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Aramid Fiber Reinforced Polymer In High Strength Concrete Compressive Structures

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Abstract*: The purpose of this study is to investigate the effect of AFRP confined HSC column under blast and impact load. High strength concrete (HSC) is widely using in the world from few years. As the name indicates its high compressive strength can be effectively use in compressive structures like piers and columns. But their effective applications in impact resistant and blast resistant building structures are held by its brittle failure and lack of ductility. AFRP sheets can effectively use for overcome this disadvantage. AFRP sheets are having high impact and blast resistance and also its provide increase in ductility of column. This paper focuses on the compressive strength, blast resistance and impact resistance of HSC circular column model confined by AFRP sheets under axial compression. The analysis is done using ANSYS software.
***Keywords*: Fiber reinforced polymers; High-strength concrete; Concrete columns**

I. INTRODUCTION

High strength concrete (HSC) is widely using in the world from few years. As the name indicates its high compressive strength can be effectively use in compressive structures like piers and columns. As the compressive strength is higher it results the reduction in column size and increases the floor area. Among these advantages it also have the disadvantage that lack of ductility and brittle failure. Because of these disadvantages its extensive applications has been held by. Aramid Fiber Reinforced Polymer (AFRP) sheets can effectively use to overcome these disadvantages. It has been proven that AFRP confined HSC columns can attain suitable ductility and increase in strength.

Fig 1**:** Aramid fiber sheet

Aramid Fiber Reinforced Polymer can effectively used for column confinement. The aramid in aramid fiber-reinforced polymer is a synthetic fiber that is produced by way of condensation and filature. Aramid fibers widespread known as a Kevlar fiber in the markets. High-Strength Concrete has been applied successfully in civil engineering for its predominant strength performance. However, its extensive application has been held by the fact that brittle failure, or lack of ductility, appears in HSC. Also, retrofitting concrete columns is of paramount importance in the rehabilitation of existing structures. In recent years, fiber-reinforced polymer (FRP) jacketing has become popular to retrofit existing deficient columns. Many experimental studies have demonstrated that FRP confinement can significantly increase column energy absorption and ductility.The studies have demonstrated that concrete columns confined by AFRP sheets can get higher compressive strength and better ductility.

In this paper the blast and impact resistance of HSC column confined with AFRP will be analysed using ANSYS. The stress and deformations of the column will be analysed under different charges of explosive at different standoff distances. For the impact study column will be analysed with equivalent truck with reduced scale.

II. FINITE ELEMENT MODELING

The analysis of the HSC column confined with AFRP is done using ANSYS WORKBENCH 15. The column geometry used and the AFRP used properties are given in table 1. The column model used in analysis is given in Fig.2. HSC of 140MPa is selected. Reinforcement of grade Fe415 is used.

Table 1. Geometry of column model and properties of AFRP sheet

Column geometry	Dimensions
Diameter of column	150 mm
Length of column	750 mm
Main reinforcement	6mmϕ 8No.s
Helical reinforcement	3mmϕ@100mm c/c
AFRP Sheet	
density	1.4 g/cm^3
Elastic modulus	118 GPa
Poisson's ratio	0.34
Tensile strength	2060 MPa

