Term Project Report of Mechanics of Composites

Analysis of Unidirectional Composites

Submitted to

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Problem Statement

The project aims to understand some theoretical assumptions made during micro-mechanics of unidirectional continuous composites.

Consider a unidirectional continuous composites,

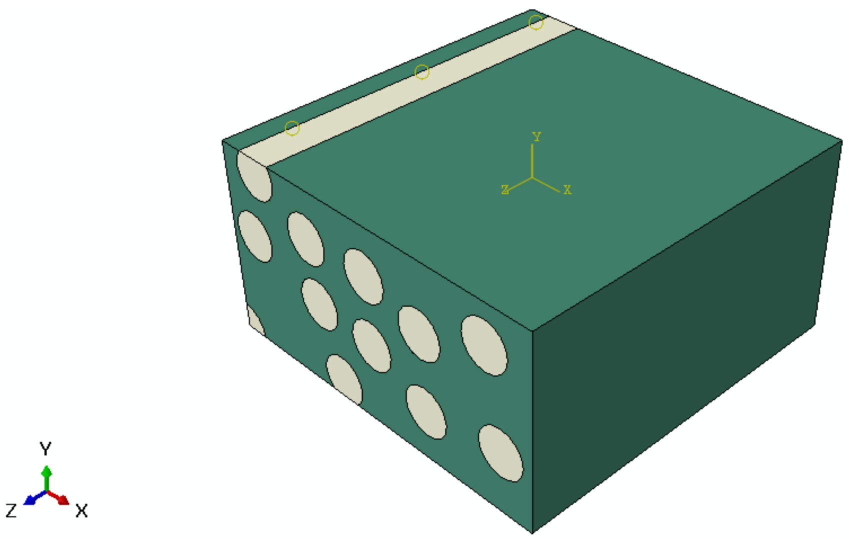

Figure 1: UD Composite model

The Young's Modules and Poisson's ratio for both fibre and matrix [Considering Isotropic] is provided.

1. To check the Iso-stress assumption, we will calculate Young's modules theoretical and compare with FEA results.
2. To check the Iso-strain assumption, we will calculate Young's modules theoretical and compare with FEA results.
3. We calculated G_{13} by applying shear at surface and compared with theoretical.
4. For specific volume fraction and Young's modules ratio of fibre and matrix, we have verified FEA result to Adams graph for stress concentration.
5. For specific volume fraction and Young's modules ratio of fibre and matrix, we have verified FEA result to Skudra chart for stress concentration .

Model Development

We have used ABAQUS 2021 [Institute Licenced].

The development of a model involves several steps listed below,

6. **Part creation**

   We have taken the dimension of cuboid 150x80x150 mm, after considering the volume fraction as 0.3 , we have calculated the number of fibre as rounded off to 12 and its diameter as 20mm.

$$N = \frac{4 * l * B * vf}{\pi d^2}$$

$$N = 11.45 \approx 12$$

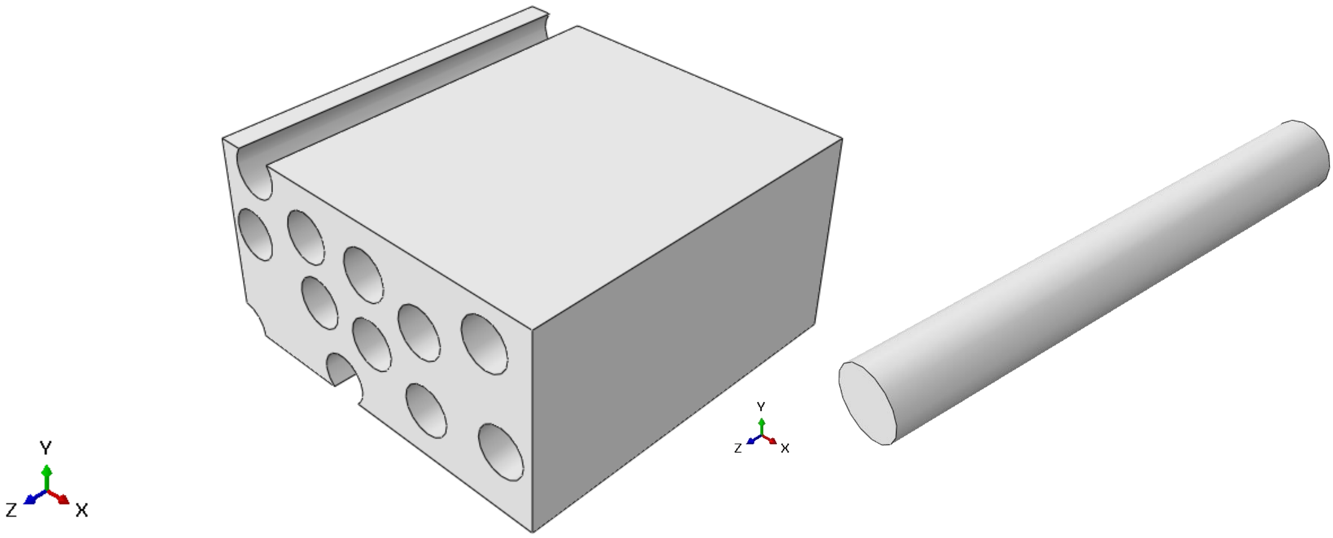

Figure 2- Matrix and Fibre

7. **Property Assignment**

   We first define the property and then assign it to the respective part.

	Young's Modules (MPa)	Poisson's ratio
Fibre	72000	0.22
Matrix	3000	0.4

8. **Assembly and Interactions**

We have created the instances for matrix and fibre in respective positions and we have constrained the fibre and matrix with the option 'Tie'.

