Finite Element Analysis of Steel Fibre Reinforced Concrete Composite Panels Subjected to Combined Effect of Fire and Blast

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Abstract - *The accidental fire generally tends to explosion in the city environment surrounded with combustible materials, and vice versa. This leads to the fact that the structures are in danger of combined effect of fire and blast. This study mainly considers the combined effect of fire and blast on SFRC panels and compares the results with that of plain concrete panels. This is the analytical study done using ANSYS 16 Workbench as finite element analysis tool. The ISO834 standard fire curve is used for temperature effect and two loads (0.1 kg and 0.2kg) with varying stand-off distances is considered. The results in form of total deformation, equivalent stress and equivalent strain are obtained.*

Key Words: **ISO 834, Fire, Blast load, Steel Fibres, Finite element method.**

1. INTRODUCTION

The accidental fire generally tends to explosion in the city environment surrounded with combustible materials, and vice versa. This leads to the fact that the structures are in danger of combined effect of fire and blast. After the terrorist attack of 9/11 in New York the concern regarding combined effect of fire and blast on reinforced structures have significantly increased. The effect of dynamic loading including impact and explosion are completely different from that of fire. The dynamic loading is short term while the fire is long term and slow.

In such situations studies on a single load are far from meeting the requirement of design and analysis. Currently many studies are focused on RC and steel structures. It has been investigated that introduction of steel fibres in concrete can increase its ductility, tensile strength and energy dissipation capacity, resulting in good performance against impact loading. Many of the studies regarding fibre reinforced concrete material separately consider the effects of high temperature and strain rate.

This study mainly considers the combined effect of fire and blast on SFRC panels and compares the results with that of plain concrete panels. This is the analytical study done using ANSYS 16 Workbench as finite element analysis tool. The SFRC panels subjected to both fire and blast were modelled with sequentially coupled thermal-stress analysis method, in which the simulation results obtained from the first step were taken as the initial state for second step. The blast loading is applied on same face as that used for applying ISO 834 standard fire. The results in form of total deformation, equivalent stress and equivalent strain were obtained.

2. AIM

The aim of this research is to calculate the combined effect of fire and blast loading on SFRC panels using Finite Element Method.

3. OBJECTIVES

3.1 To study the effect of fire and blast loading on SFRC panel in ANSYS Workbench.

3.2 compare the results of SFRC panel with plain concrete panel for total deformation, equivalent stress and equivalent strain.

4. MATERIAL PROPERTIES

The panel size of 400×400×50 mm was considered for modelling in ANSYS.

Table -1: steel fibre properties used in SFRC panels in ANSYS modeling

Type of Fiber	Hooked End Steel Fiber
Aspect Ratio	80
Diameter (mm)	0.7
Length (mm)	56
Density (kg/m^3)	7850
Percentage (%)	1.5
Yield strength (Mpa)	1100
Orientation	random

Table -2: concrete properties used in PCC and SFRC panels

Property	Concrete
Compressive strength [N/mm^2]	M_{40}
Young's modulus (E) [N/mm^2]	30000
Poisson's ratio µ	0.16
Density [kg/m^3]	2400

5. MODELLING IN ANSYS

ANSYS 16 WORKBENCH

ANSYS WB 16 is used for simulation and study of the finite elements. ANSYS Workbench meshing aims to include reliable, easy-to-use meshing software that will improve the mesh generation phase. The models were simulated using thermal-stress method in ANSYS. It works in two steps, firstly the fire was applied using steady state thermal method and the final results were used as the initial data for Blast loading carried in static structural part of ANSYS.

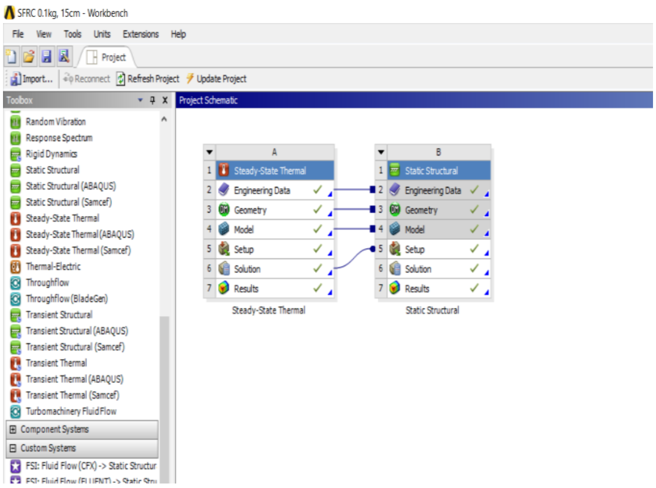

Fig -1: linking of final results from fire test to the initial data of blast test

