International Journal of Engineering Research And Advanced Technology (IJERAT)

DOI: http://dx.doi.org/10.7324/IJERAT.2017.3143

E-ISSN : 2454-6135

Vol.3 (10) Oct -2017

Analytical Study of Reinforced Concrete Element Strengthened With Polypropylene Fibers Subjected to Elevated Temperature

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ABSTRACT

Risk of accidents due to fire is more often and has become a common occurrence leading to the loss of lives and property In this regard, the study investigates the effects of fire on concrete members reinforced or strengthened with polypropylene fibers. The amount of spalling and the extent of cracking of concrete can considerably be reduced by use of suitable amount of polypropylene fibers. In this paper, finite element software ANSYS is used for studying the temperature propagation in concrete exposed to elevated temperatures. An attempt will be done to study the impact of fire on reinforced concrete structural components considering a beam member of cross sectional dimensions 230mm × 600mm providing clear cover according to the specifications of fire safety building code. Based on these parametric studies, results including the effects of high temperature on properties of fiber reinforced concrete together with the strength, stiffness, thermal stress, thermal strains under load and heat flux will be obtained by performing the analysis.

Key words: *Temperature, Polypropylene fiber, Thermal analysis, clear cover, ANSYS.*

1. INTRODUCTION

Fire safety must be absorbed as a main concern at the initial stage of a building project as it can have major impact on the design of a building & its structural form where risk of accidents due to fire may be predictable or unpredictable owing to this the damages are caused to structures. Compounds are multifunctional material systems that provide physical characteristics not available from any distinct material. They are cohesive structures made by physically combining two or more distinct materials. The application of polypropylene fiber as lamination or cover for reinforcement has expected much concentration for structural engineering. Internal bonding of 3 distinct materials can increase the flexural strength, thermal resistance and failure of structure takes more time under high elevated temperature and increase the failure time. Polypropylene fiber applied as cover to the reinforcement which is done experimental test of individual element is time consuming and the use of material may be quite costlier. Hence for the analysis of this multifunctioning compound material the finite element analysis is best method to analyze the individual element and the effect of RC element with fiber used.Themajor role of fibers in a composite mixture is to control cracks, improve the deformation characteristics and increase the tensile strength, toughness of the structural element. Most importantly polypropylene fiber is versatile with concrete, chemically inert,rust free, Alkali resistant, safe and easy to use.

Ansys software is a wide ranging finite element analysis tool for structural analysis including linear, nonlinear, static, dynamic, hydrodynamic, computational fluid dynamics, explicit and implicit methods and heat transfer studies.

The Ansys simulation process is discretization of the single model element to fine element , considering material properties , boundary conditions support condition and ana loading comes under simulation process to get accurate result and to saves the time for the analysis of single elements different type of analysis.

2. LITERATURE REFERENCES

N Muruli Krishna et al. [2] Studied the experimental result that concrete member exposed to different thermal conductivity with temperature and porosity as parameter and result of conductivity v/s temperature for 10min of time interval as a result until 120min the temperature did not reach the core of the reinforcement.

YakudimaAkibuGhali et al. [3] This study include behavior of steel reinforcement in reinforced concrete structure subjected to elevated temperature and analyzed experimentally and analytically using finite element analysis and validated with software Ansys and safir.As a result the bar fails at 430^{o}C after 90minutes addition of fiber time period for fire resistance increased by 30minutes and there was 3 minutes variation for analytical result.

L Dahmani et al.[1]In this paper they presented the spalling resistance of normal concrete and addition of polypropylene fiber in concrete mix with different sequenceas a result spalling of concrete is reduced and spalling effect of hardened concrete is studied.

Antony Nkem Ede et al. [1] they studied the behavior of RC structure after adding coconut husk fiber and polypropylene fibers while casting and exposed to 200^{o}C to 1000^{o}C.As a result there is an increase in compressive strength, fire resistance of the structure.

T.Subramani et al. [1] analytical and experimental study carried out to find the behavior of concrete in addition of glass fiber reinforced polymer as cover to the structural element. As a result addition of glass fiber reinforced polymer gives better stiffness less deformation high strength less stess and strain value compare to only concrete.