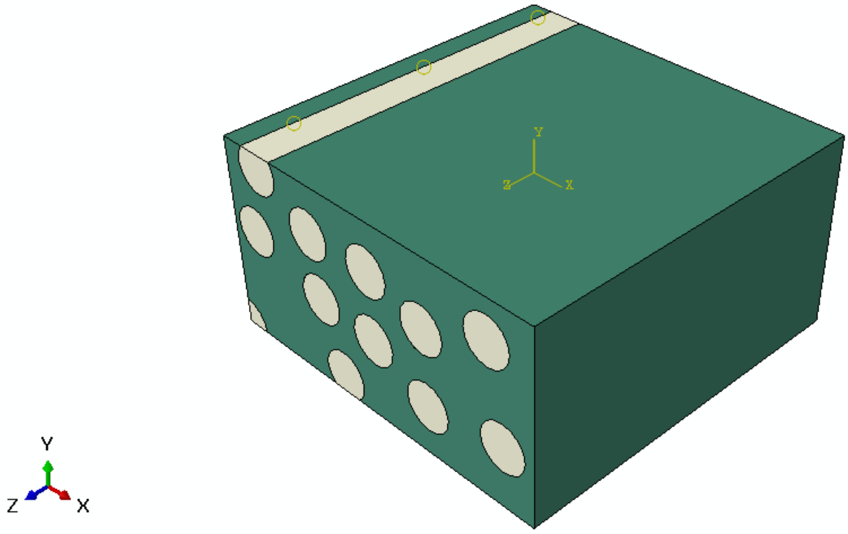

Figure 3 – Assemble of fibre and matrix

9. Meshing of Assembly

Seed size – 5

Total elements (fibre + matrix) – 369981

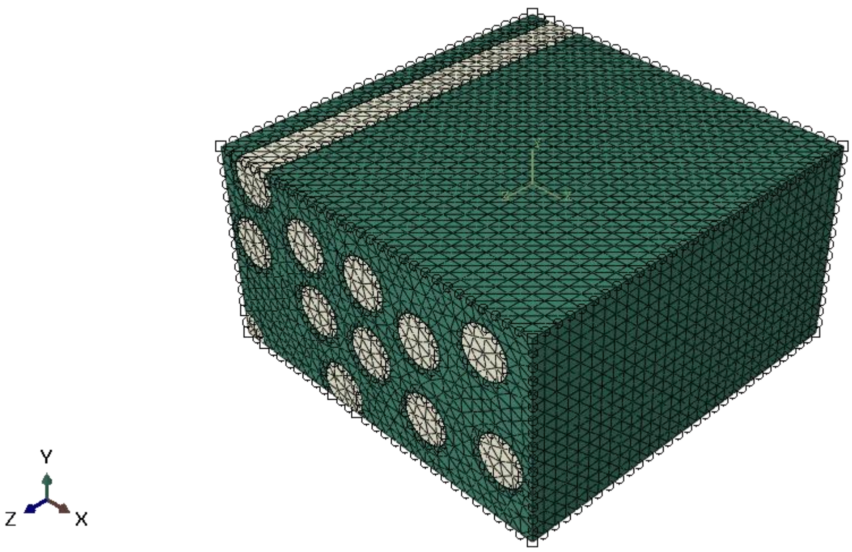

Figure 4 – Meshed Assembly

10.Load module

Loading the assembly depends upon the type of analysis.

Note: - In the Case 1 , Case 2 and Case 3 the meshing model is the same as shown above and in the last two cases it is displayed separately.

Case 1: Iso-stress

- Analysis of Iso-stress along x- axis

  Load is applied perpendicular to fibre length

  The bottom surface of cuboid along y-axis is fixed.

  The top surface of the cuboid was given loaded by pressure of 15MPa.

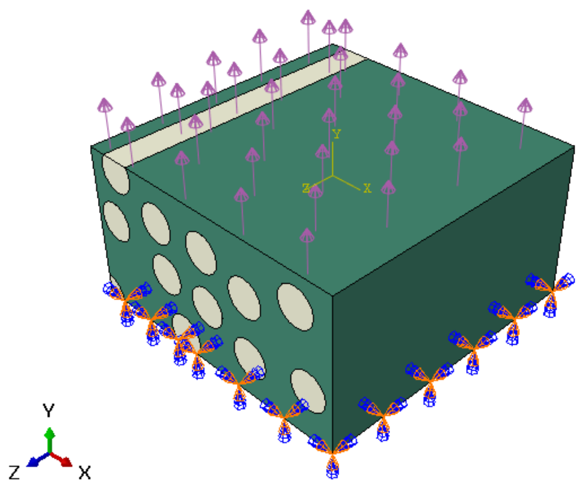

Figure 5 – Composite Loaded in YY direction

Theoretical Calculation

$E_F = 7200\ MPa$

$E_m = 3000 MPa$

$V_f = 0.3$

$$\frac{1}{E_c} = \frac{V_f}{E_f} + \frac{1-V_f}{E_m}$$

$E_c = 4210\ MPa$

FEA results

- We have exported the stress and strain of each element and took the average to find average stress and strain.
- Since the load is along Y direction, we have taken Average stress and strain along Y direction i.e., S_{22}, e_{22} .
- For Young's modules along Y direction, we have taken Average stress divided by Average strain.
- U_2 , e_{22} , S_{22} distribution is shown below

