams weak in flexure by bonding the laminate at the bottom soffit and for strengthening the beam weak in shear, laminates are bonded to the side faces of the RC beam. But unfortunately, no proper guidelines or provisions are included in the current Indian design codes for strengthening of concrete structural elements with FRP laminates. At the same time, research in recent years focussing on the application of FRP laminates for strengthening of RC structures has led to its increasing application practically.

FRP laminates are composite materials that consist of high strength fibres of glass, carbon or aramid in a matrix, where the main load is carried by the fibres. These laminates are plates that may be bonded to the surface by either dry bonding or wet bonding technique. These laminates can be used to strengthen beams and slabs weak in shear or flexure, columns to increase the concrete confinement or even walls to increase the lateral load carrying capacity.

MERITS AND DEMERITS OF FIBRE REINFORCED POLYMER COMPOSITES

MERITS

FRP or Fibre Reinforced Polymers are very efficient in strengthening of reinforced concrete structural elements. They have high ultimate strength and have lower density as compared to that of steel. It is very convenient to handle and transport because of its light weight. Moreover, its flexible nature makes installation process much convenient as compared to installation of heavy steel plates. Another major advantage of using FRP laminates in strengthening of RC structural elements is that it doesn’t require full scaffolding while installation at soffits of bridge. In case of strengthening RC structures by using FRP laminates, no bulky lifting gear is required and there is no requirement of fittings such as bolts that are susceptible to corrosion. Moreover, application of FRP laminates is just as easy as application of wallpapers on wall. Also, there is no risk of damage to the steel reinforcement as no drilling is required for inserting bolts. Nowadays, wet-bonding technique is used which further reduces the risk of debonding of the laminates. Furthermore, another most important advantage in the use of FRP laminates in strengthening of RC structures is that these laminates are available in long lengths and varying widths due to which no joints or laps are required.

Application of FRP laminates on irregular surfaces or curved profiles is not a problem due to its flexible nature. If the application of FRP laminates is done carefully by keeping care of proper measures, it proves to be durable. Moreover, it is comparatively convenient to repair by application of another layer.

Use of FRP laminates for strengthening of bridges and other important structures like tunnels is very suitable as their light weight and less thickness do not alter the dimensions of the strengthened element or add to the weight of structure.

Most important advantage of the use of FRP laminates for strengthening RC structural elements is that it is non-corrosive in nature. Because of the ease in application, it results in saving both the man-power and useful resources.

Thus, all these merits in combination results in a significant and effective means of strengthening technique that is much more quicker and simpler as compared to other strengthening techniques like use of steel plates.

DEMERITS

Along with several advantages of FRP or Fibre Reinforced Polymers, there are few disadvantages that may hinder its application. FRP laminates that are mainly used for external strengthening of structures are susceptible to exposure of external environment. So, in order to protect it from fire or any other accidental damage, proper protection measures are to be adopted. Another major problem occurred in the application of FRP laminates in strengthening of RC structures is delamination or debonding of the laminate. It problem can be overcome by taking proper measures while bonding it with the help of epoxy. Nowadays, even the technique of wet bonding is in practice in order to eliminate such problems.

Another major disadvantage that may hinder its application is its high cost. But, after a complete comparison of the total cost and the strengthening achieved with that of other strengthening methods like use of steel plates etc., the application of FRP in strengthening may prove to be economical and more efficient.

INTRODUCTION TO FINITE ELEMENT MODELLING/METHOD

Finite Element Method or (FEM)is an approximatenumerical techniquefor determining solutions toboundary problemsfordifferential equations. In this method, a stable solution is produced by reducing error function by employing variational method. In this method, a structure or a model to be analyzed is discretized or broken down in number of small sub-domains, and are called elements or finite elements. These elements are connected to one another by points known as nodes. There are many finite element packages available.

ANSYS which means Analysis System is a FEM software package which offers engineering simulation solution sets in engineering simulation that a design process requires. Companies in a wide variety of industries use ANSYS software. The tools put a virtual product through a rigorous testing procedure before it becomes a physical object.

IMPORTANCE OF FINITE ELEMENT MODELLING

It is difficult to model the complex behaviour of reinforced concrete analytically in its non-linear zone. And we know that experimental testing which has been used since ages for the purpose of research work is very time consuming along with being expensive. But with the advancement in computer and technology, and powerful techniques of analysis such as Finite Element Method or FEM, many efforts have been under taken by the investigators to obviate the need for creating multiple models in case of experimental investigation. Thus, finite element approach is gaining popularity not only because it is cost effective and less time consuming, along with this it obviates the need to create multiple models for the purpose of research or investigation, preventing wastage of useful resources. Along with this, it is a powerful tool that allows modeling and analyzing complex non-linear behaviour of RC structures efficiently. Moreover, not only modelling and analyzing, it is also useful in obtaining the load deflection behavior and crack patterns under various loading conditions. Thus, Numerical investigation or finite element analysis is comparatively much more effective and less complicated than development of analytical models because of the several obvious reasons.

OBJECTIVES OF THE WORK

The specific objectives of the present investigation are as follows:

1. To numerically investigate the behaviour of RC beams strengthened with FRP laminates using ANSYS
2. To obtain the corresponding load deflection curve of RC beam without FRP and RC beams strengthened with varying configuration of GFRP and CFRP laminates.
3. To draw the comparison between ANSYS results & experimental results available in the literature.
4. To study the comparison between the behaviour and the load deflection profile of RC beams strengthened with glass fibre and carbon fibre laminates.

SIGNIFICANCE OF THE WORK

Experimental testing is one of the most commonly used methods for prediction of the behaviour of reinforced concrete elements till failure. This is both time consuming and costly. Thus, finite element approach is gaining popularity not only because it is cost effective and less time consuming, along with this it obviates the need to create multiple models for the purpose of research or investigation, preventing wastage of useful resources and manpower.

In the present investigation, the non-linear response of reinforced concrete (RC) beams strengthened with FRP laminates has been carried out with the intention to investigate the effectiveness of GFRP and CFRP laminates bonded in varying configuration. In this investigation, ANSYS software is used to carry out Finite element modelling of RC beam. A total of nine beams are modelled and analyzed using ANSYS software up to the failure and the load deformation curves are plotted and the cracking behaviour is monitored.

Concrete block is modelled by using SOLID65 element while the steel reinforcement is modelled using LINK180 element by using discrete method. While, for modelling of FRP laminates SOLID185 (layered solid) element is used. The result obtained from finite element investigation is then compared with the experimental results in the referred literature (Sandeep G. Sawant, 2013) with respect to load-deflection values, formation of initial crack, failure mode and the ultimate load carrying capacity of the RC beam.