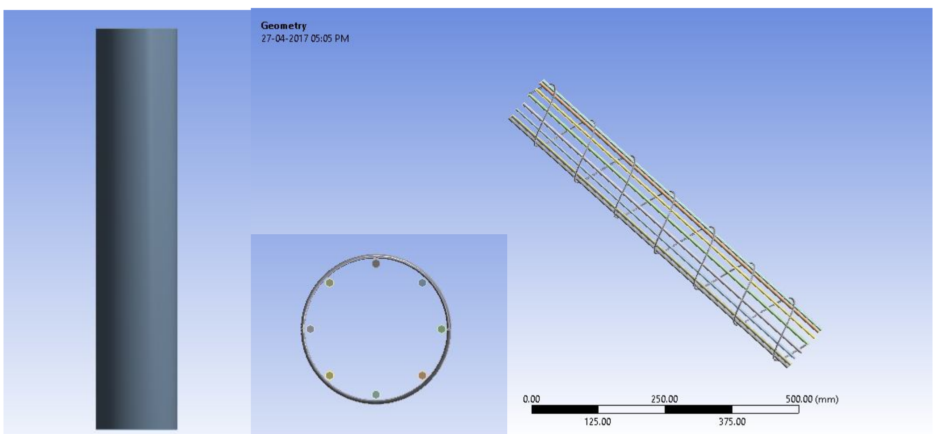

Fig.2 Geometry of column

A. *Elements used and modelling*

The concrete column is modelled using eight node SOLID65 element. SOLID65 is used because it is capable of simulating tension cracks, compressive crushing, plastic deformation, and creep for the concrete. The reinforcement is modelled using LINK180, and the AFRP sheets are modelled using SHELL181. The element types are given through the ANSYS WORKBENCH command line. The blast load checking of column is done using explosive charge creation in ANSYS. The explosive type used is TNT. For the impact analysis a block with same material property and with reduced scale that of a F800 truck is used. For that the truck block is modelled using SOLID186. The material for the truck is steel with density 7850g/m^3. SOLID186 is used for the steel truck because the element supports plasticity, hyperelasticity, creep, stress stiffening, large deflection, and large strain capabilities.

III. COMPRESSIVE STRENGTH OF AFRP CONFINED COLUMN

Strength of column can be increased by using confinement to the columns. FRP confinements are widely using now a days every were around the world. Various researchers found that using AFRP for the confinement of column the strength can be increase upto 220%. In this paper the HSC column's increase in compressive strength using AFRP confinement is discussed. The top and bottom of the column is fixed. The movement in all directions are restricted. The load is applied as pressure.

A. *Results and discussions*

Due to the confined reinforcement provided the column can have an increase in compressive strength. Additionally the AFRP confinement will increase the strength of the column. The Fig.3 and Fig.4 shows the column stress without AFRP confinement deformation respectively. Table 2 shows the results of the AFRP confined column. The results show that there is an increase in compressive strength as the number of layers of AFRP increases. Also reduction in the deformation of column as the number of layers of AFRP increases.

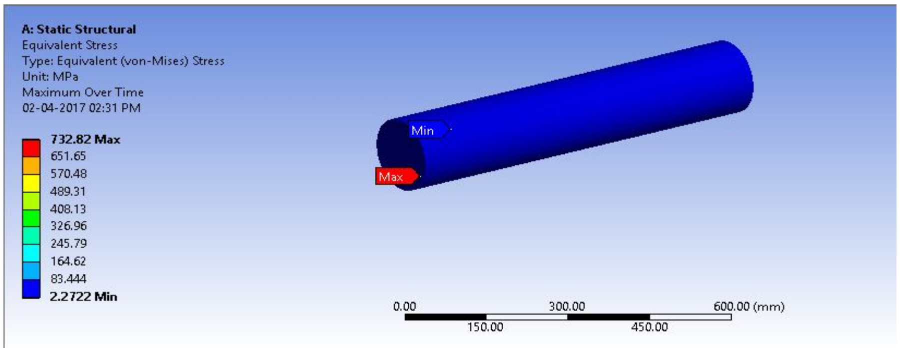

Fig.3 Equivalent stress in column without AFRP

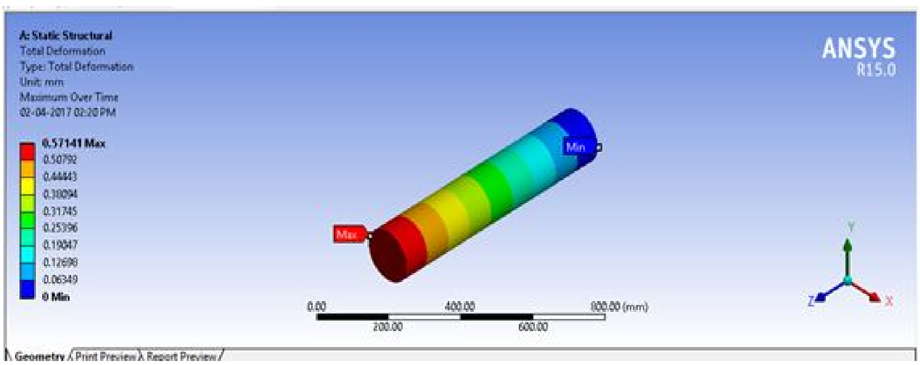

Fig.4 Total deformation in column without AFRP

Table 2 Stress and deformations of confined concrete column

HSC column without AFRP	HSC column with AFRP		
	1 layer	2 layer	3 layer
Maximum stress -732.82 Mpa	767.81 MPa	801.82 MPa	901.65 MPa
Maximum deformation -0.571 mm	0.39 mm	0.32 mm	0.29mm

