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MECHANICAL BEHAVIOR ANALYSIS OF GFRP AND STRUCTURED STEEL FOR A FLAT PLATE UNDER TENSILE LOAD USING ANSYS

Vishnu S Rajan [1] , Shyam Sundar V [2]

[1]*M.tech Student,* [2]*Assistant Professor*

Department of Mechanical Engineering, Mohandas College of Engineering and Technology (India)

ABSTRACT

The use of composite materials has been increased in strengthening of concrete columns in recent years. One of the applications is to use FRP (fiber reinforced polymer) reinforcement instead of structured steel reinforcement in concrete columns.In the current project work a comparison of mechanical behavior of GFRP and structured steel for a flat plate is done. A steel flat plate and GFRP flat plate is simulated using ANSYS. Element type used for composite is Shell 3D 4node 181 and for steel is beam 3node 189. A tensile load is applied at two ends of the flat plates arresting the deformation in the perpendicular direction. It is found out that an increase of relative percentage of mechanical behaviors about 1% is obtained for GFRP compared to Steel.

Keywords: Composite, Concrete, GFRP, Steel, Flat plate, ANSYS.

I. INTRODUCTION

Composite materials now a days find wide range of applications in engineering field, especially in mechanical and civil engineering applications. Composites are considered due to its greater strength, light weight and corrosive resistant. In structural applications, composites find their way in strengthening of reinforced concrete structures and other components. It is necessary for many reasons such as earthquakes, inadequate strength-strain properties etc. In addition to traditional strengthening methods such as externally-bonded steel plates, jacketing, advanced composite materials has become widespread in the strengthening of reinforced concrete (RC) structures. Especially, usage of fiber reinforced polymers (FRP) materials for strengthening has rapidly increased in recent years. Due to their lightweight, high strength, resistance to corrosion, speed and ease of application and formed on site into different shapes can be made them preferences. The composite materials applications are used for strengthening of reinforced concrete structures instead of classical method.

Common fibers in commercial use for production of civil engineering applications including composite reinforced concrete are glass, carbon, and aramid. Laminates are the most common form of fiber reinforced composites used in structural applications. They are made by stacking a number of thin layers (lamina) of fibers and matrix and consolidating them into the desired thickness. Fiber orientation in each layer as well as the stacking sequence of the various layers can be controlled to generate a range of physical and mechanical properties. The major factors affecting performance of the fiber matrix composite are fiber orientation, length, shape and composition of the fibers, the mechanical properties of the resin matrix, and the adhesion or bond between the fibers and the matrix. Fibers are the principal load-carrying component in a fiber reinforced composite material.

The effectiveness of fiber reinforcement depends on the type, length, volume fractions and orientation of fibers in the matrix. The strength properties of FRPcollectively make up one of the primary reasons for which civil engineers select them in the design of structures. A material's strength is governed by its ability to sustain a load without excessive deformation or failure. When an FRP specimen is tested in axial tension, the applied force per unit cross-sectional area (stress) is proportional to the ratio ofchange in a specimen's length to its original length (strain). When the applied load is removed, FRPreturns to its original shape or length. In other words, FRP responds linear-elastically to axial stress.

II. FINITE ELEMENT MODELLING OF STEEL AND GFRP

In order to study the behavior of steel and GFRP a flat plate is simulated using ANSYS software. The dimension of the flat plate is 20 mm length and 12mm width. The element type considered for steel is beam 3node 189. The element type used for GFRP is Shel 3D 4node 181. The glass fibre (E-glass) is used as reinforcement material and Epoxy resin is used as a binding material of thickness 0.5mm in between the matrix material of thickness 2mm. The orientation selected for this composite is [0/45/90/135/180]. 5 layers of matrix material is bonded together with resin material in between them. The image of 2D FRP composite showing dimensions and orientation is given below.