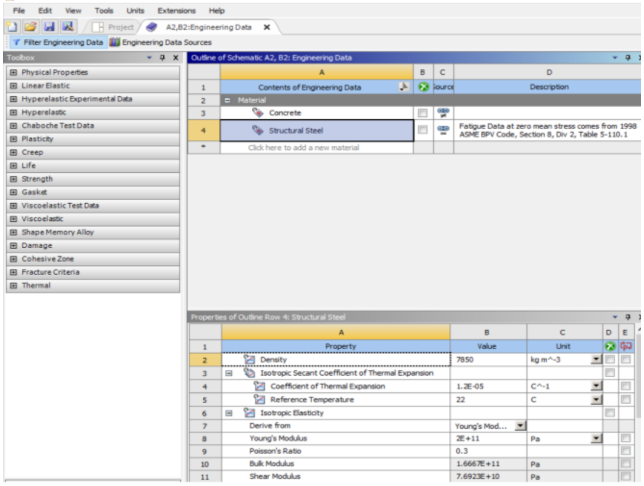

Fig-2: Adding of material properties for SFRC panel.

5.1 MODELLING OF PLAIN CEMENT CONCRETE PANEL

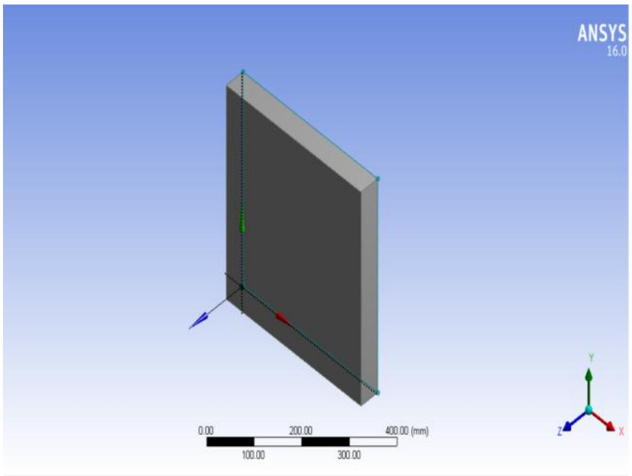

Fig-3: Sketching of plain cement concrete model

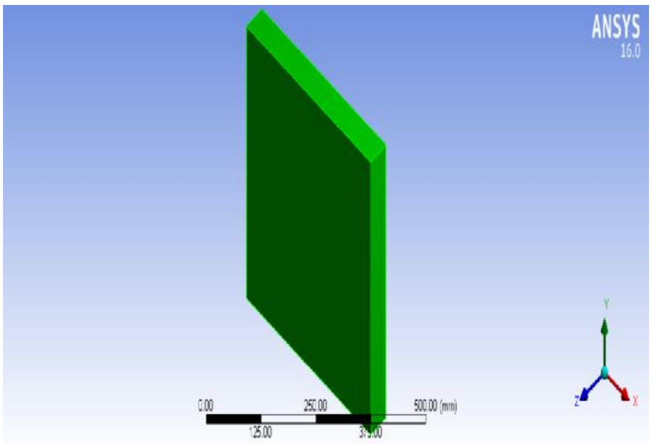

Fig-4: Assigning properties to plain cement concrete model

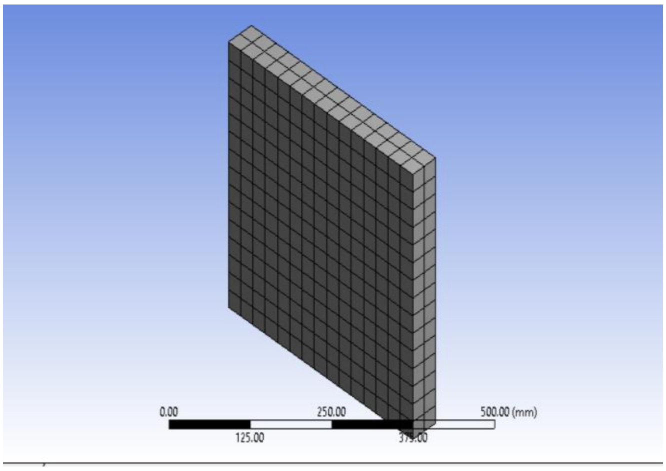

Fig-5: meshing of plain cement concrete model

5.2 MODELLING OF STEEL FIBRE REINFORCED CONCRETE PANEL

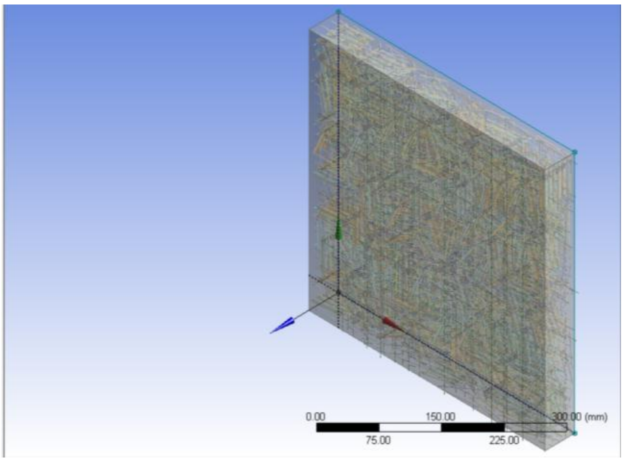

Fig-6: Sketching of steel fibre reinforced concrete panel