3. METHODOLOGY

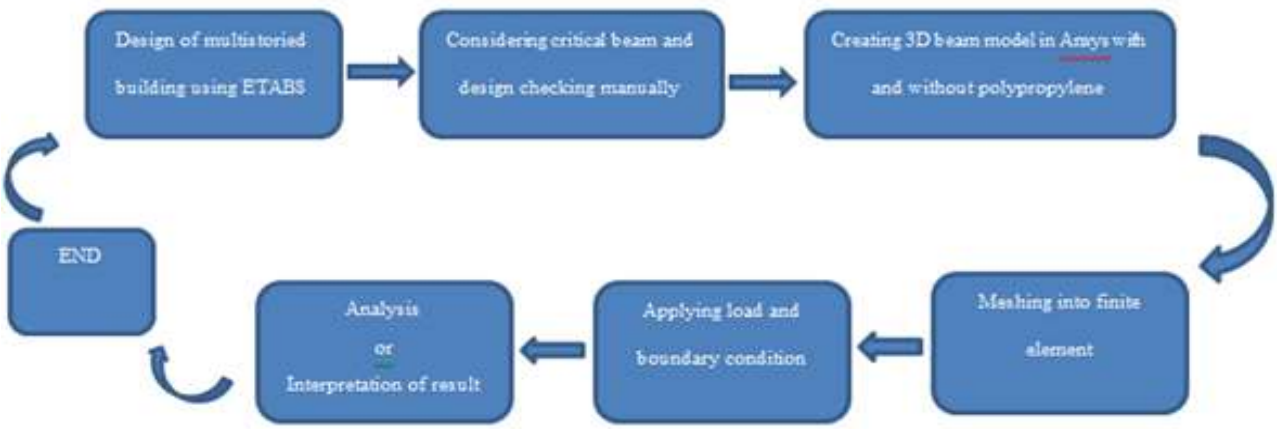


Fig.1 Flow chart of work

Parameters considered:

- Clear cover according to fire code and IS456
- Materials considered
- Different faces exposed to fire

4. MODELING GEOMETRY AND ANALYSIS

In our work two models are modeled and analyzed using finite element analysis software.one model of beam with two composite material and another model of beam with three composite material.one beam with 30mm clear cover according IS456 [FIG.1] and without polypropylene, another beam with clear cover of 60mm according to fire safety

code[FIG2] and with polypropylene fiber sheet of 10mm thickthat is covered around steel reinforcement. Material properties are mentioned below in Table.1, Table.2 and Table.3.