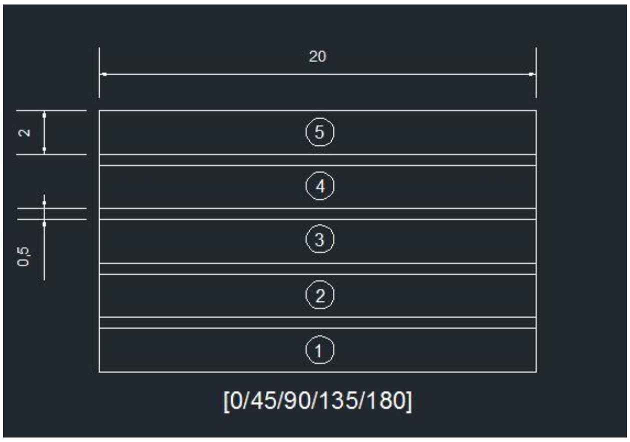

Fig.1 2D Image of GFRP composite showing dimensions and orientation

III. MESHING AND LOADING OF STEEL AND GFRP

After modelling of steel and GFRP the flat plate is meshed and its degrees of freedom is restricted to unidirectional. The material properties given is isotropic and the deformation is constrained in the direction perpendicular to the direction of the applied load.The mesh or model is a representation of the physics behind the real part that the model or mesh is referring to. Without an underlying knowledge of the physics behind how the component works the mesh may not be setup correctly.The real issue with mesh sizes is that yes bigger meshes are easier to solve but yield less complexity and vice versa, but large meshes should be used where we expect relatively low activity in the part with finer meshes being used where more activity should be found in the part or in an area of focus.

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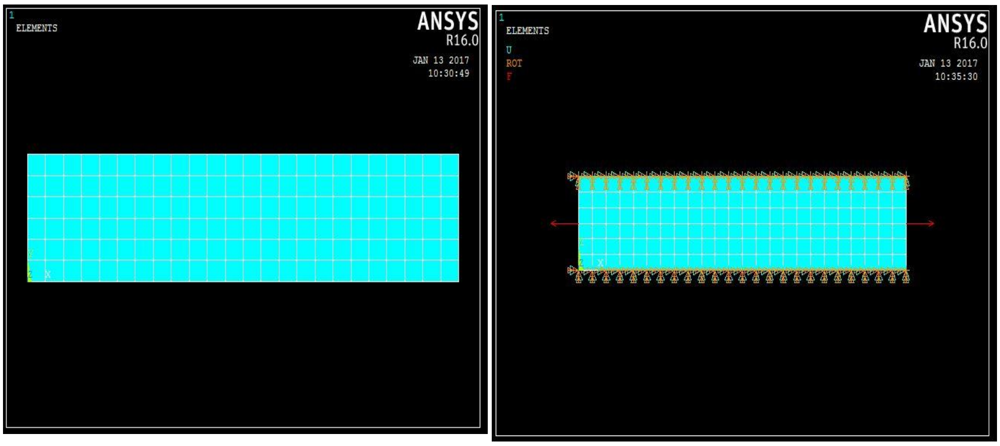

Fig 2. Meshed view with load and constraints

A load of 1000N is applied in X-direction at its two ends. Y-direction deformation is restricted. After load is applied the deformed views of steel and composite are shown in figure 3 below.