IV. BLAST LOAD EFFECT OF AFRP CONFINED COLUMN

When explosion is a design criterion for buildings either due to the combustible materials contained within the structure or due to an intentional explosion (bomb), a common material chosen for blast resistance design is reinforced concrete, because of its large mass and flexibility in detailing. An explosion is a rapid release of energy taking the form of light, heat, sound and a shock-wave. This event differs from other loading types for buildings because of its short duration and high pressures. The time interval for the blast wave, t_d, is between 0.1 and 0.001 seconds. The explosive charge used is TNT which has the density of 1630 kg/m^3 and having the detonation velocity and energy/unit mas, 6930 m/s and $3.68x10^6$ J/kg respectively. The charge is created in a sphere form which having the size corresponding for the required charge weight. The detonation point is specified (1m, 2m). The analysis theory used for the blast wave action is Eularian’s theory.

A. Results and discussions

The blast resistance of AFRP is analysed using ANSYS WORKBENCH 15. The column confined with AFRP is analysed against different explosive charge weight conditions. The Equivalent stress and the total deformation at different cases is found. To know the charge weight upto which AFRP can resist after 5kg, 20kg, and 50kg is tested. From the results obtained it is clear that upto 50 kg TNT the stress on the column and the deformations are very small.

The analysis carried out for 20kg, 50kg and 400kg charge weight of TNT with standoff distance 1m and 2m and also for one and two layer of AFRP confined cases. The obtained results for the different cases are given in the Table 6.1 and Table 6.2.

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Table 3 TNT charge at 1m standoff distance

	1 layer AFRP		2 layer AFRP	
Charge (kg)	Total deformation (mm)	Equivalent stress (MPa)	Total deformation (mm)	Equivalent stress (MPa)
5	0.18	10.35	0.175	9.3
20	0.19	23.6	0.188	22.1
50	0.6	34.31	0.54	31.56
200	4.19	2356	3.987	2103.47

Table 4 TNT charge at 2m standoff distance

	1 layer AFRP		2 layer AFRP	
Charge (kg)	Total deformation (mm)	Equivalent stress (MPa)	Total deformation (mm)	Equivalent stress (MPa)
5	0.12	9.7	0.10	7.5
20	0.13	19.7	0.109	17.98
50	0.22	25.7	0.213	22.98
400	5.5	2414	5.32	2320

kThe Fig.5 shows that the equivalent stress on the AFRP confined column at 400kg TNT at 2m standoff distance. Fig.6 shows the total deformation. The column will fail due to the deformation because it is clear from the results that the AFRP sheet experiences only the minimum stress. The maximum stress is occurring at the two ends where fixity is provided. Fig.7 shows the equivalent stress in case of 200kg TNT at 1m standoff distance. Here also we can see that the column experience the maximum stress at fixed ends and the column deformation is large. The column will fail under the condition of lateral deformation.