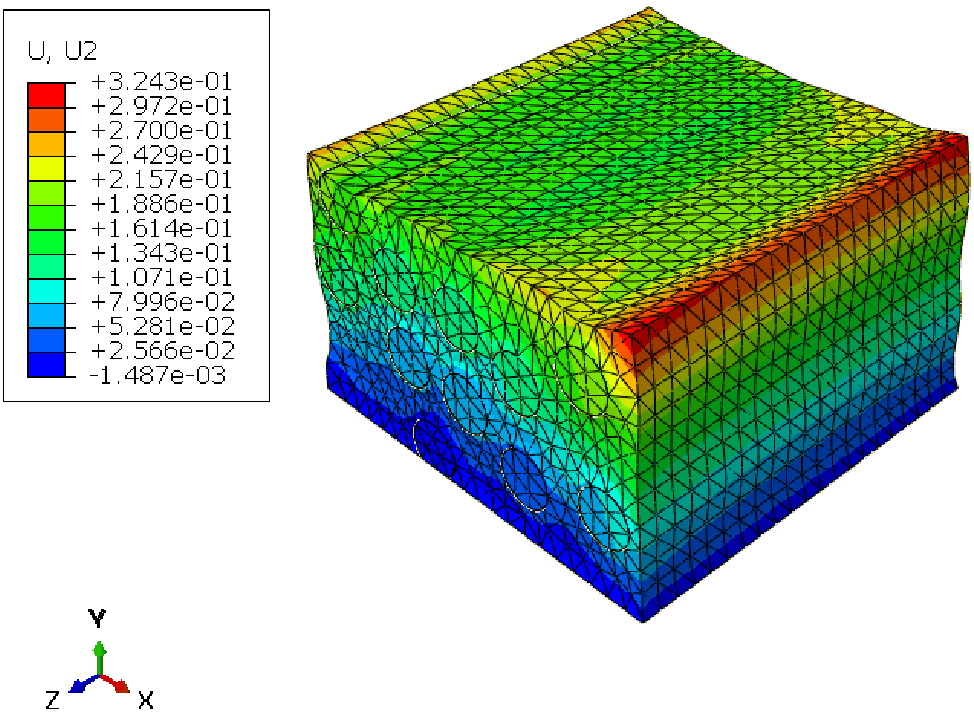

Figure 6 - U_2 $distribution$

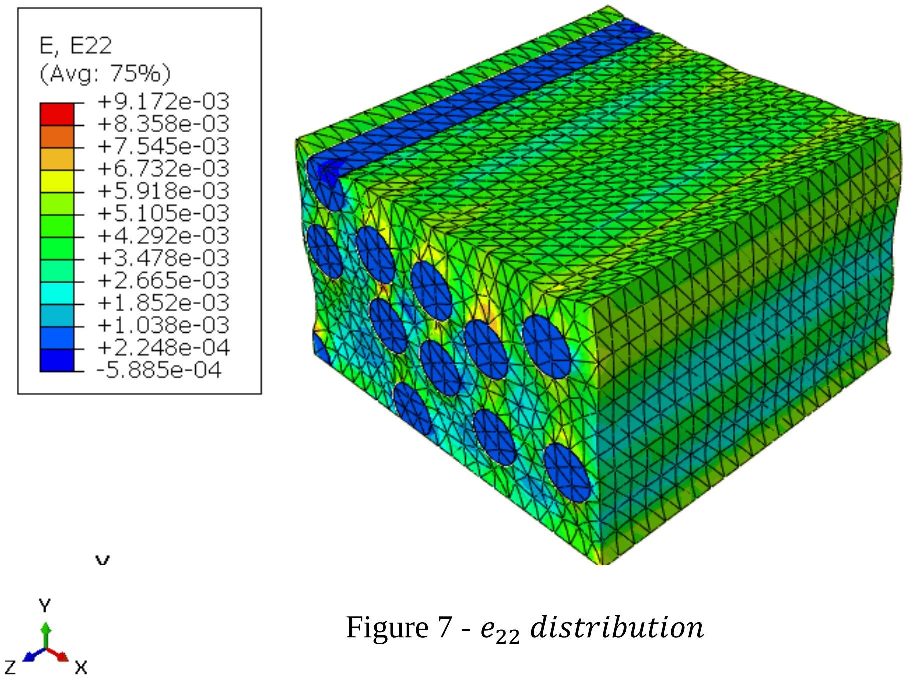

Figure 7 - e_{22} *distribution*

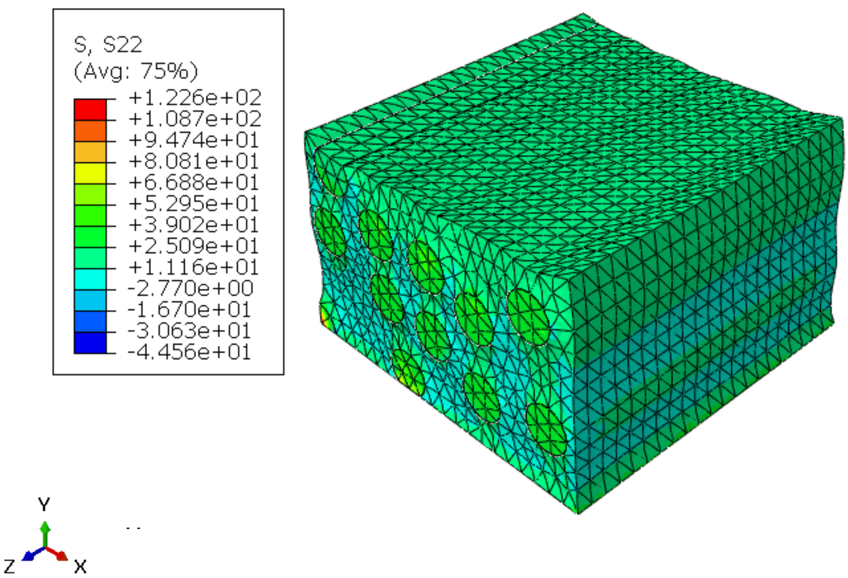

Figure 8 - S_{22} *distribution*

- From the data sheet

  Average stress = 12.9150 MPa

  Average strain = $2.51 * 10^{-3}$

  Young's Modules = $5.14*10^{3}$ Mpa

	Theoretical (GPa)	FEA result (GPa)
Young's Modules	4.21	5.14

- Analysis of Iso-stress along x- axis

  Load is applied perpendicular to fibre length

  The backward surface of cuboid along x-axis is fixed.

  The front surface of the cuboid was given loaded by pressure of 15MPa.

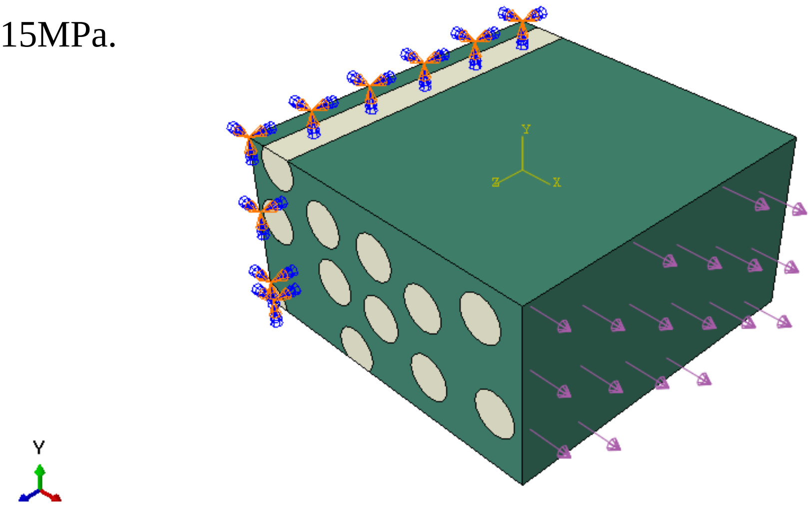

Figure 9 – Composite Loaded in XX direction

Theoretical Calculation

$E_F = 7200\ MPa$

$E_m = 3000MPa$

$V_f = 0.3$

$\frac{1}{E_c} = \frac{V_f}{E_f} + \frac{1-V_f}{E_m}$

$E_c = 4210\ MPa$

FEA results

- Similar to the previous analysis since the load is along X direction, we have taken Average stress and strain along X direction i.e., S_{11}, e_{11} and finding the Young's Modules.
- U_1 , e_{11} , S_{11} distribution is shown below