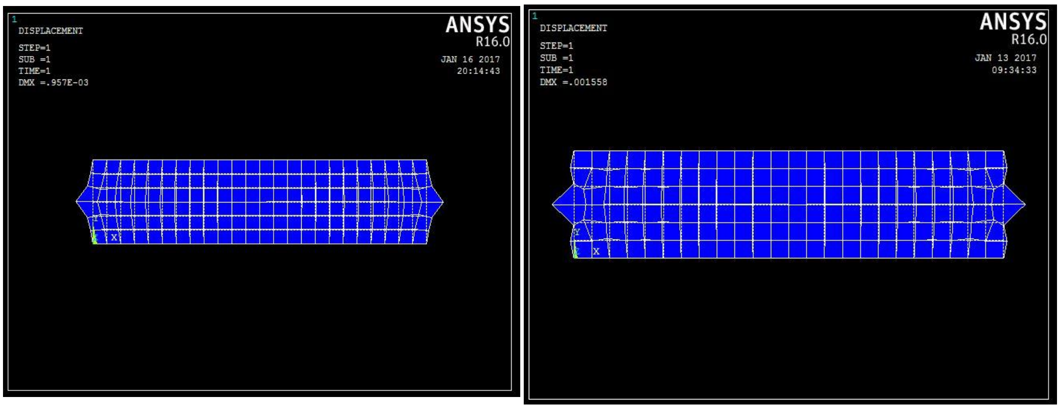

Fig. 3 Meshed view of Steel and Composite when loaded

1V DIRECTIONAL DEFORMATIONS AND TOTAL DEFORMATION

Whenever a problem is solved in ANSYS the output will be displacements and stresses. Deformations in all 3 directions is called directional deformations and total deformation will be the overall deformation of the system. It is the square root of sum of squares of deformations in X, Y and Z directions.Figures 4, 5, 6 shows the comparison of directional deformation, deformation in X and Y axis for steel and composite respectively.