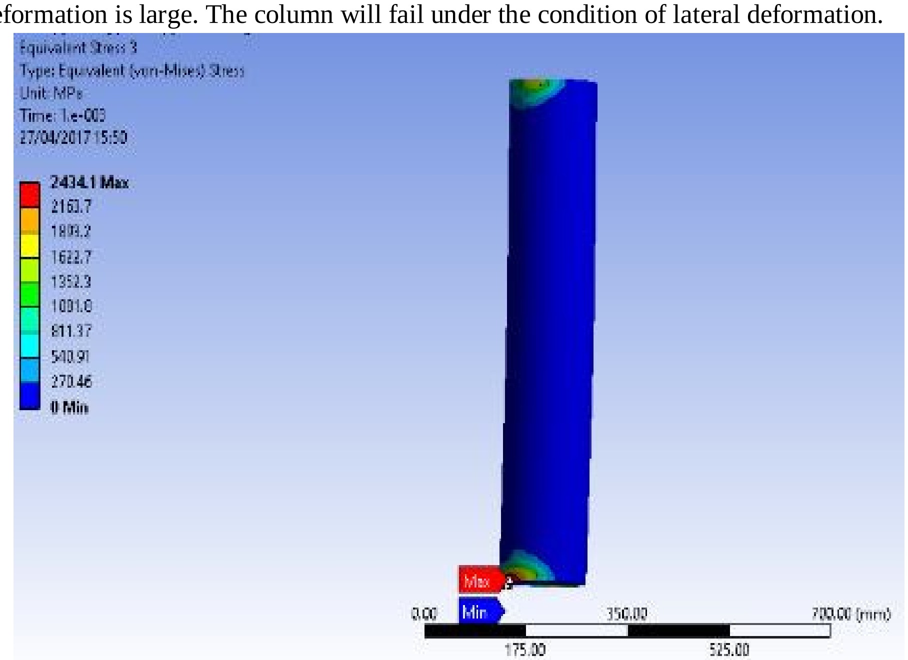

Fig.5 Equivalent stress for 1 Layer AFRP, 400kg charge at 2m standoff distance

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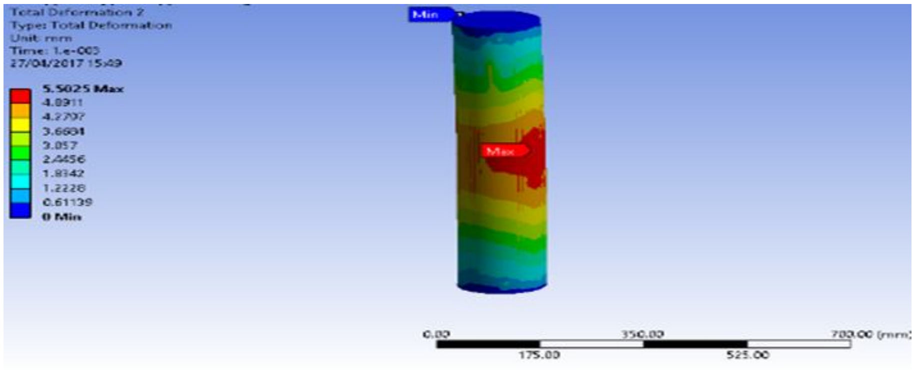

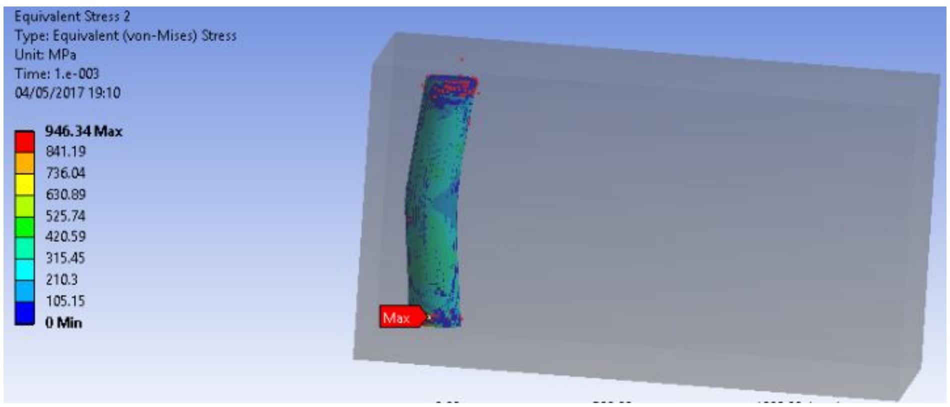

Fig.7 Equivalent Stress for 1 Layer AFRP, 200kg charge at 2m standoff

From the analysis result it is clear that there is not much difference in stress value while using 1 layer and 2 layers AFRP. Also at 1m and 2m standoff distance there is not much difference is obtained. The AFRP layer can withstand upto 400kg TNT weight at 2m standoff distance. Also at 1m standoff distance it can withstand upto 200kg charge of TNT. The Fig.8 shows the effect of stress with different layer of AFRP.

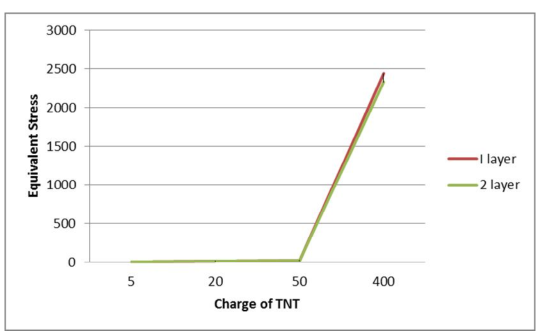

Fig.8 Effect of stress with different AFRP layers

V. IMPACT LOAD EFFECT ON AFRP CONFINED COLUMN

Truck collisions with bridge piers occur all over the world, sometimes with catastrophic results. In this chapter the effect of impact load on an AFRP confined HSC column will be discussed using an equivalent truck frame.