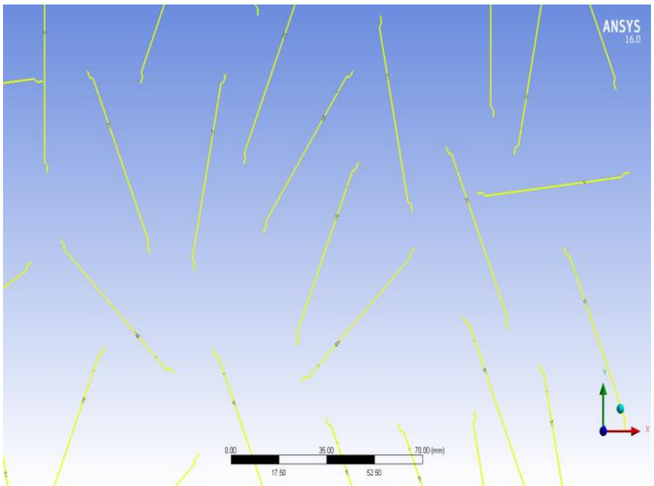

Fig-7: Hooked end shape steel fibre used in modelling

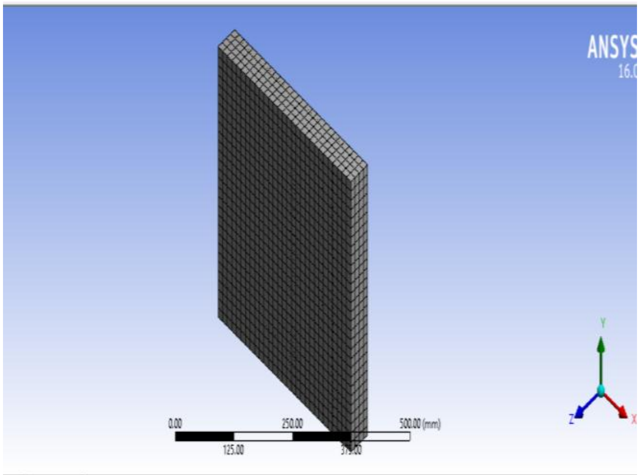

Fig-8: Meshing of SFRC panel model

5.3 MODELLING OF PANELS UNDER FIRE LOADING

Both panels with and without steel fibre were heated for 120 min, according to the standard temperature time history suggested by ISO834 which can be expressed by eq.

$$T = T_0 + 345\lg(8t + 1)$$

Where T_0 (°c) is the initial temperature taken as 20°c, and T is the ambient temperature subjected to fire after t minutes. The panel was heated uniformly on one face only.