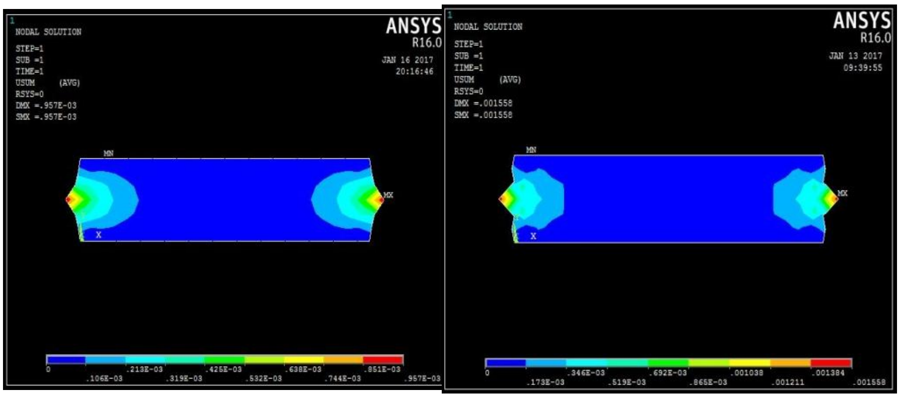

Fig.4 Directional deformation of steel and composite

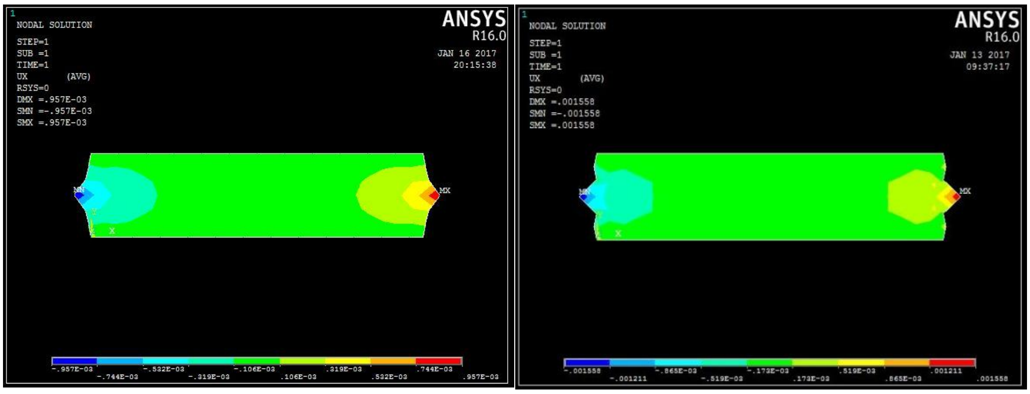

Fig 5. Deformation in X direction-Steel and Composite

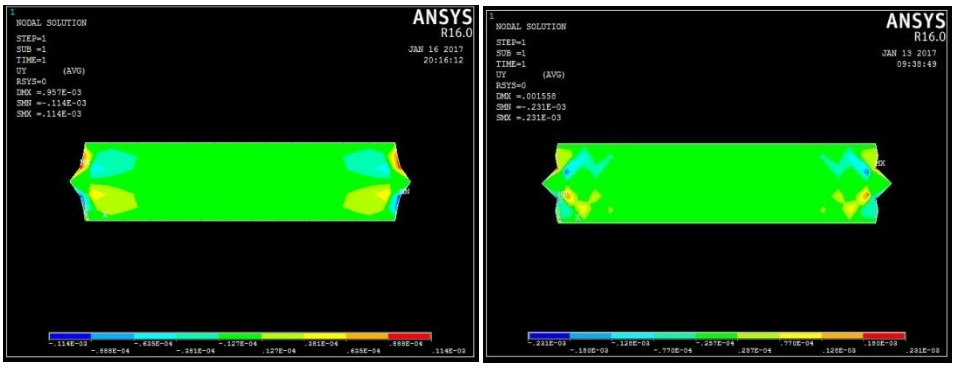

Fig 6. Deformation in Y direction-Steel and Composite

V. PRINCIPLE STRESSES AND SHEAR STRESS

Principle stresses are those stresses in principle planes where the shear stresses is zero. There are 3 principle planes for a body under stress and so there will be 3 principle stresses. First principle stress that is normal to the plane in which shear stress is zero. It helps you understand the maximum tensile stress induced in the flat plate due to loading conditions. Third principle stress helps you understand the maximum compressive stress induced in the flat plate due to loading conditions. First principle stress value is maximum and third principle stress value is the minimum value. Second principle stress value is just in the mid-range. Shear stress is a stress component which acts perpendicular to the material cross section. Figures 7, 8, 9 gives the comparisons between first, second, third principle stresses of steel and composite and figure 10 gives the comparison of shear stress value in XY direction of steel and composite.