A. Reference truck

Trucks are generally divided into three categories in the United States according to their gross vehicular weight rating (GVWR), i.e.,

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light-duty, medium-duty, and heavy-duty trucks. As shown in Fig.9, a medium-duty truck [a 1995 Ford F800 (Ford Motor, Dearborn, Michigan), hereafter referred to as F800 truck] is selected as the reference truck. This category and specific truck type are selected because: (1) light-duty trucks generally do not generate severe enough damage to bridge piers even at a relatively high-speed collision; (2) earlier studies by the authors showed that medium-duty trucks, loaded to capacity with cargo, could result in impact demands that are as severe as those generated by heavy-duty trucks; (3) the gross vehicular weight rating (GVWR) of the 1995 Ford F800 truck is close to 12t, which is actually the lower bound for the heavy-duty truck category. Considering that trucks are routinely overloaded in many countries around the world, an overloaded F800 truck can also potentially cover some aspects of the heavy-duty truck category; and (4) among the publically available finite-element truck models, the F800 truck model has been widely used and validated by many scholars. Fig.9 shows the F800 truck model.

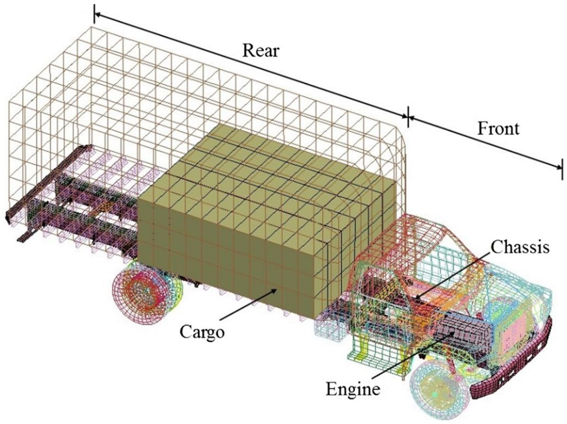

Fig.9 F800 truck model

B. Results and discussions

The equivalent stress of HSC column confined with one layer AFRP is shown in Fig.10. The equivalent stress in the AFRP sheet only is shown in Fig.11. The equivalent strain obtained in the analysis is shown in Fig. 12.