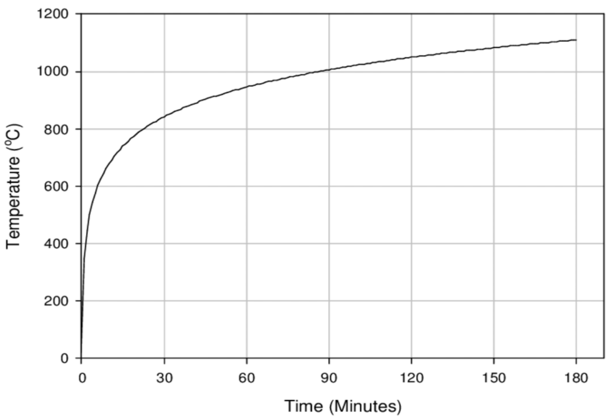

Fig-9: standard temperature-time curve of indoor fire by ISO834

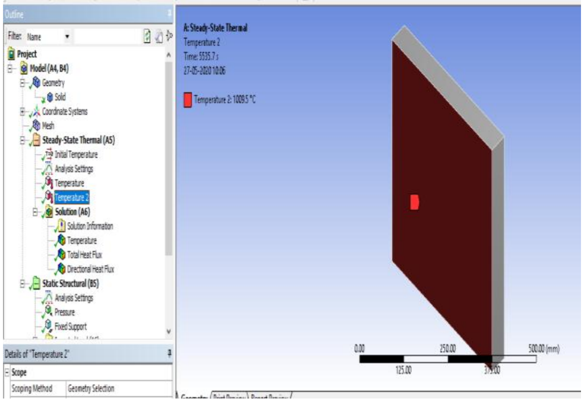

Fig-10: Applying temperature time history curve on one face of panel in ANSYS

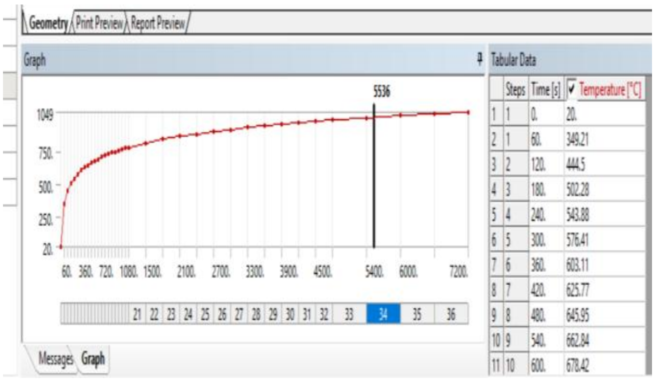

Fig-11: temperature time history curve data input in ANSYS

5.4 MODELING IN ANSYS OF PANELS UNDER BLAST LOADING

DEFINITION OF BLAST LOAD

As per the IS 4991:1968, A blast is a rapidly moving shock wave which may release pressure many times greater than those experienced under the greatest of the hurricanes. However, in blast phenomenon, the peak intensity lasts for very small amount of time.

5.4.1 CALCULATION OF BLAST LOAD

Equivalent weight of TNT- W (Kg.)

Scaled Distance (Z)= $R/\sqrt[3]{W}$

Where, R = distance from the point of interest (m) to the detonation source

W = the weight (more absolutely: the mass) of the explosive (Kg).

Table -3: Blast Pressure for different TNT charges

TNT charge (kg)	Stand -off distances(m)	Scaled distance Z (m)	Blast pressure(N/mm^2)
0.1	0.15	0.32	85.616
	0.30	0.64	23.48
	0.50	1.07	6.645
0.2	0.15	0.25	125.44
	0.30	0.51	37.6
	0.50	0.85	12.24

5.4.2 APPLYING PRESSURE & END TIME FACTOR ON PCC AND SFRC PANELS

Blast pressure was applied on same face on which temperature was applied.