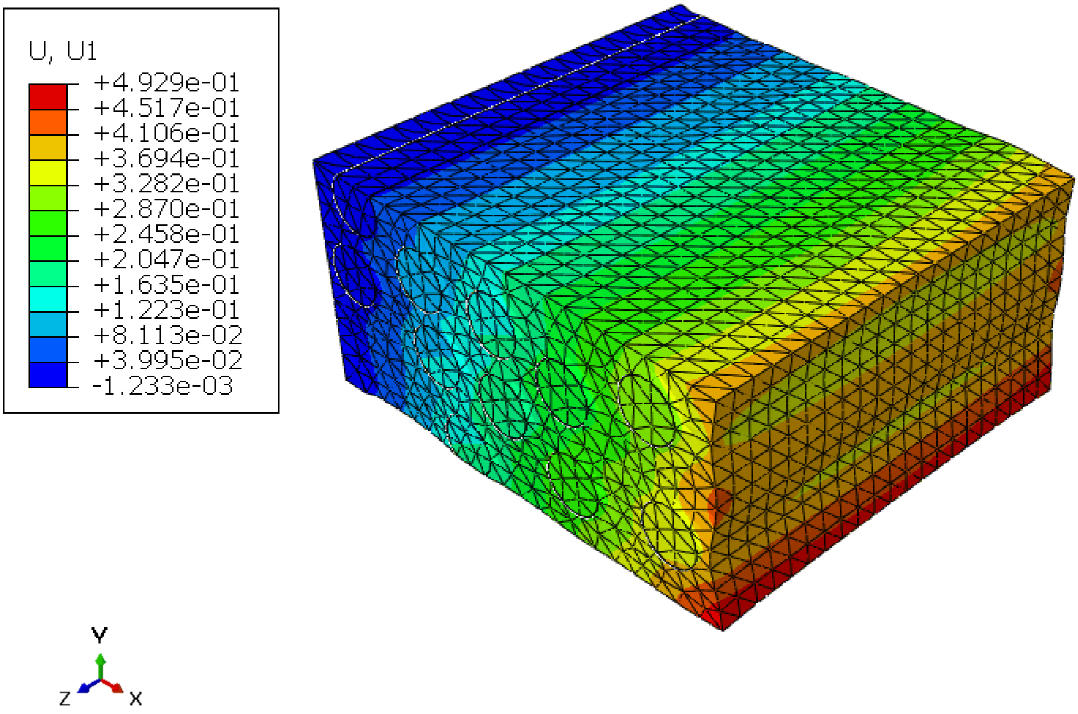

Figure 10 - U_1 *distribution*

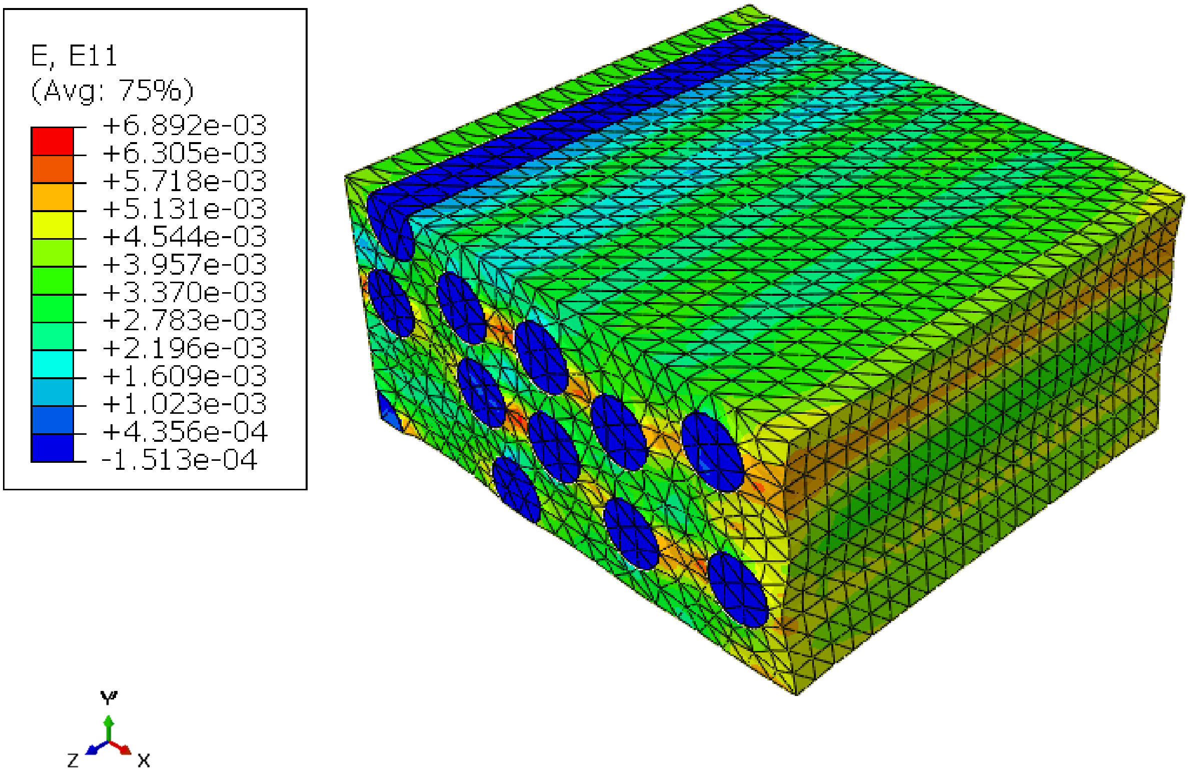

Figure 11 - e_{11} *distribution*

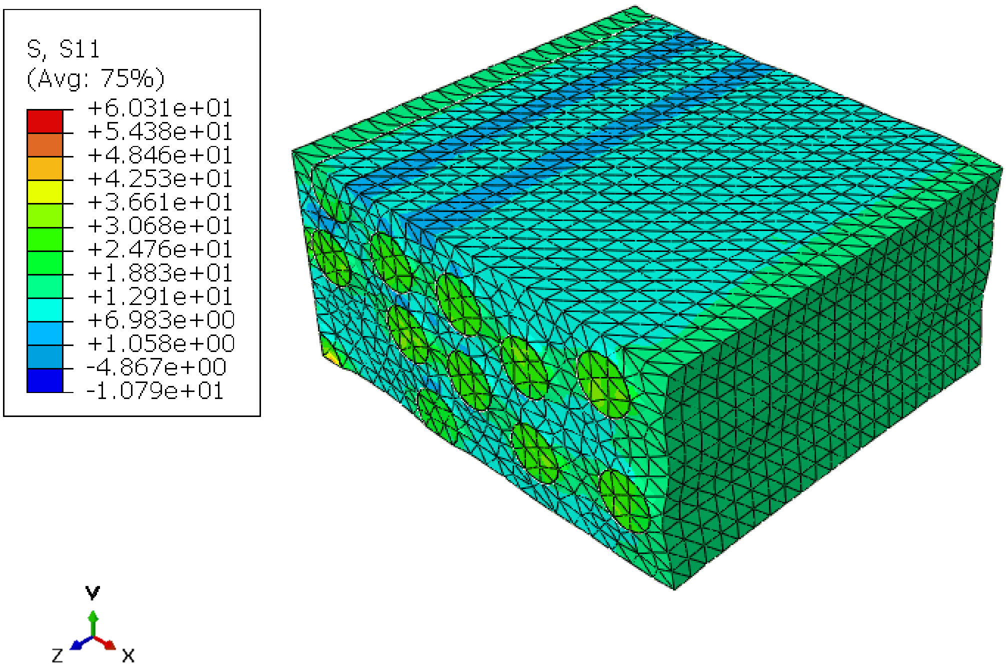

Figure 12 - S_{11} *distribution*

- From the data sheet

  Average stress = 15.02 MPa

  Average strain = 2.67* 10^{-3}

  Young's Modules = 5.63*10^3 MPa

	Theoretical (GPa)	FEA result (GPa)
Young's Modules	4.21	5.63

Conclusion:

Young's modules valve of FE analysis appears to be closer to theoretical valve in both x and y directions with some variation.

Case 2 – Iso-strain

Analysis of Iso-stress along x- axis

Load is applied parallel to fibre

The backward surface of cuboid along z-axis is fixed.

The front surface of cuboid is loaded with 15 MPa pressure.

