Transient Thermal Analysis of Steel, CFRP & GFRP Reinforced Beams

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***Abstract*— Fibre Reinforced Polymers are used for strengthening concrete structures to eliminate cracks and damages formed as a result of environmental effects, increasing loads, natural disasters and toxics emitted. FRP are composite materials which consist of fibres in a polymer matrix. FRP materials are used in aerospace industries and construction of bridges as they offer high tensile strength, lightweight, high stiffness, high fatigue strength, excellent durability and highly versatile. FRP bars are used in concrete structures as an alternative to steel reinforcement as it has high corrosion resistance, strength to weight ratio and moderate modulus of elasticity. This paper portrays a brief study on transient thermal analysis conducted to investigate deflection behaviors on beams based on different material property of reinforcement in FEM softwares.**

Keywords—Fibre reinforced polymers,concrete structures, CFRP,GFRP

I. INTRODUCTION

Fibre Reinforced Polymer (FRP) as reinforcement in concrete structures is used as an alternative to the steel reinforcement in recent years. FRP are composite materials made up of fibers and polymer matrix. FRP are of different types such as GFRP, CFRP, AFRP. FRP materials are used in construction of bridges and aerospace industries. The key factor of structural deficiency and deterioration in reinforced concrete (RC) members has been identified as the corrosion of steel reinforcement. FRP reinforcement is mainly used in bridges, its use in multistory buildings, industrial structures and parking areas have an enormous economic potential. However, the stability of FRP members to overcome the fire effects should be established before to be used to reinforce the concrete structural members. FRP materials are highly versatile as they are available as tubes, sheets, bars, tendons and many other forms.

To strengthen structural RC members in shear, torsion and flexure, FRP bar reinforcement seems to be a promising solution [6, 14]. As compared to conventional steel reinforced concrete the behavior of FRP bar under fire exposure is quite different. The drawback of using FRP embedded bars is the tendency to change state; from solid to liquid at elevated temperatures and their low glass temperature. Hence, under elevated temperatures the performance of FRP reinforced members draws many concerns and doubts and warrants further investigation. Only few tests have been conducted in the previous years on the fire performances of RC beams reinforced with FRP bars due to the tremendous amount of preparation, high costs of such tests and shortage of specialized facilities.

Many expressions are developed to predict the required stiffness and strength of composite bars and concrete matrix at elevated temperatures [1]. Fire exposure played a major effect on the behavior of FRP reinforced concrete and its failure load. The response of FRP reinforced beams depends mainly on the concrete cover. FRP reinforced concrete beams exhibit greater degradation in flexural resistance than the steel reinforced concrete [2]. The transient temperature distributions and the structural response analysis due to effect of mechanical and thermal load [3] and finite element analysis using the ABAQUS on FRP bars reinforced concrete columns with varied cover thickness [4] showed a good agreement by the comparison of the predicted and test results. GFRP bars as reinforcement as satisfied fire design requirements, [5]. Flexural strength and ultimate load capacity were improved by retrofitted with GFRP [10]. When worked on RC structures damaged during earthquake, the ANSYS results showed that the deflection of the retrofitted beam with CFRP was minimized about 73%, with GFRP was minimized about 65%, with KFRP was minimized about 60% when compared to controlled beam and higher load carrying capacity than the controlled RC beam specimen [11].

This paper presents an attempt to model the nonlinear behaviour of beams at elevated temperatures. The beams were reinforced with steel, CFRP & GFRP bars. Validation is done analytically and the objectives of the project are

- To understand the concept of FRP reinforced beams
- To model beams with different material reinforcements
- To conduct transient thermal analysis to determine deformations

II. NON LINEAR FINITE ELEMENT ANALYSIS

Non-linear finite element analysis was conducted to simulate the thermal behavior of concrete beams reinforced with fully steel, fully GFRP & fully CFRP bars. In this study three beams with same geometric properties are modeled with both ends fixed. The thermal behavior of these sections is compared. Mainly, deformation of reinforcement of each section is taken into consideration. Finite element method has been extensively used to study the structural behavior of steel concrete sections. Finite element model is developed using ANSYS 16.2 version. In this study, beam of M 25 grade concrete and Fe 500 grade steel as internal reinforcement is designed. Table 1 shows the geometric properties of the beam.