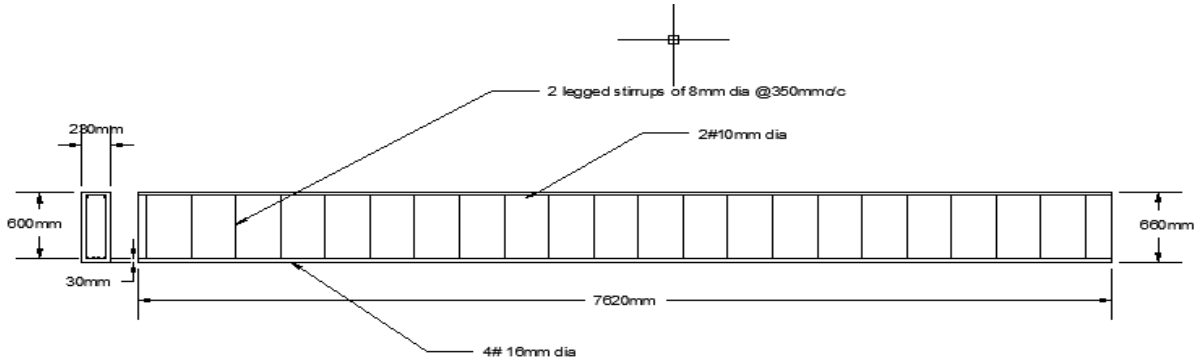


Fig.2 Beam 30mm clear cover

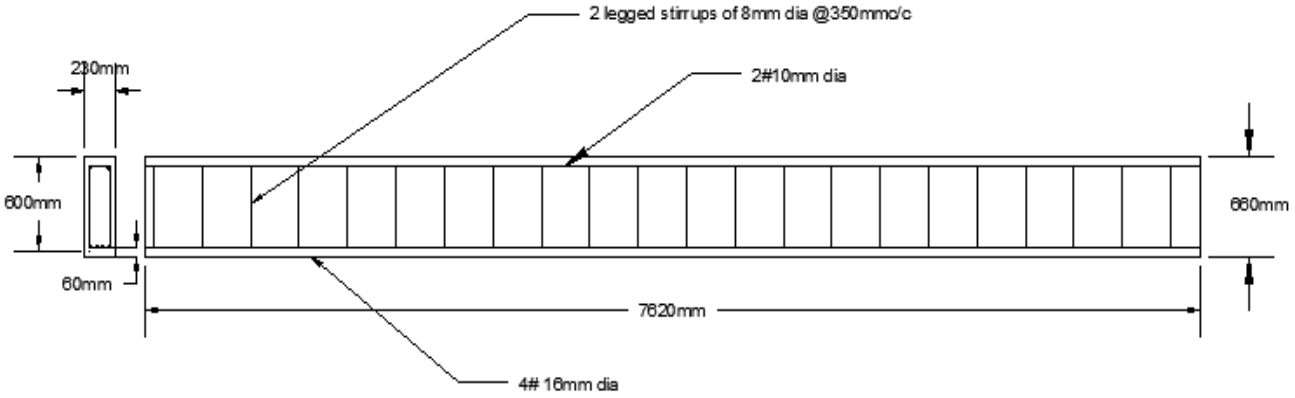


Fig.3 Beam 60mm clear cover

Table.1: Material Properties For Concrete

S.No	Property	Value	Units
1	Density	2400	Kg/m^3
2	Young's modulus	$3x10^{10}$	Pa
3	Poisson's ratio	0.18	
4	Thermal conductivity	0.72	$w/m/^oC$
5	Coefficient of thermal expansion	$1.4x10^{-5}$	$/^oC$

Table.2: Material Properties For Steel

S.No	Property	Value	Units
1	Density	7850	Kg/m^3
2	Young's modulus	$2x10^{11}$	Pa
3	Poisson's ratio	0.3	
4	Thermal conductivity	60.5	$w/m/^oC$
5	Coefficient of thermal expansion	$1.2x10^{-5}$	$/^oC$

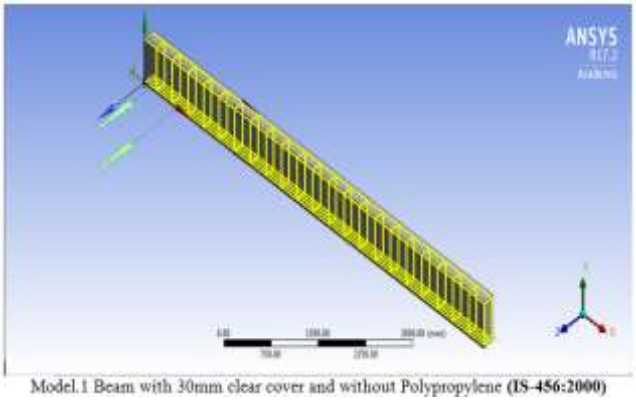
Table.3: Material Properties ForPolypropelene fibers

S.No	Property	Value	Units
1	Density	9050	Kg/m^3
2	Young's modulus	$1.5x10^9$	Pa
3	Poisson's ratio	0.4	

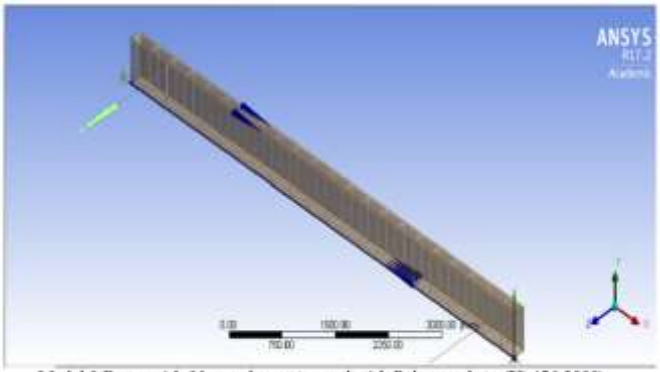
4	Thermal conductivity	0.22	w/m/^{o}C
5	Coefficient of thermal expansion	$1.2x10^{-5}$	/^{o}C
6	Melting point	160^{o}C to 170^{o}C	

