Static Analysis of Cracked RC Beam Retrofitted Using FRP

[1]Anisha Jacob,[2]Dony Paulose
[1]PG Student,[2]Assistant Professor
Department of Civil Engineering,
Amal Jyothi College of Engineering, Kanjirapally, Kerala, India

Abstract: Cracks in reinforced concrete sections can lead to sudden and total failure from which recovery is impossible. This results in change in the physical characteristics of a structure and thus the static and dynamic response also varies. Depth of crack and its location are the main parameters for the analysis of the cracked beam. It becomes very important to know the changes in these parameters of the structure in order to access its reliability, performance and safety. The use of externally bonded composite sheets is to strengthen existing reinforced concrete structure and hence it improves the service life of the structure. In this paper, the static characteristics of cracked reinforced concrete beam are examined by finite element analysis using ANSYS. Also, comparison between normal beams and cracked beams retrofitted with FRP under various conditions including FRP as sheet below the cover, FRP sheet as cover, FRP as strip below the cover, FRP strip instead of cover and grooving of FRP into the concrete are studied in this paper. It may be concluded that FRP Strip Removing Cover has better result in case of both maximum principal stress and minimum total deformation. The studies were performed using ANSYS 16.

Keywords: Cracked RC beam, retrofitting, FRP

I. INTRODUCTION

Cracking in reinforced concrete structures has an effect on structural performance including stiffness, energy absorption, capacity and ductility. The presence of cracks in a structural member such as beam causes the reduction in stiffness of the structure which in turn depends mainly on location and depth of the cracks. These variations have significant effect on the static and vibration behavior of the entire structure. In order to ensure the safety of the structure, it is important to know whether their members are free of cracks and to detect their crack location and to provide safety measures. Any damage in a structure alters its dynamic characteristics like natural frequency, mode shapes and also its static characteristics. The damage reduces the stiffness of the structure and increases the damping value. The reduction in stiffness is associated with decrease in natural frequencies and changes in corresponding mode shapes. The mode shape of the damaged structure may seem to be similar as the mode shape of the undamaged structure. But the derivatives of the mode shapes show a discontinuity at the damaged location. Cracks occurring in structural elements are responsible for local stiffness variations, which in consequence affect their dynamic characteristics. Response parameters of a structure have been used for the assessment of structural integrity, performance and safety. The main causes of cracks in structural member are moisture change, thermal variation, elastic deformation, creep, chemical reaction and foundation movement and settlement of soil.

A) TYPES OF CRACK

There are different types of cracks in reinforced concrete beam namely

1) Flexural cracks

Cracking in reinforced concrete beams subject to bending usually starts in the tensile zone. The width of flexural cracks in reinforced concrete beams for short term may stay narrow from the surface to the steel. However, in long term under continuous loading, the width of crack may get increased and become more uniform across the member.

2) Shear cracks

Shear cracks in reinforced concrete beams occurs in hardened stage and it is usually caused by structural loading and movement. These types of cracks are better illustrates as diagonal tension cracks due to combined effects of flexural and shearing action.

B) STRENGTHENING USING FRP

Only a few years ago, the construction market started to use FRP for structural reinforcement, generally in combination with other construction materials like wood, concrete and steel. FRPs exhibits several improved properties such as high strength- weight ratio, high stiffness- weight ratio, flexibility in design, non- corrosiveness, high fatigue strength and ease of application. Cracks that occurred in structural members like beams can be retrofitted using FRP. Strengthening of structural members by fiber reinforced polymer has become a widely used technique where high strength is needed for carrying heavy loads and repairing is done due to fatigue cracking, failure modes and corrosion. The use of FRP with their excellent mechanical property will retrofit the structural member induced cracking. FRP composites are made of high tensile strength to weight ratio, high mechanical strength, and a fast and economical way of rehabilitation or repair of beams, columns or slab. The efficiency and quality of bond between the FRP composites and concrete plays a major role in transferring the stress between concrete structures and externally bonded FRP plate

II.LITERATURE REVIEW

This chapter provides a brief introduction of various research works carried out by various researchers on FRP retrofitting of beams. A number of methodologies, crack patterns and materials have been used by them in attaining maximum efficiency. Journals selected for review mainly concentrates on GFRP and CFRP as retrofitting materials.