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TABLE 1: Geometric properties

Span	2.55m
Section	0.2m X 0.3m
Compression Reinf:	2# 10mm dia bars
Tension Reinf: @ Midspan	4# 12mm dia bars
Tension Reinf: @ Support	2# 12mm dia bars
Shear Reinf:	2L 8mm dia bars @ 125mm c/c

III. VALIDATION

For the validation of thermal analysis in ANSYS a long bar is considered which is solved analytically using thermal equations. Then the values are compared with ANSYS results. The long bar has thermal conductivity varied with temperature. The bar is constrained at both ends by frictionless surfaces. A temperature of T °C is applied at one end of the bar.

A. Results Comparison

Results obtained analytically and with help of ANSYS software are compared. Table 2 shows the comparison of results. Clearly, the FE model provides closer predictions of deformations and thermal strains. The close agreement between the analytical and FE results demonstrates the validity and accuracy of the proposed FE model.

TABLE 2: Comparison of Results

Results	Analytical value	FEM value
Minimum Temperature (°C)	38.047	38.015
Maximum Thermal strain (z = 20) (mm/mm)	0.0004953	0.00049523
Maximum Thermal strain (z = 0) (mm/mm)	0.001425	0.001425
Maximum Z Deformation (mm)	2.32	2.3459

IV. TRANSIENT THERMAL ANALYSIS

Temperature and all other thermal quantities are determined using transient thermal analyse which varys over time. Thermal analyse can be executed to find temperature gradient, deformations, temperature distribution and heat flowing in the model, heat exchanged between the model and the environment. Thermal effects such as temperatures are easy to simulate, but quite difficult to measure especially inside parts and assemblies, or if temperatures are changing rapidly. Analysis is done with varying time (end time 2500s) and temperature (1200^{0}C) (fig.1). Transient analysis is done on the beam model with steel (fig.2), CFRP (fig.3) & GFRP (fig.4) reinforcements. Deformation variation is noted to find out the best reinforcement material to withstand thermal effects as well as to find out replacement reinforcement to conventional steel reinforcement.