5. CREATION OF 3D MODELING IN ANSYS:

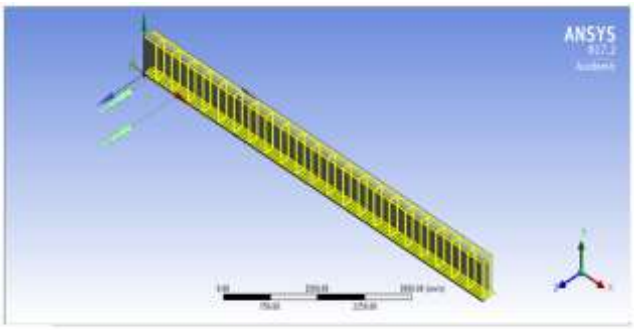
The model has been created according to design considerations with specific material properties, loadings, boundary condition as shown in Fig.[2] and Fig.[3].Based on ETABS design dimensions following models are generated by using the Finite element analysis software. The analysis of structure subjected to fire, ANSYS (Finite element software) best way to study with proper result for single elements of multistoryed structures.In finite element analysis software the study includes on trainsient analysis, steady state analysis (Study of structure with constant loading with varying temperture and varying load with constant temperature.)



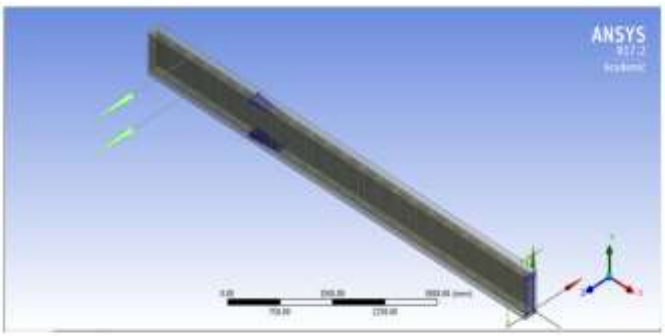
Model.1 Beam with 30mm clear cover and without Polypropylene **(IS-456:2000)**



Model.2 Beam with 30mm clear cover and with Polypropylene **(IS-456:2000)**

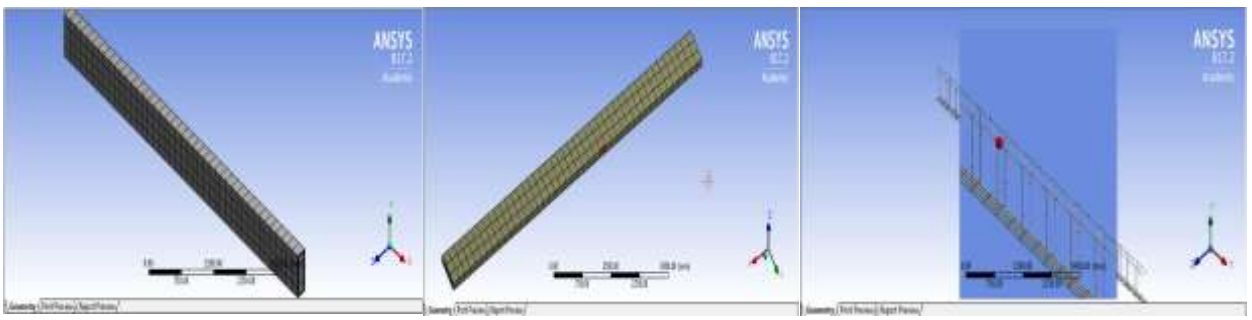


Model.3 Beam with 60mm clear cover and without Polypropylene
(Fire safety building code)



Model.4 Beam with 60mm clear cover and with Polypropylene
(Fire safety building code)

Meshing of a beam element: Meshing is done in order to divide the beam into a number of finite elements which helps to connect each element and to create perfect bondingbetween the different elements. A uniform mesh technique is used for meshing to decrease both the number of elements and the computational time.