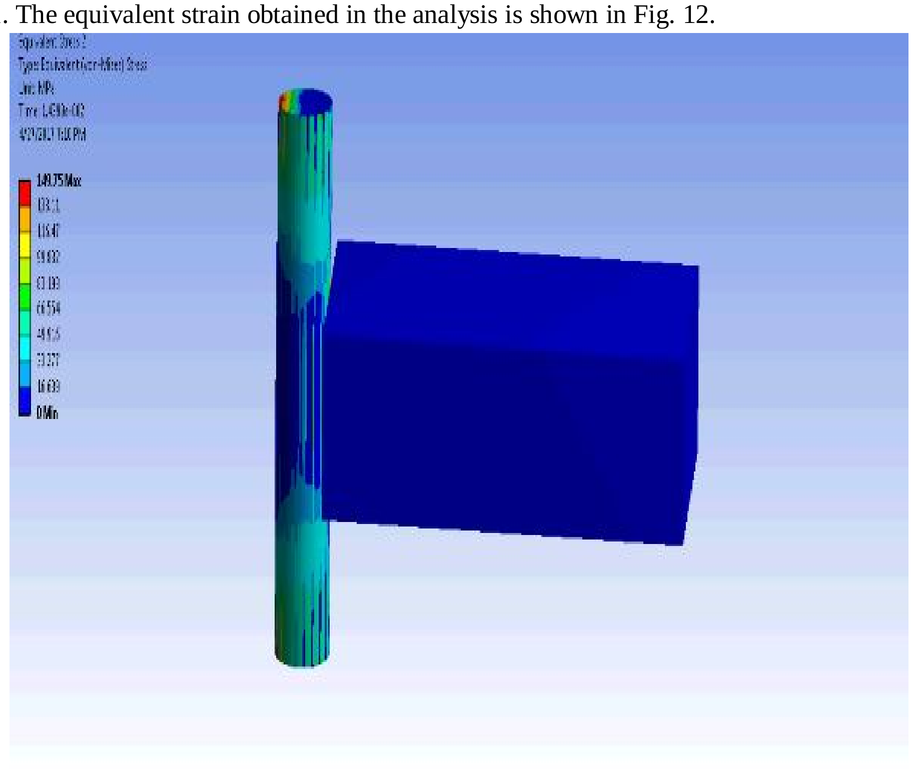

Fig.10 Equivalent stress of HSC column confined with one layer AFRP

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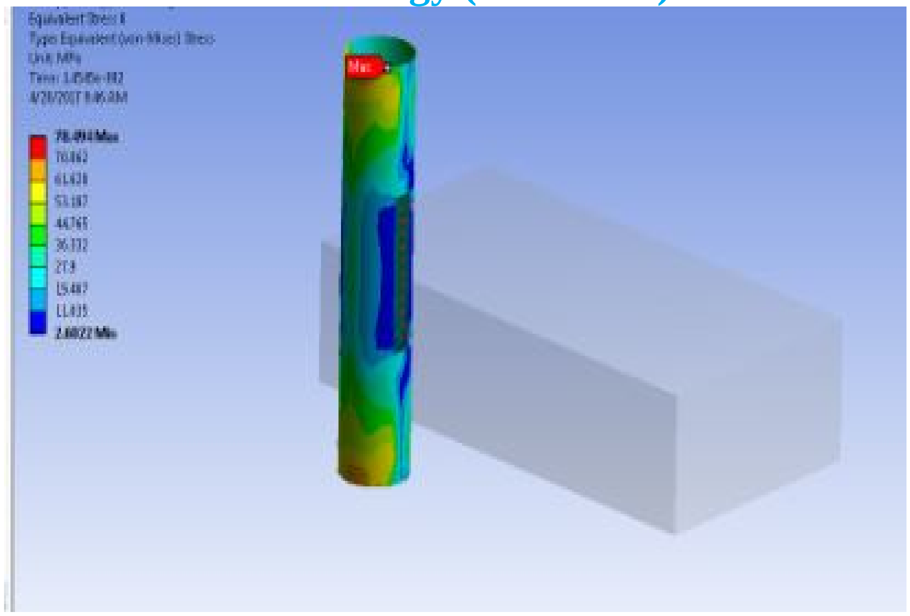