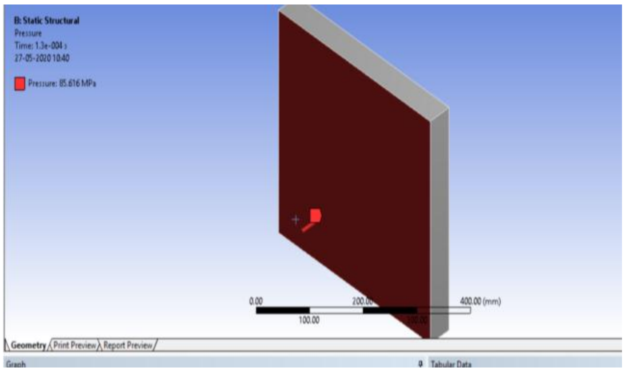

Fig -12: Applying Pressure & End Time Factor PCC panel

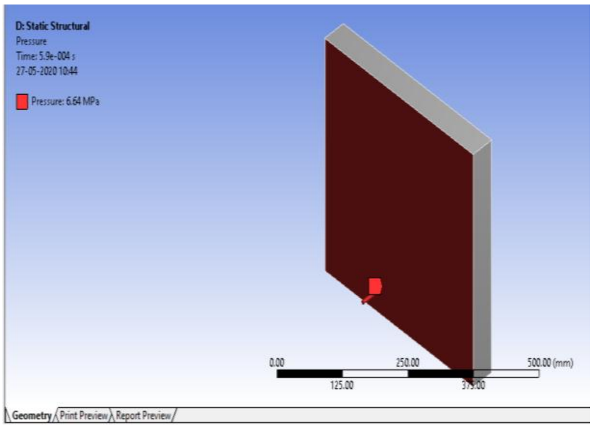

Fig -13: Applying Pressure & End Time Factor on SFRC panel

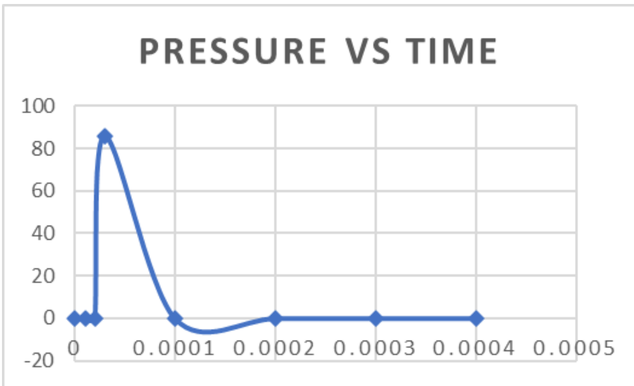

Chart -1: Pressure vs. Time for 0.1Kg of TNT equivalent for 0.15m Standoff Distance