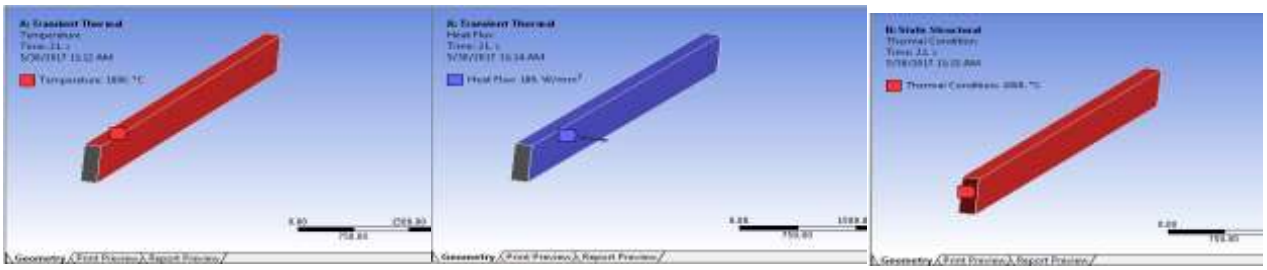


Meshing of Concrete Meshing of Polypropylene Meshing of Reinforcement Element

Boundary condition: Beam models are constrained to obtain the desired solutions.

- The support of the model is fixed at both the end as it is the main beam.

- Heat flux is applied on the three faces of a beam.
- Varying Temperature from 22^{o}C to 1000^{o}C is applied on the three faces of Beam.
- Varying Temperature from 22^{o}C to 1000^{o}C is applied on the over faces of Beam.

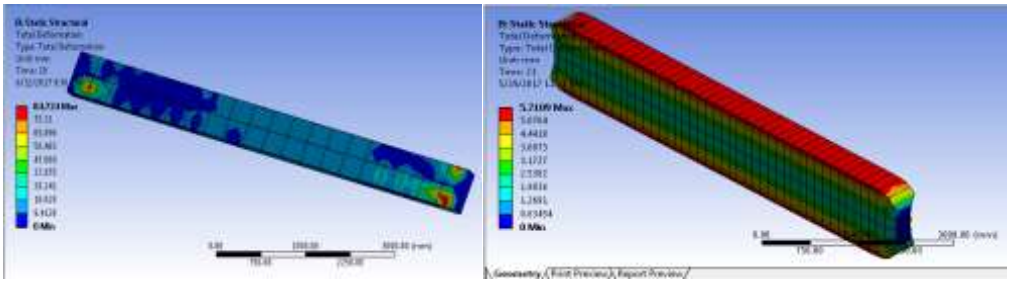


Three faces of Beam exposed varying temperature | Three faces of Beam exposed Heat flux | Overall Beam exposed to varying Temperature

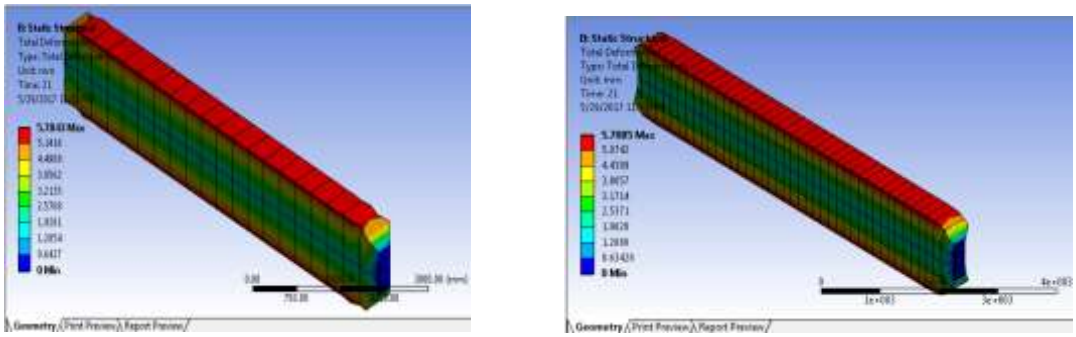
6. RESULT AND DISCUSSION

Based on analytical work and it was observed that use of polypropylene fibers in the RC beam member results in an increase in strength, lesser deformation and stress compared to beam without polypropylene fibers. As a result, maximum deformation occurs in the beam without polypropylene fibers at elevated temperatures varying from 800^{o}C to 1000^{o}C. But in the case of polypropylene FRC beams as the temperature goes on increasing and reaches the fiber melting point the polypropylene fibers start melting and form a liquid layer which allows cooling the temperature of concrete and intern prevents the temperature to reach the reinforcement. As the temperature goes on further increasing failure occurs but the time to reach the failure is increased.