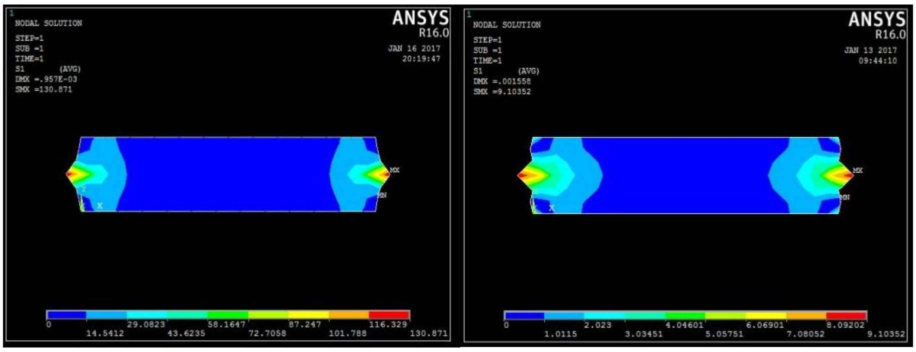

Fig 7. First Principle Stress - Steel and Composite

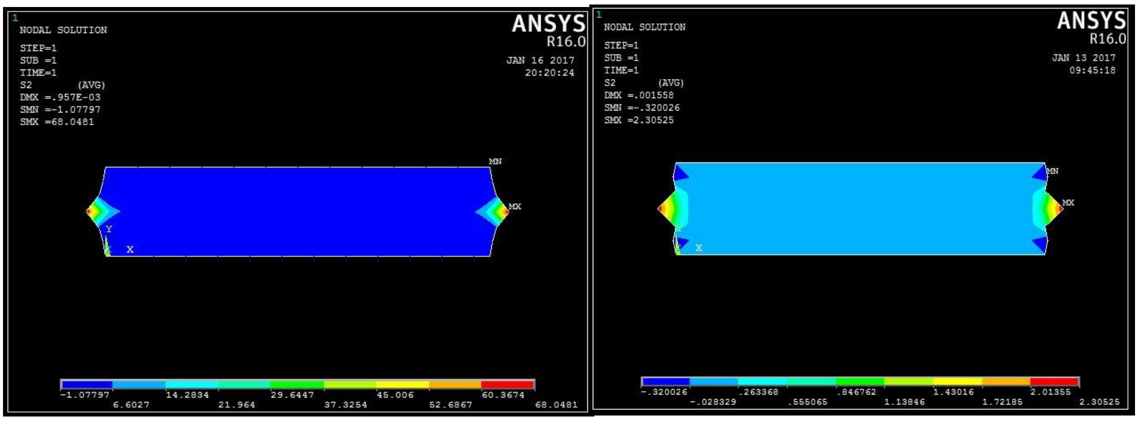

Fig 8. Second Principle Stress - Steel and Composite

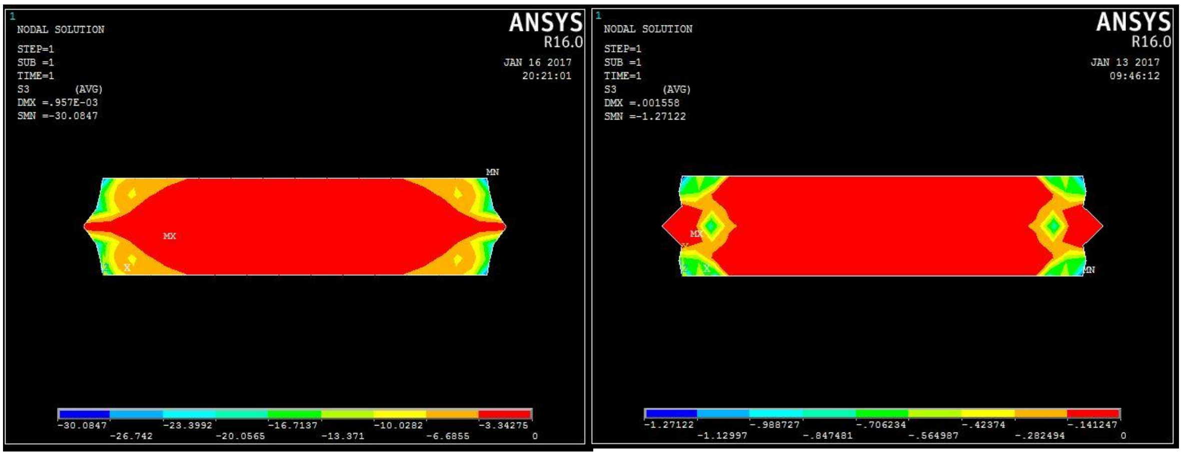

Fig 9. Third Principle Stress - Steel and Composite

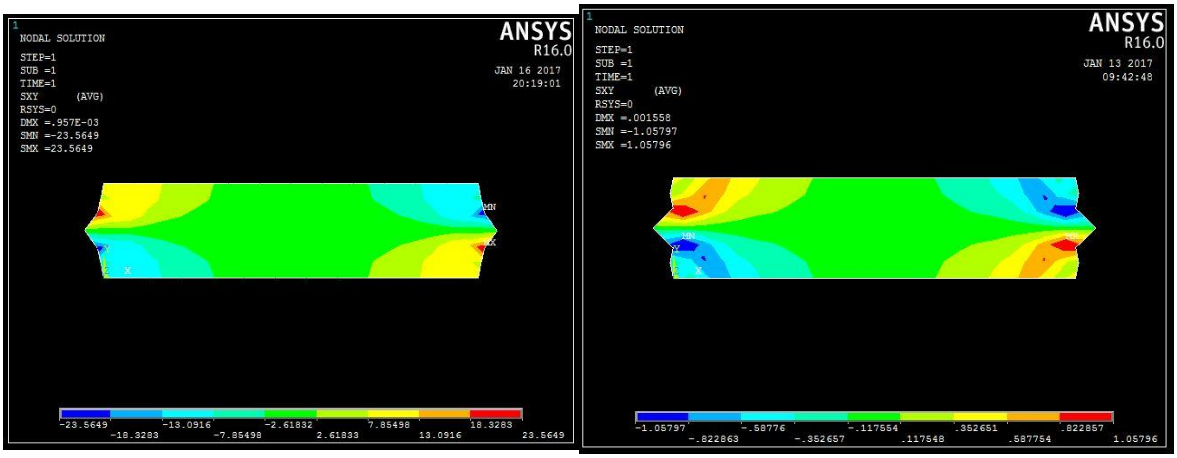

Fig 10. Shear Stress in XY plane - Steel and Composite

VI. DIRECTIONAL STRESSES AND VON-MISES STRESS

The von Mises yield criterion suggests that the yielding of materials begins when the second deviatoric stress invariant reaches a critical value. It is part of a plasticity theory that applies best to ductile materials, such as metals. Prior to yield, material response can be assumed to be anything i.e. nonlinear elastic, viscoelastic or simply linear elastic. In materials science and engineering the von Mises yield criterion can be also formulated in terms of the von Mises stress or equivalent tensile stress, a scalar stress value that can be computed from the Cauchy stress tensor. In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength. The von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress.