6. RESULTS

6.1 PLAIN CEMENT CONCRETE PANEL RESULTS

6.1.1 TOTAL DEFORMATION

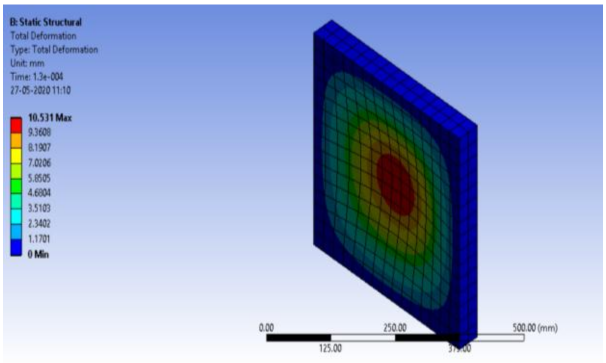

Fig -14: Total Deformation in plain cement concrete panel

6.1.2 EQUIVALENT STRESS

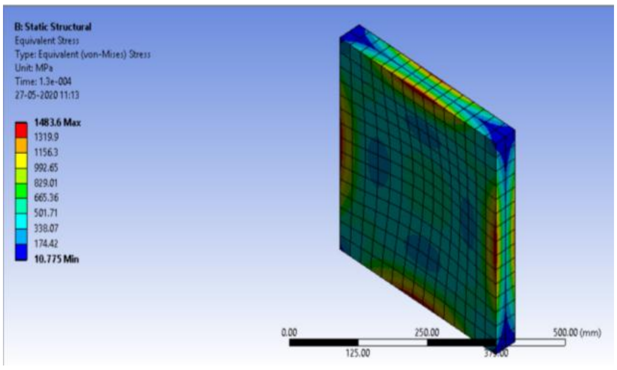

Fig -15: Equivalent Stress in plain cement concrete panel

6.1.3 EQUIVALENT ELASTIC STRAIN

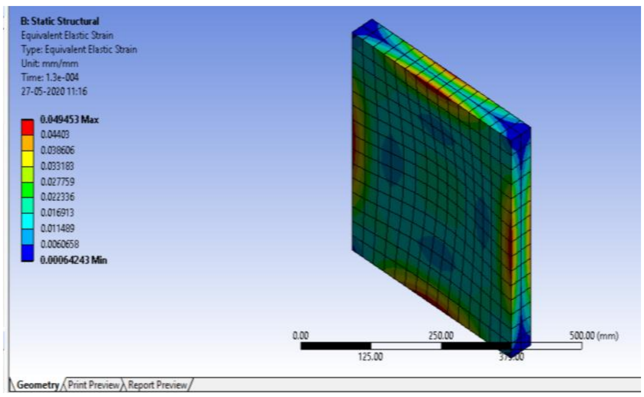

Fig -16: Equivalent Elastic Strain in plain cement concrete panel

6.2 STEEL FIBRE REINORCED CONCRETE PANEL RESULTS

6.2.1 TOTAL DEFORMATION

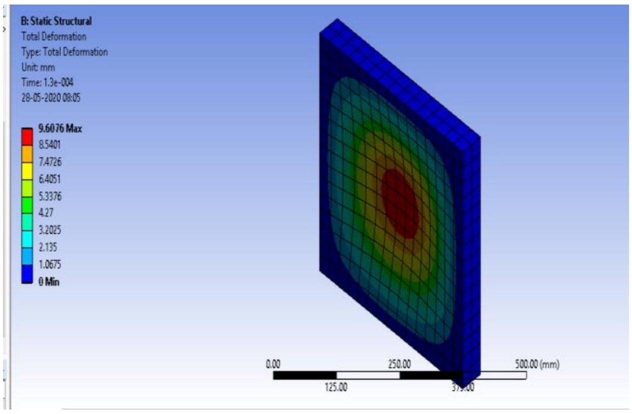

Fig -17: Total Deformation in SFRC panel

6.2.2 EQUIVALENT STRESS

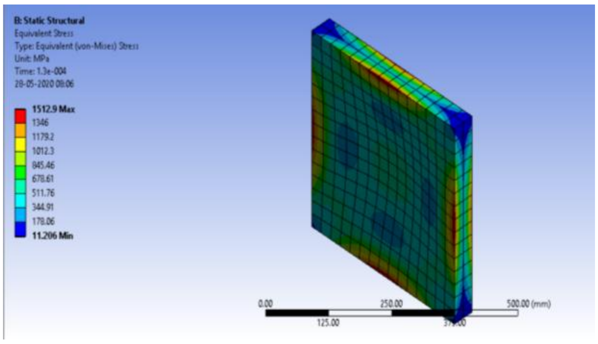

Fig -18: Equivalent Stress in Corner SFRC panel

6.2.3 EQUIVALENT ELASTIC STRAIN

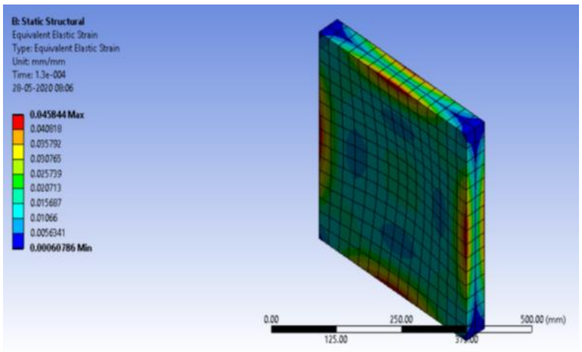

Fig -19: Equivalent Elastic Strain in SFRC panel

6.3 PLAIN CEMENT CONCRETE PANEL FINAL RESULTS

Table -4: plain cement concrete panel

TNT charge (kg)	Stand off distance (m)	Max total deformation (mm)	Max equivalent elastic strain	Max equivalent stress (Mpa)
0.1	0.15	10.531	0.0494	1483.6
	0.30	2.88	0.0135	406.81
	0.50	0.81	0.0038	114.75
0.2	0.15	15.49	0.0724	2173.7
	0.30	4.63	0.0217	651.51
	0.50	0.816	0.0038	114.86

6.4 STEEL FIBRE REINORCED CONCRETE PANEL RESULTS

Table -5: steel fibre reinforced concrete panel

TNT charge (kg)	Stand off distance (m)	Max total deformation (mm)	Max equivalent elastic strain	Max equivalent stress (Mpa)
0.1	0.15	9.606	0.0458	1512.6
	0.30	2.634	0.0125	414.83
	0.50	0.745	0.0035	116.84
0.2	0.15	14.077	0.0671	2216.6
	0.30	4.21	0.0200	664.36
	0.50	1.373	0.0065	216.08