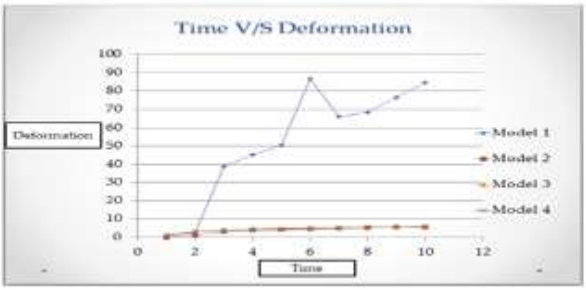
Total Deformation: Deformation is high in the beam without polypropylene fiber and clear cover of 30mm as maximum deformation observed is 84.724[mm] as compare to beam with polypropylene fiber and clear cover of 60mm as maximum deformation observed is 5.7085[mm].i e, the use of polypropylene fibers in RC beams make the beam stiffer and also helps in increasing the resistance time to reach maximum deformation. Below figure shows the variation of beam deformation due to ambient temperature from 22^{o}C to 1000^{o}C.



Deformation of the Beam without Polypropyleneand 30mm clear cover | Deformation of the Beam with Polypropylene and 30mm clear cover

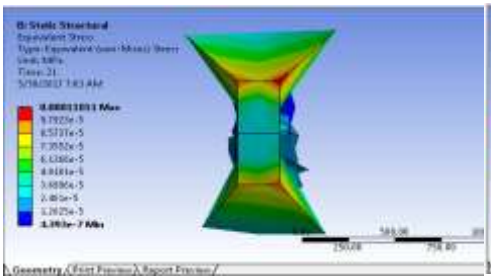


Deformation of the Beam without Polypropylene and 60mm clear cover | Deformation of Beam with Polypropylene and 60mm clear cover

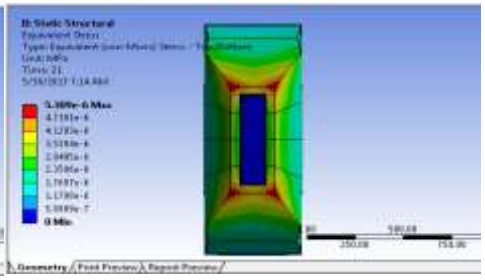


Graph.1 Total deformation graph for different beam model

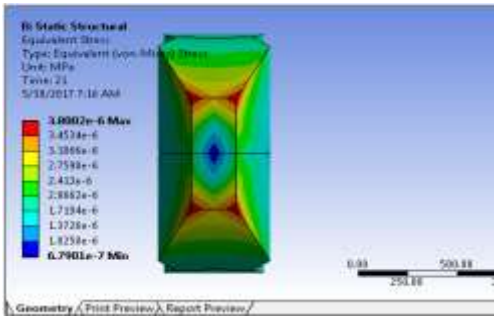
Equivalent stress: Stress is utilized to determine the stress state near thesplit/crack caused by a temperature or residual stresses. Higher stress is developed for the beam without polypropylene fiber and less clear cover as the contrast with polypropylene fiber covered beam for a similar change in temperature condition.The beam that displays less yielding at a broken tipdue to temperature conditions starting from 22^{o}C to 1000^{o}C.From the analysis of the beam under temperature it was found that by increasing the temperature, stress intensity is increased and maximum at the supports of the beam.



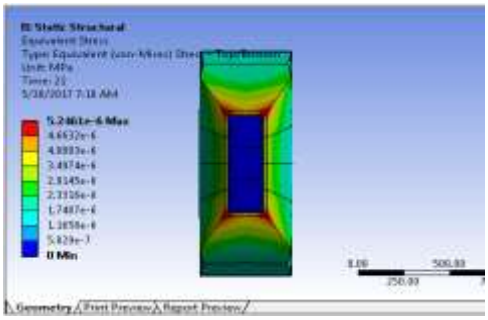
Stressfor Beam without Polypropylene and 30mm clear cover



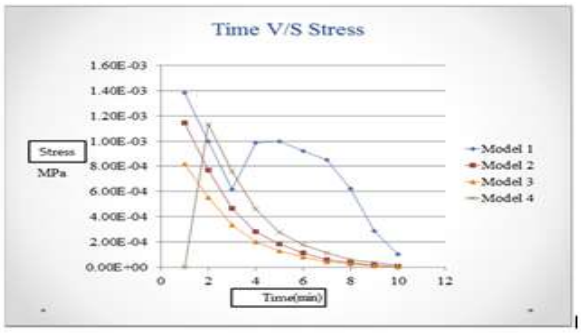
Stress for Beam with Polypropylene and 30mm clear cover