- Akbas (1995), studied the static bending of edge cracked micro beams analytically based on modified couple stress theory. The cracked beam was modeled using a proper modification of the classical cracked beam theory consisting of two sub-beams connected to a mass less elastic rotational spring. They determined the deflection curve expressions of the edge cracked micro beam segments separated by rotational spring using the integration method.

- ChuanchuanHou (2002), presented an experimental study on the cracked beam element model for crack damage identification in the physical testing environment. Five solid beam specimens were prepared with different number of cracks and were subjected to modal testing and analysis procedure to extract the natural frequencies and mode shapes. Result showed that all the cracks can be identified correctly with accurate crack depth and location information.
- Li feng (1998), studied for the crack identification of box section beams with a suitable cracked-element description for the type of structural member. The general identification adopts a model-based approach, in which a structural model was employed and variable model parameters are updated in accordance with measured modal data. In order for the crack parameters to be identified accurately through this procedure, first a cracked beam element model was developed for the cracked box- section beams with explicit descriptions of the crack parameters including crack severity and its relative location within an element. The outcome of this study will give a way for the extension of cracked beam element model to other types of cross section for the crack damage identification purposes.
- Kiang Hwee Tan (2006) , a FRP strengthening of beams in both long term and short term are investigated. An empirical equation-based n the regression analysis of test results obtained from 36 beams was derived for the evaluation of crack widths in FRP strengthened RC beams under short term loading. The effectiveness of a glass FRP system in controlling long term crack width in RC beams was investigated. An accurate and simple strength model based on interfacial shear stress distribution for finite element analysis is also done. A simple strength model for predicting the Intermediate crack debonding failure is also proposed. A dual local debonding criterion was employed to monitor local debonding along the interface.

III. SCOPE AND OVERVIEW

The review given in above is based on composite sheet bonding for beam retrofitting. It has demonstrated the improvement in structural strength and stiffness brought about by externally bonded material. The worldwide level of interest in the technique reflects its potential benefits and also the current importance placed on economical rehabilitation and upgrading methods. Although the level of experience in the bonding technique is limited, the investigations reported in this chapter have gone some way to illustrate its potential and to establish a basic technical understanding of short term and long-term behavior.

A. Objectives:

- To study the effect of normal beam and cracked reinforced concrete beams.
- To study the effect of cover with the replacement of conventional cover with FRP.
- To calculate the deformation and shear stress of cracked reinforced concrete beam.

B. Steps Involved In Present Work:

- Extensive literature review
- Conceptual studies
- Modelling of cracked RC beam
- Analysis
- Detailed analysis of the results obtained from the numerical models. Appropriate conclusions are then drawn.

C. Modelling And Analysis:

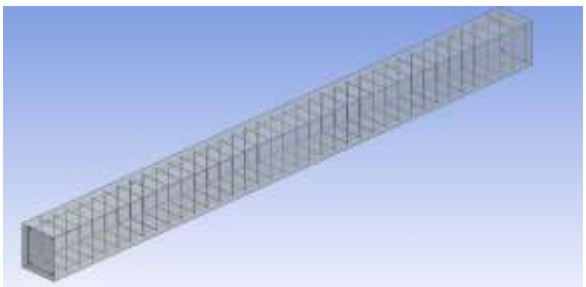
Reinforced concrete structures are made up of two materials having different characteristics namely concrete and steel. In this study, static characteristics of cracked reinforced concrete beams retrofitted with FRP were analyzed. Static analysis was carried out in order to find shear stress and deformation of cracked beam. The different cases considered are normal beam, FRP Layer under Beam, FRP Sheet as Cover, FRP Strip below Cover, FRP Strip Removing Cover, and FRP by Applying Groove. Six cases were modeled by selecting the dimensions as

- Length- 3m
- Breadth- 0.2m
- Depth- 0.3m

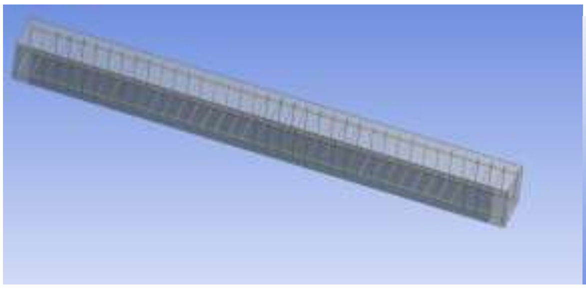
Materials commonly used for analysis of cracked reinforced concrete beam are steel, concrete and CFRP for retrofitting. A fixed support boundary condition was adopted. Fixed support can resist vertical and horizontal forces as well as moment. Since they restrain both rotation and translation, they are also known as rigid support. This means that a structure only needs one fixed support in order to be stable. The representation of fixed supports always includes two forces horizontal and vertical.