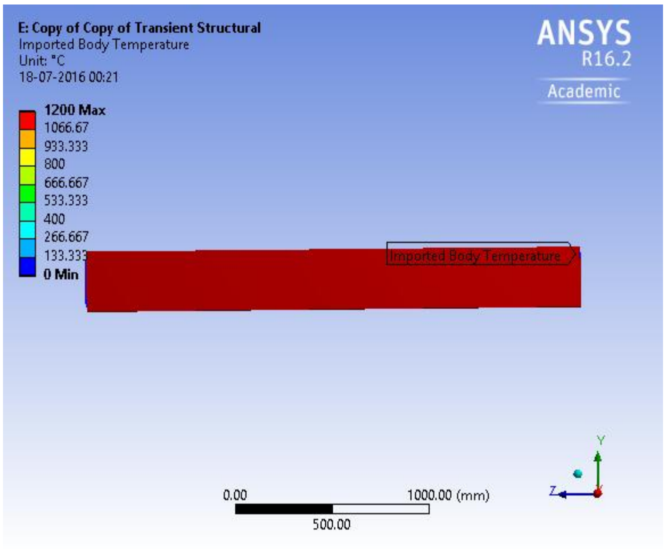

Fig. 1: Temperature Input to Beam

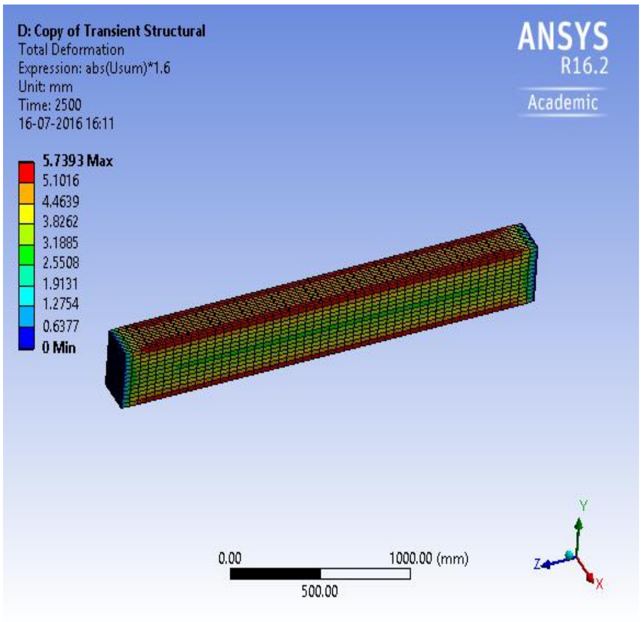

Fig. 2: Total deformation in steel reinforced beam, max 5.73mm

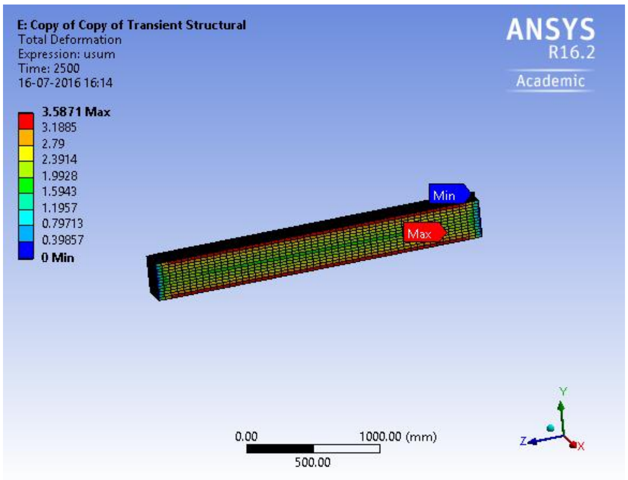

Fig. 3: Total deformation in CFRP reinforced beam, max 3.587mm

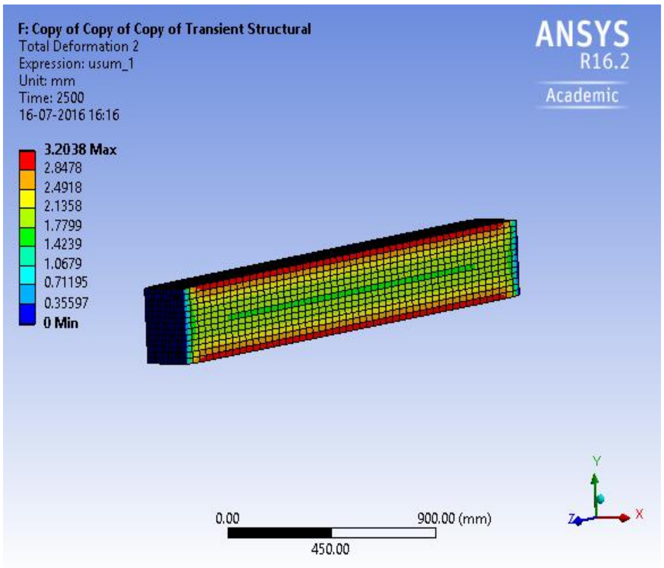

Fig. 4: Total deformation in GFRP reinforced beam, max 3.2mm

V. THERMAL ANALYSIS RESULTS AND DISCUSSIONS

From the thermal analysis of beams with different reinforcement materials the maximum deflection value for steel bars is 0.5449mm, for CFRP bar is 0.0564mm and for GFRP bars is 0.055mm and after a temperature of 1200^{0}c the values become steady state in nature. Table 3 shows the tabulated deformation results.

TABLE 3: Tabulated Deformation Results

Beam reinforcement material	Deformation rebar(mm)	Total deformation (mm)	Total U_y (mm)	U_y rebar (mm)
steel	0.5449	5.73	4.799	0.0761
CFRP	0.0564	3.587	3.749	0.0041
GFRP	0.055	3.2	2.99	0.0034

VI. CONCLUSION

From the transient thermal analysis it is clear that GFRP reinforced beam has lesser deformation as compared with CFRP reinforced beam and steel reinforced beam. FRP can be used as a better alternative to steel reinforcement as both CFRP & GFRP bars have nearly equal deformation result which is very small compared with steel bars.

VII. FUTURE SCOPE

FRP bars are made of different types of polymers with varying thermal resistance. There is a need to find out the best polymer which can withstand thermal effects. Bond behavior between concrete and FRP bars should be studied.

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