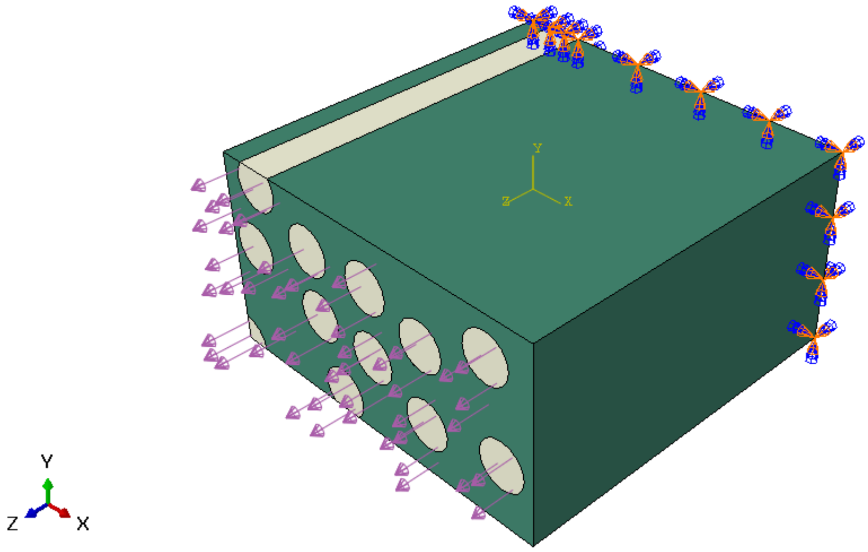

Figure 13 – Composite Loaded in Z direction

Theoretical Calculation

$E_F = 7200\ MPa$

$E_m = 3000MPa$

$V_f = 0.3$

$E_c = E_f V_f + (1 - V_f) E_m$

$E_c = 23.7 * 10^3\ MPa$

FEA results

- Similar to the previous analysis since the load is along X direction, we have taken Average stress and strain along X direction i.e., S_{11}, e_{11} and finding the Young's Modules.
- U_3 , e_{33} , S_{33} distribution is shown below

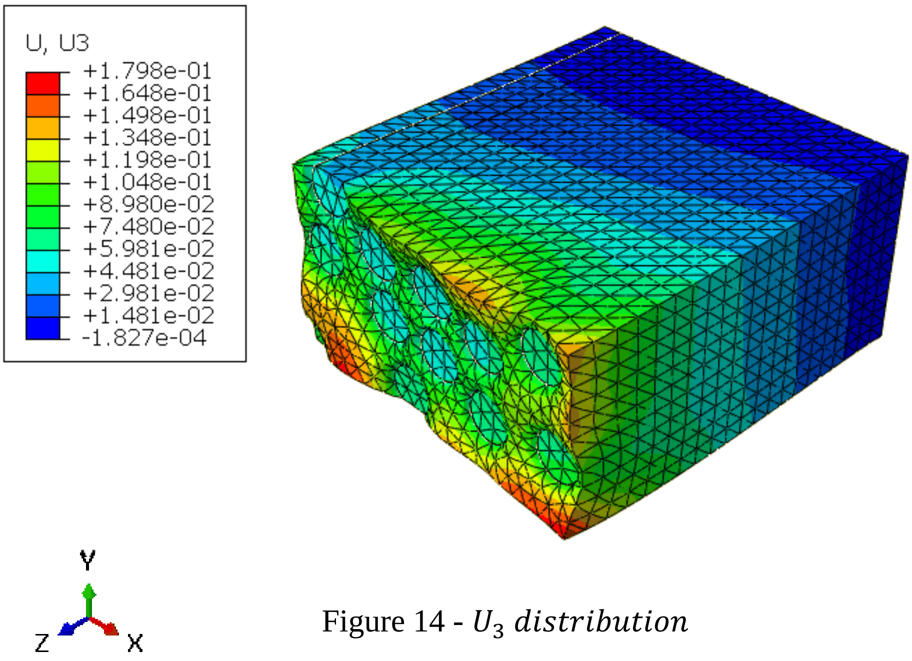

Figure 14 - U_3 *distribution*

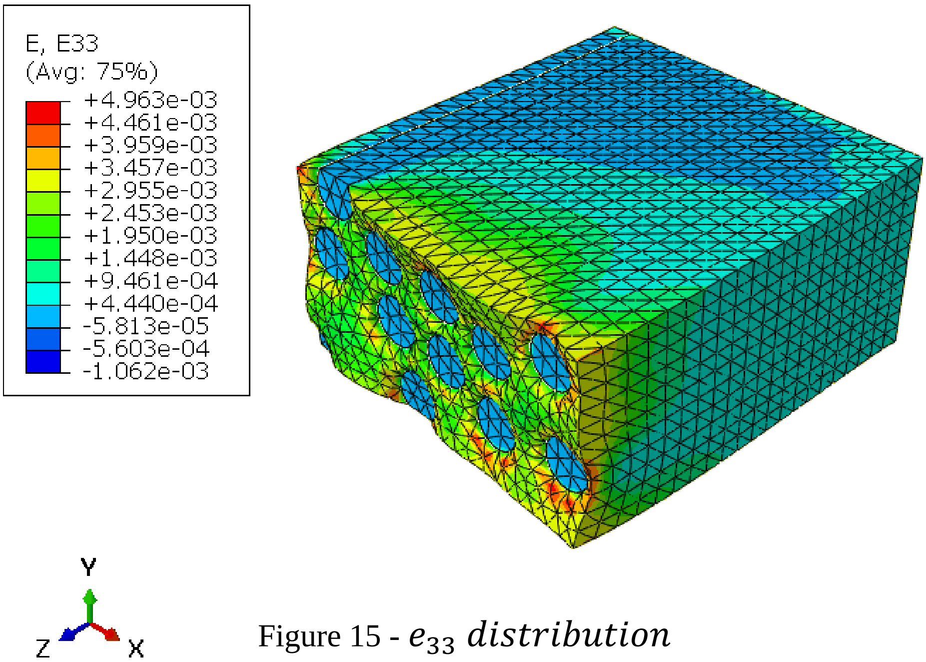

Figure 15 - e_{33} *distribution*

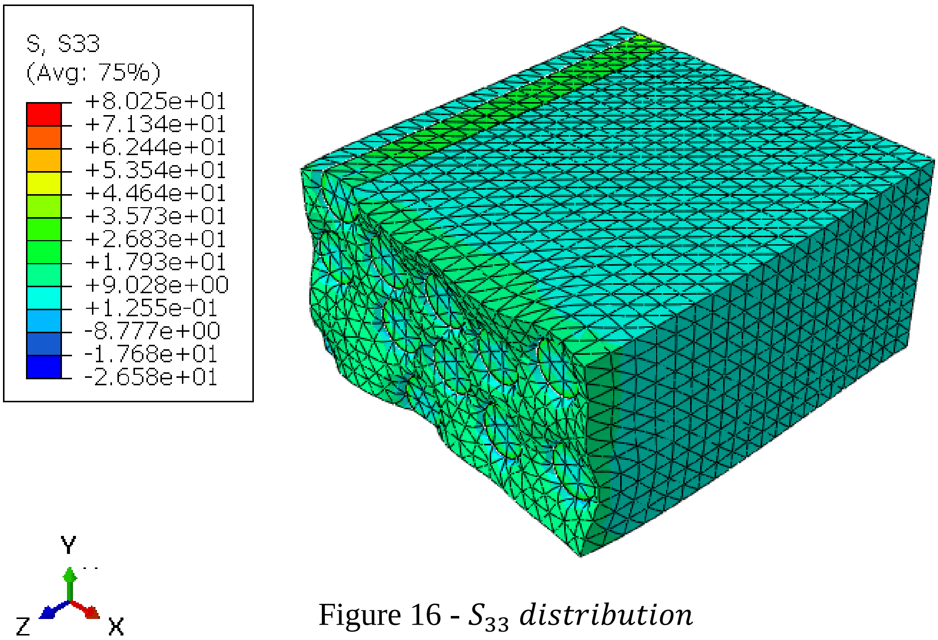

Figure 16 - S_{33} *distribution*

- From the data sheet

  Average stress along z = 10.22 MPa

  Average strain along z = 6.11* 10^{-4}

  Average strain along x = -1.96* 10^{-4}

Young's Modules = 16.7 *10^3 MPa

	Theoretical	FEA results
Young's Modules	$23.7\ GPa$	$16.7\ GPa$
Poisson's ratio	0.346	0.32

Conclusion:

Young's modules valve of our FE analysis along z direction appears to have an error nearly 26%.