Stressfor Beam without Polypropylene and 60mm clear cover



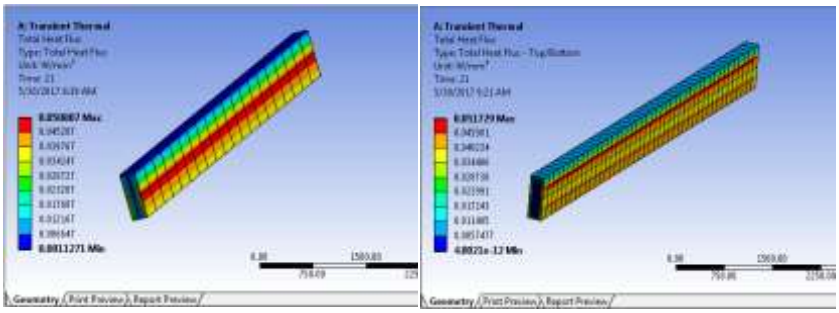
Stress for Beam with Polypropylene and 60mm clear cover



Graph.2 Equivalent stress graph for different beam model

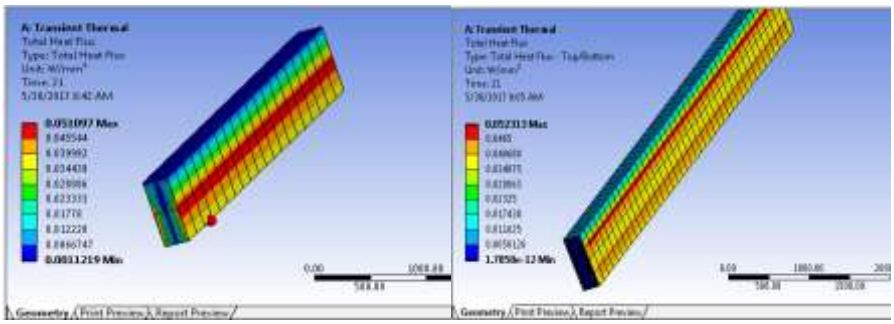
Total Heat Flux: Heat flux is characterized as the measure of heat exchanged per unit area per unit time from/ to a surface and the measure of heat exchanged per unit time also, the range from/to which this warmth exchange happens. As three faces of the beam are subjected to the Heat flux of 100 W/mm^2 maximum heat flux observed at faces with polypropylene is 0.052313 [W/mm^2] and without polypropylene maximum heat flux observed is 0.050807 [W/mm^2]. As the temperature reaches from concrete to fiber

surface heat is distributed to overall body and is not allowed to reach the core of reinforcement whereas in the case of the beam without polypropylene it reaches to the core of reinforcement.



Heat fluxfor a Beam without Polypropylene and 30mm clear cover

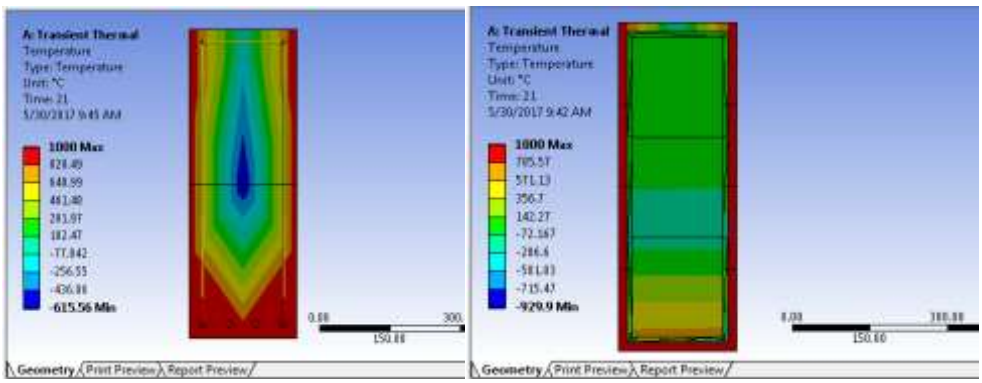
Heat flux for a Beam with Polypropylene and 30mm clear cover