Fig.11 Equivalent stress on AFRP sheet only

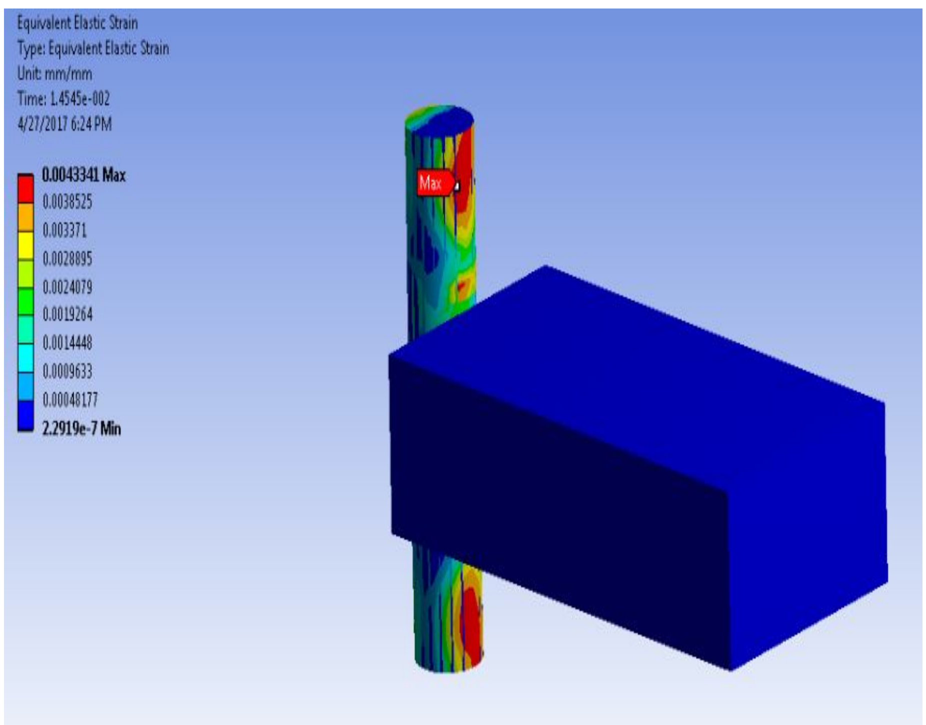

Fig.12 Equivalent strain in AFRP confined column

The results shows that while impacting a column with a truck of 10.5 m/s the AFRP sheet experience only 78.9MPa stress. Which indicate that while a truck is just colliding with a AFRP confined HSC column it will not fail under the velocity 10.5m/s. But if the truck is impacted the column fully then because of the impact touches the concrete also there is not much reduction in stress is obtained. It is also found that the equivalent strain of the model is 0.004. Fig.13 shows the 2 layer AFRP confined HSC column equivalent stress. Fig.14 shows the stress in AFRP layer only.

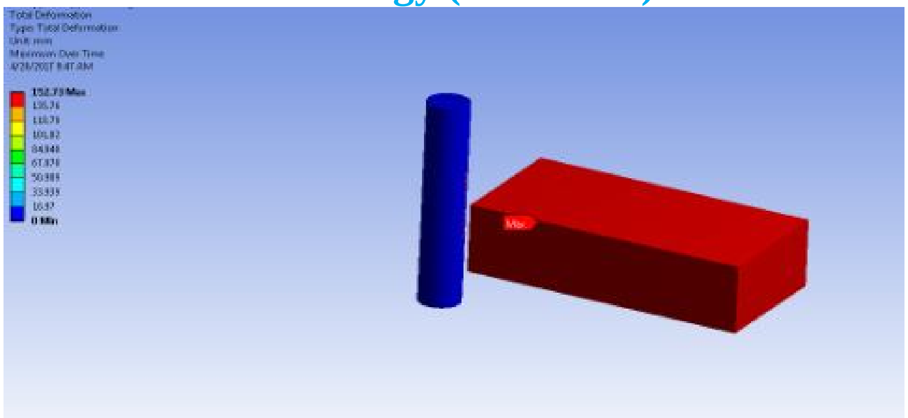

Fig.13 Equivalent stress in HSC column confined by 2 layers of AFRP

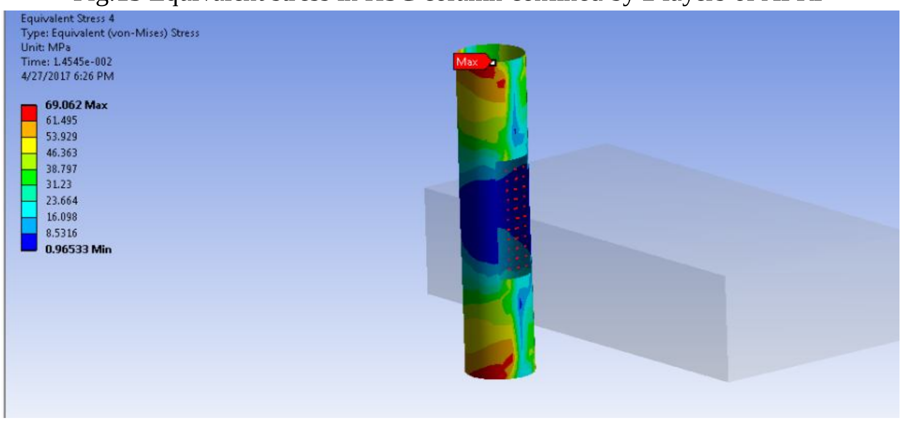

Fig.14 Equivalent stress in AFRP layer only

The results show that there is not much reduction in stress is obtained while using 2 layers of AFRP. After providing confinement with two layers of AFRP the tress on the AFRP layer is 69.062 MPa.

VI.CONCLUSIONS

HSC columns confined with AFRP is a good option for blast resistant structures. AFRP confined column can resist the blast load upto 400kg. HSC column confined with AFRP can have increase in compressive strength upto 200%**.** AFRP confined column can resist the blast load upto 200kg in a standoff distance 1m and upto 400 kg in a stand of distance 2m**.**Impact resistance of column is also increased**.** About 15% reduction of stress can obtain while using AFRP confinement in column.

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