The Poisson ratio value in the FE analysis seems to be closer to that of the theoretical valve.

Case 3: calculating G_{13} by applying shear at surface

Load is applied on front x plane and in z direction as shown.

Traction load of 15MPa is applied on x plane and z direction .

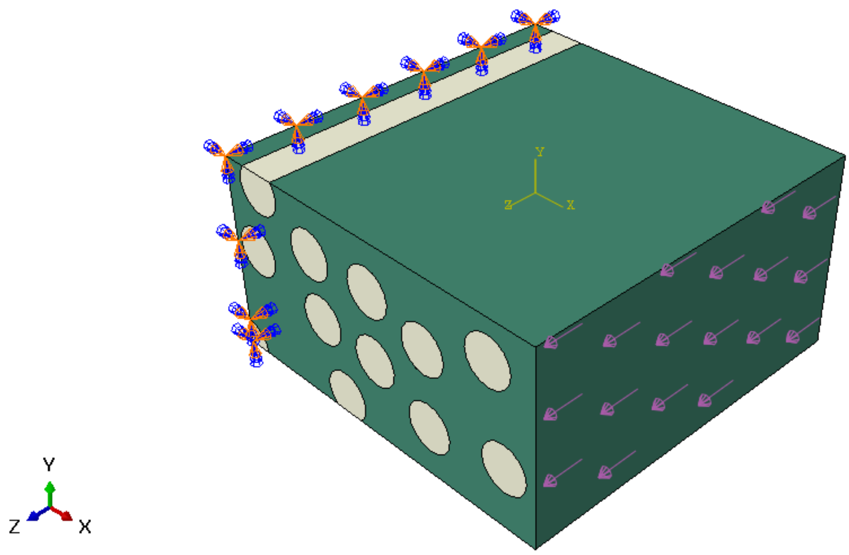

Figure 17 – Composite shear Loaded

Theoretical Calculation

$G_F = 29508.19\ MPa$

$E_m = 1071.4\ MPa$

$V_f = 0.3$

$$\frac{1}{G_c} = \frac{V_f}{G_f} + \frac{1-V_f}{G_m}$$

$G_c = 1507.12\ MPa$

FEA results

- Similarly, we export the valve of e_{13} , S_{13} to excel sheet and take average of each and finding the G_{13} .
- U_3, e_{13} , S_{13} distribution is shown below.