6.5 TOTAL DEFORMATION RESULT

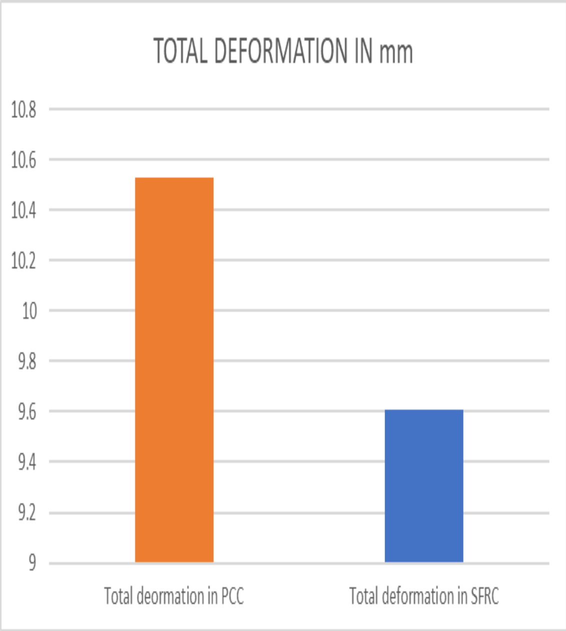

Chart -2: total deformation for 0.1 kg charge of TNT

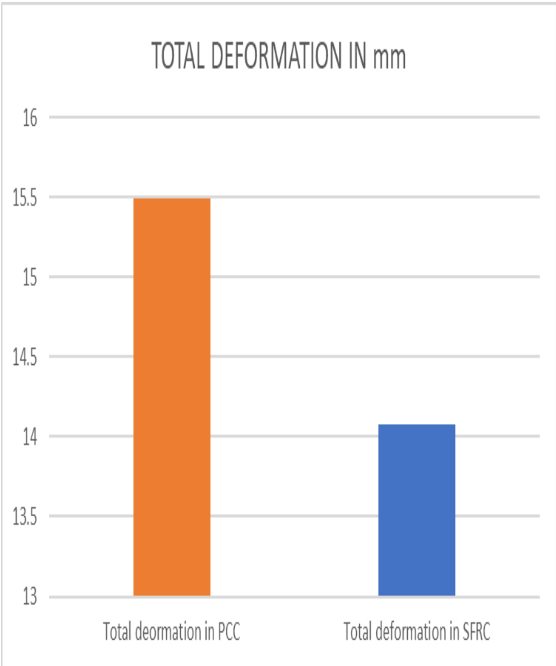

Chart -3: total deformation for 0.2 kg charge of TNT

6.6 TOTAL EQUIVALENT STRAIN RESULT

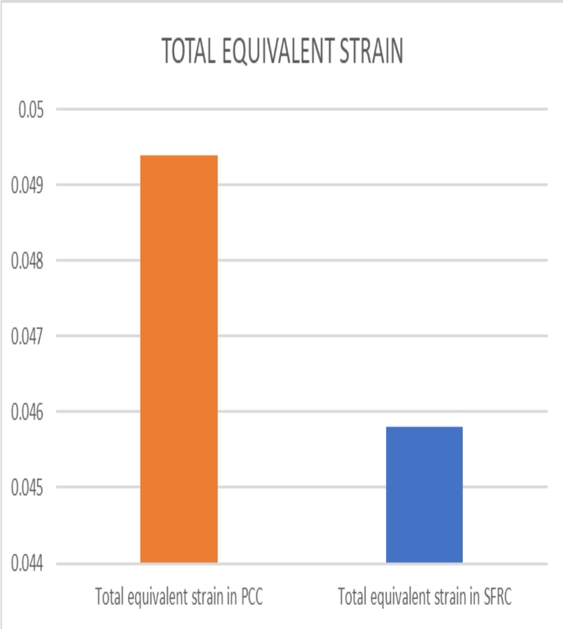

Chart -4: Total equivalent strain for 0.1 kg charge of TNT

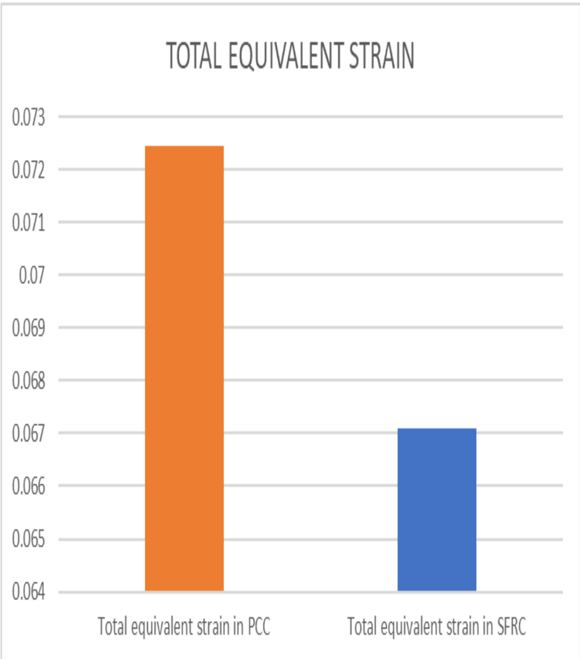

Chart -5: Total equivalent strain for 0.2 kg charge of TNT

6.7 TOTAL EQUIVALENT STRESS RESULT

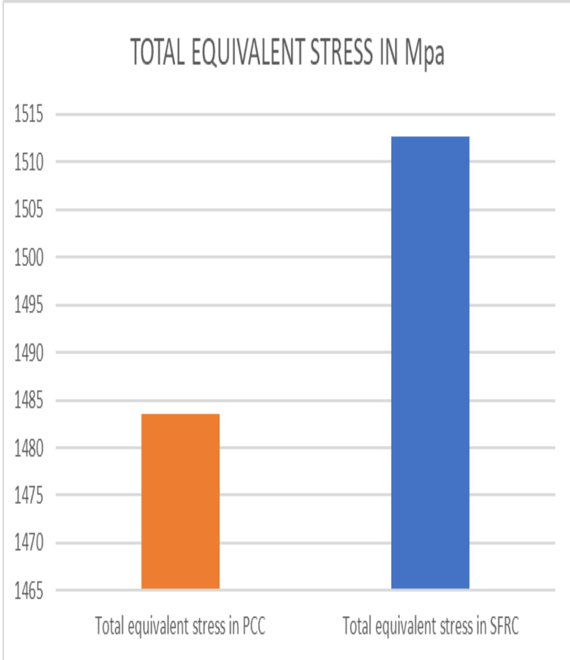

Chart -6: Total equivalent stress for 0.1 kg charge of TNT

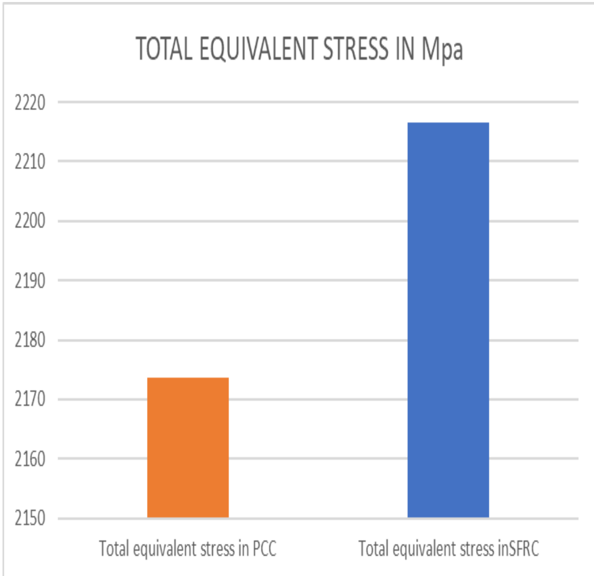

Chart -7: Total equivalent stress for 0.2 kg charge of TNT

7. CONCLUSIONS

In this paper the comparative study was conducted on PCC and SFRC panels under combined effect of fire and blast analytically in ANSYS 16.

1. It is observed that the total deformation for steel fibre reinforced concrete panels is 9% less than that of plain cement concrete panels.

2. Maximum equivalent strain developed in steel fire reinforced panels is 7% less than that of plain cement concrete panels.
3. Maximum equivalent stress developed in steel fibre reinforced concrete panels is 2% more than that of plain cement concrete panels.
4. From the above discussions and results it is concluded that results of adding steel fibres in concrete shows good results than that without steel fibres.
5. Hence it is concluded that steel fibre reinforced concrete has better resistance to combined effect of fire and blast than that o plain cement concrete.

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