Heat fluxfor a Beam without Polypropylene and 60mm clear cover

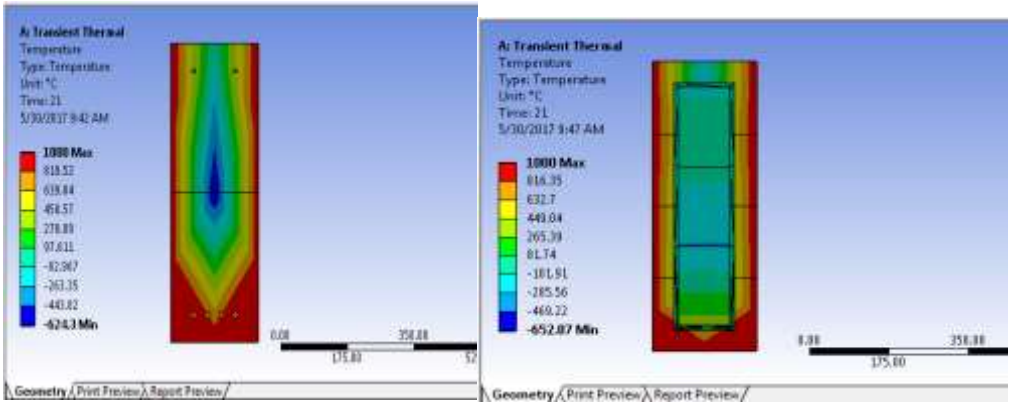
Heat flux for a Beam with Polypropylene and 60mm clear cover

The temperature on the faces of the beam: As a beam exposed to temperature over all body gets heated due to the flow of heat. In this work according to Euro code exposed faces are subjected to heat further increase in temperature heat flows to other faces of a member due to the sudden fire where the bottom face and two side faces are exposed to the environment. As below figure shows the variation of heat flow subjected to temperature polypropylene fiber and clear cover provided for the RC beam more resistant to heat or fire to cause maximum deformation or failure.



Beam without varying temperature without Polypropylene and 30mm clear cover

Beam with varying temperature with Polypropylene and 30mm clear cover



Beam without varying temperature without Polypropylene and 60mm clear cover

Beam with varying temperature with Polypropylene and 60mm clear cover

7. CONCLUSIONS

The behaviors of the beam with and without polypropylene subjected to different parameters are analyzed using finite element method and the following conclusions are drawn:

- Use of polypropylene as cover for the beams subjected to ambient temperatures results in increase in strength, stiffness, time to reach maximum deformation.
- Fibers exposed to elevated temperatures when reaching its melting point develop air voids which help in reducing the temperature of concrete. As the temperature goes on increasing fiber starts melting and form a liquid layer which cools the surrounding temperature easily.
- Clear cover to RC beam according to fire safety code is very effective when compared to clear cover provided according to IS-456:2000. The temperature to reach the core of reinforcement takes more time in case of 60mm clear cover.
- The rate of heat exchange can be improved by providing fiber as cover by varying clear cover distance as the fiber has high resistant to fire and have low melting point when subjected to temperature.
- Deformation of beam without polypropylene is more when compare to beam with polypropylene, Hence use of polypropylene fiber gives more stiffness to the structural elements.

REFERENCES

[1] PrateekShrivastava, YogeshBajpai, AnubhavRai,Finite element analysis and comparative study of reinforced Concrete beams laminated with and without FRP ISSN 2277-2685 IJESR/Jan 2015/ Vol-5/Issue-1/12-18

[2] YakudimaAkibuGhali, Impact of fire on steel reinforcement in Reinforced concrete structures, IJSRP, volume 5, issue 10, ISSN2250-3153

[3] L.Dahmani, M.Kouane, Thermal cracking response of Reinforced concrete beam to gradient temperature.

[4] Anthony Nkem Ede, AdebodunOluwaseyiAina, Effect of coconut husk fiber and polypropylene fiber on spalling resistance of concrete.ISSN: 2277-5528, Jan to March 2015

[5] T. Subramani1, S.Krishnan, M.S.Saravanan, SubodhThomasAnalysis of retrofitting non-linear finite element of RCC beam And column using AnsysISSN: 2248-9622, Vol. 4, Issue 12(Part 5), December 2014, pp.77-87

[6] EN 1992.1.2.2004 Eurocode 2: Design of concrete structures – Part 1-6: General Rules – Structural fire design.

[7] NIST.TN.1681 Best Practice Guidelines for Structural Fire Resistance Design of Concrete and Steel Buildings