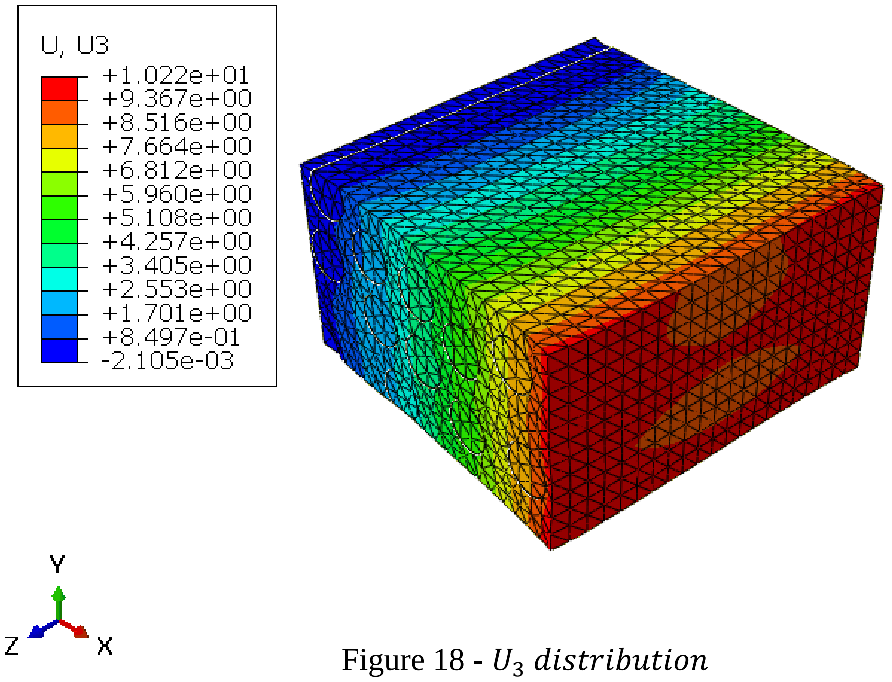

Figure 18 - U_3 *distribution*

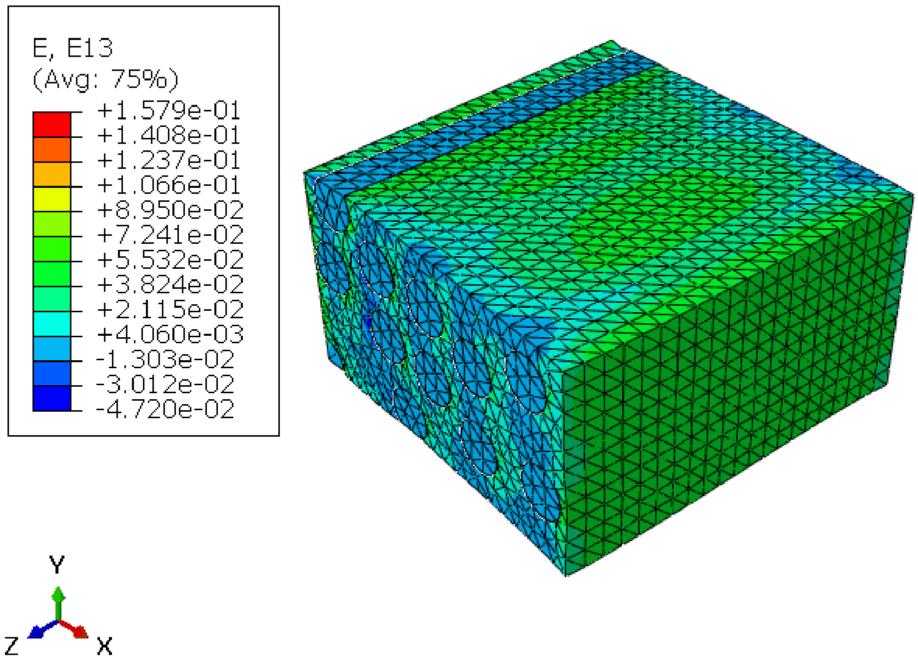

Figure 19 - e_{13} *distribution*

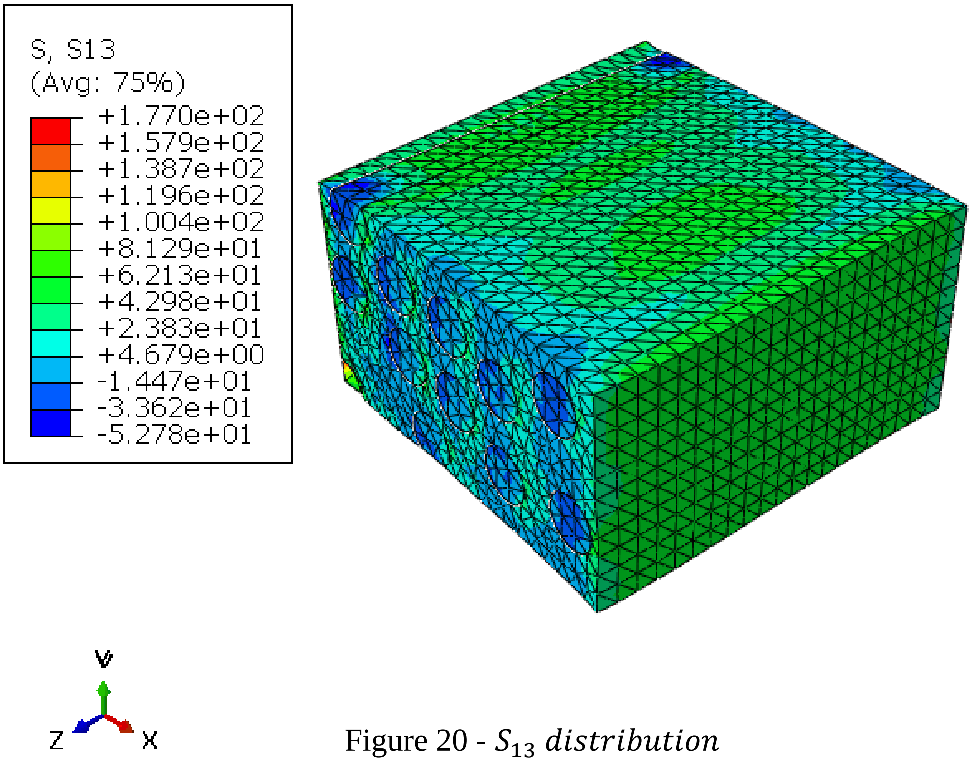

Figure 20 - S_{13} *distribution*

- From the data sheet

  Average S_{13} = 48.90 MPa

  Average e_{13} = $2.73 * 10^{-2}$

  G_{13} = $1.79 * 10^{3}$ MPa

	Theoretical (GPa)	FEA result (GPa)
Shear Modules (G_{13})	1.50	1.79

Conclusion:

Our FE analysis valve of shear's modules appears to be closer to the theoretical valve .

Case 4 – Stress concentration prediction by Adams.

- We have created model that is appropriate for calculation for Adams method and Meshed with Seed size 3 and number of elements 54694, as shown below.
- We have changed the volume fraction to 0.4 calculated the diameter, Also properties of fibre and matrix is changed to get ratio of Young's Modules as Whole number [for easier estimation from chart] .

	Young's Modules (MPa)	Poisson's ratio
Fibre	80000	0.22
Matrix	1333.3	0.4

- The Assembly is Loaded with pressure of 10 MPa on both side in x-direction.

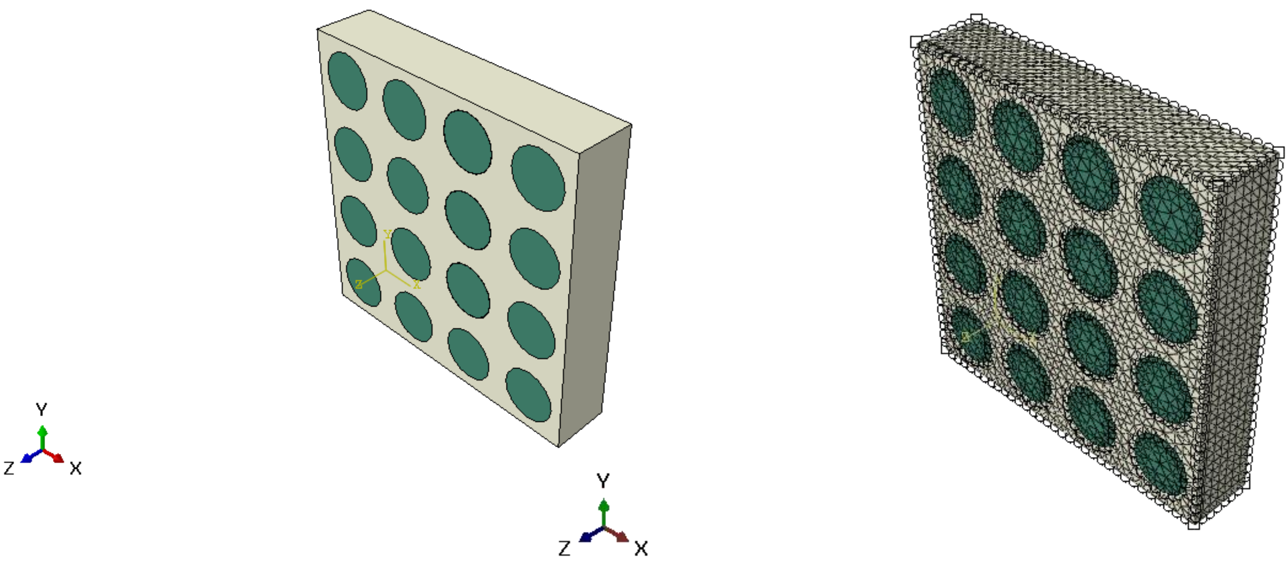

Figure 21: Assembly for Adams Stress concentration prediction

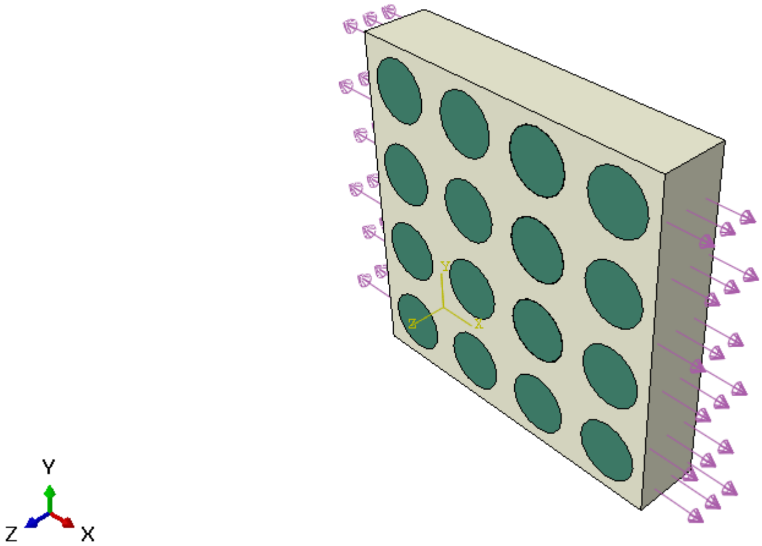

Figure 22: Loaded assembly

FEA result and Adams chart comparison

- The distribution of S_{11} is shown below
- For Stress concentration, we take the stress value near the interface [in matrix] or just outside the fibre, on matrix we take the value.