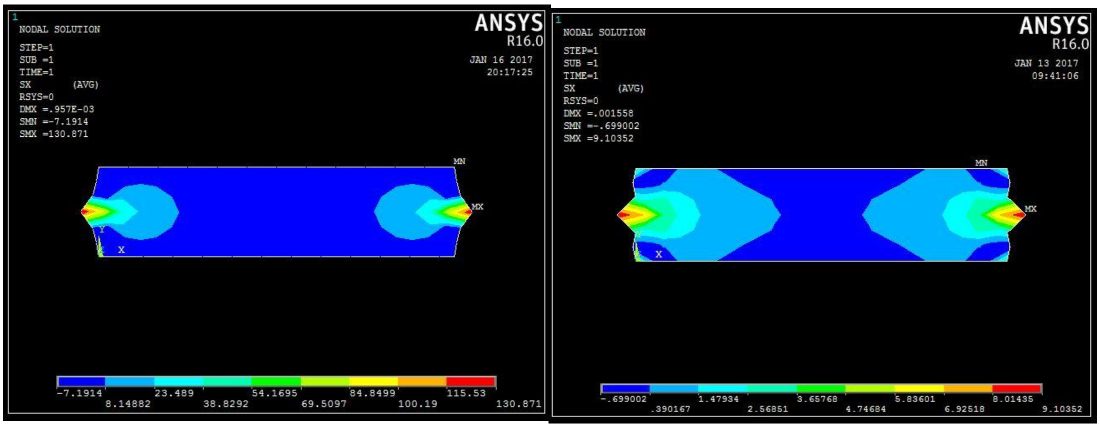

Fig 11. Stress in X direction - Steel and Composite

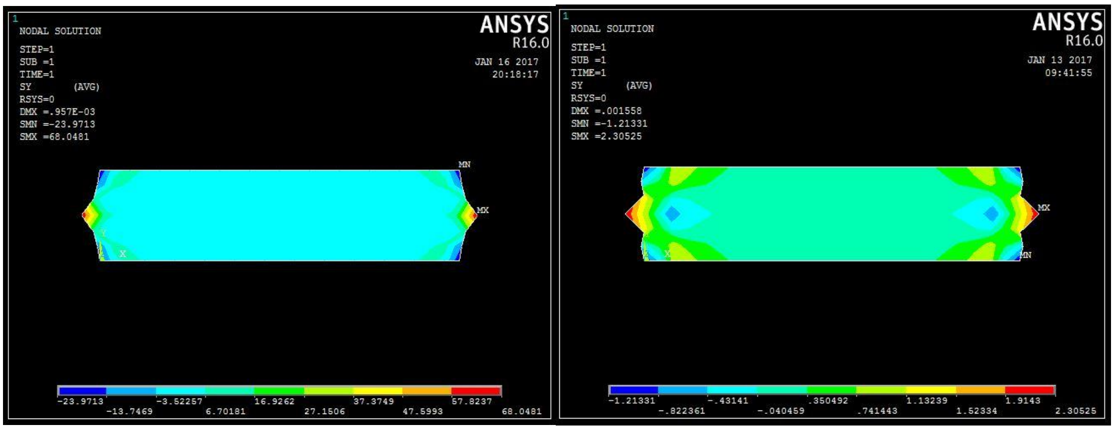

Fig 12. Stress in Y direction - Steel and Composite

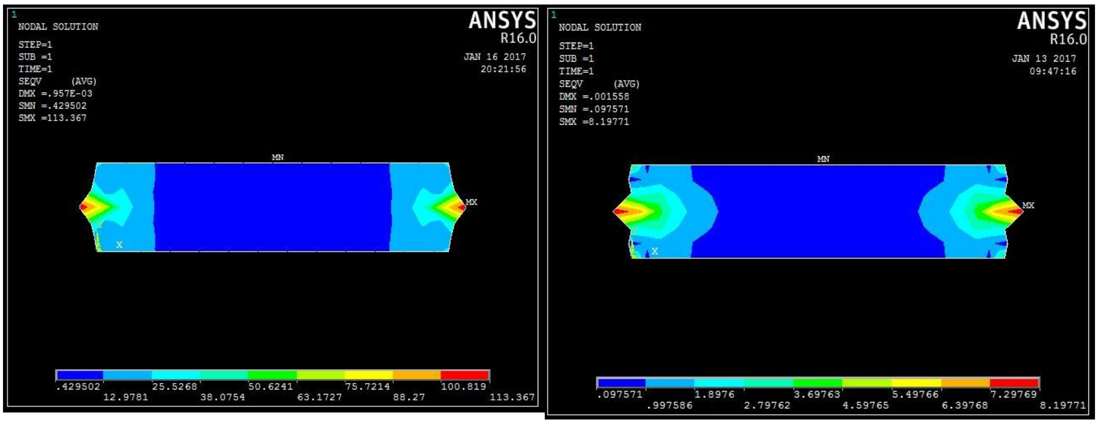

Fig 13. Von-Mises Stress - Steel and Composite

Figure 11, 12, 13 explains the comparison between directional stresses and Von-Mises stress values of steel and composite.

VII. RESULTS AND CONCLUSION

Table 1 Comparison of various parameters of steel and GFRP

Sl No.	Plot Type	Value-Steel	Value-GFRP	% increase
1	Deformation X-direction	0.957e-3	0.001558	0.998
2	Deformation Y direction	.114e-3	.231e-3	0.993
3	First principle Stress	130.871	9.10352	0.930
4	Second principle Stress	68.0481	2.30525	0.9661
5	Third principle Stress	-30.0847	-1.27122	0.957
6	Shear stress in XY plane	23.5649	1.05796	0.955
7	Stress in X-direction	130.871	9.10352	0.930
8	Stress in Y-direction	68.0481	2.30525	0.9661
9	Von- Mises Stress	113.367	8.19771	0.927

From the simulation of flat plate of steel and composite, various values of mechanical behavior parameters are tabulated below and the relative increase of parameter in composite is also found out. It is clear from the tables that an increase of almost 1% in relative percentage in properties of composites.

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