Table 1. Property Of Steel

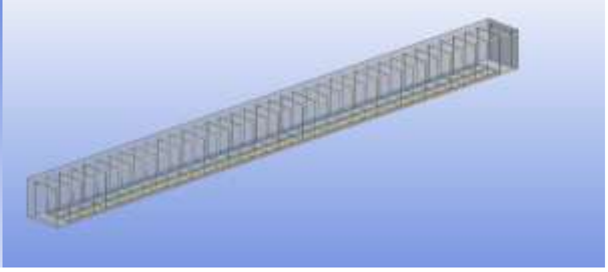
Mechanical Property	Value
Modulus of elasticity (Gpa)	293
Poisson's ratio	0.3
Density (kg/m^{3})	7800
Yield stress (MPa)	310
Post el astic stiffness(Gpa)	1.23



Normalbeam



FRP layer under beam



FRP strip removing cover

IV. RESULT AND DISCUSSION:

The reinforced beam models with a fixed support conditions were analyzed for their deformation and shear stress for a load of 5500N which was obtained from the design calculations. Total deformation is the vector sum of all directional displacements of the structure.

CASES	TOTAL DEFORMATION (m)
NORMAL BEAM	4.4601 X10^-5
FRP LAYER UNDER BEAM	4.16 X10^-5
FRP SHEET AS COVER	4.956X10^-5
3 FRP STRIP BELOW COVER	4.457X10^-5
FRP STRIP REMOVING COVER	4.997X10^-5
FRP BY APPLYING GROOVE	4.621X10^-5

Shear stress is a stress state where the stress is parallel to the surface of the material, as opposed to normal stress when the stress is vertical to the surface. The shear stress causes the deformation on the structure. A shear stress is the component of shear coplanar with a material cross section. Shear stress arises from a force vector component parallel to the cross section.

In this work, static characteristics of cracked reinforced concrete beams retrofitted with FRP were analyzed. Static analysis was carried out in order to find shear stress and deformation of cracked beam. The study was carried out using ANSYS16 software. In this study, cracked reinforced beams are retrofitted with FRP were modeled using six different cases. Also, comparison between normal beams and cracked beam retrofitted with FRP under various conditions including FRP as sheet below the cover, FRP sheet as cover, FRP as strip below the cover, FRP strip instead of cover and grooving of FRP in to the concrete are studied. Maximum shear stress is observed in case of FRP strip removing cover with minimum deformation.

CASES	MAXIMUM SHEAR STRESS (Pa)
NORMAL BEAM	4.28 X 10 ^5
FRP LAYER UNDER BEAM	4.492 X 10 ^5
FRP SHEET AS COVER	5.787 X 10 ^5
3 FRP STRIP BELOW COVER	4.479X 10 ^5
FRP STRIP REMOVING COVER	7.656 X 10 ^5
FRP BY APPLYING GROOVE	5.744 X 10 ^5

CONCLUSIONS

In this work, static and dynamic characteristics of cracked reinforced concrete beams retrofitted with FRP were analyzed. Static analysis was carried out in order to find shear stress and deformation of cracked beam and dynamic analysis were carried out to find natural frequency and mode shape. The study was carried out using ANSYS16 software. In this study, cracked reinforced beams are retrofitted with FRP were modeled using six different cases. Also, comparison between normal beams and cracked beam retrofitted with FRP under various conditions including FRP as sheet below the cover, FRP sheet as cover, FRP as strip below the cover, FRP strip instead of cover and grooving of FRP in to the concrete are studied. Response parameters of a structure have been used for the assessment of structural integrity, performance and safety. The following major conclusions were drawn based on the studies carried out under this investigation

➢ Maximum shear stress is observed in case of FRP strip removing cover with minimum deformation ➢ in modal analysis, different mode shapes were investigated and natural frequency increases with minimum deformations.

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