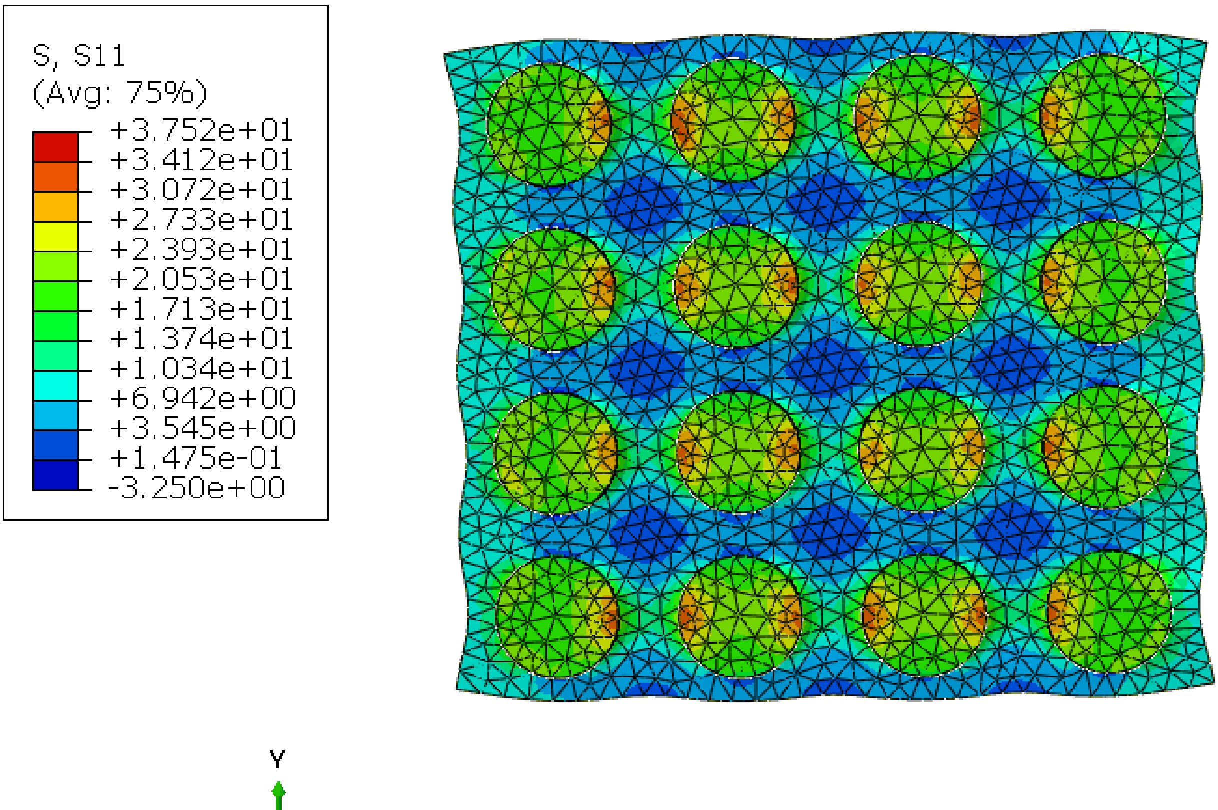

Figure 23 - S_{11} *distribution*

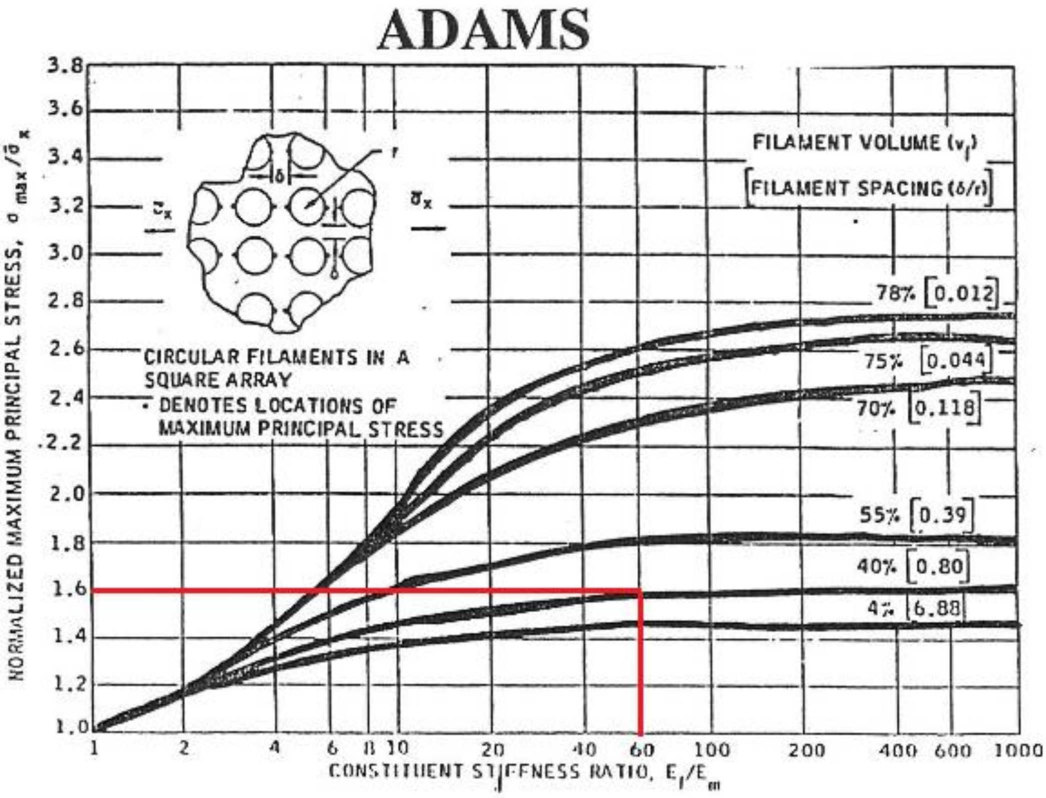

Figure 25: Adams Chart

- From the Adams chart , we find that stress concentration factor

$$K_c = 1.6$$

- From the FE analysis,

  The stress the interface – 17.13 Mpa and 13.74 Mpa

  Taking average - $\frac{17.13+13.74}{2}$ = 15.435 Mpa.

$$K_c = \frac{Stress\ at\ interface}{stress\ applied} = \frac{15.435}{10} = 1.5435$$

Conclusion

The Adams prediction of stress concentration is accurate for specific geometry, it may vary if the geometry changes.

Case 5 – Stress concentration prediction by Skudra.

- We have created model that is appropriate for calculation for Skudra method and Meshed with Seed size 3 and number of elements 54694, as shown below.
- We have changed the volume fraction to 0.4 calculated the diameter, Also properties of fibre and matrix is changed [to same as Adams analysis] .
- The Assembly is Loaded with pressure of 10 MPa on both side in x-direction.

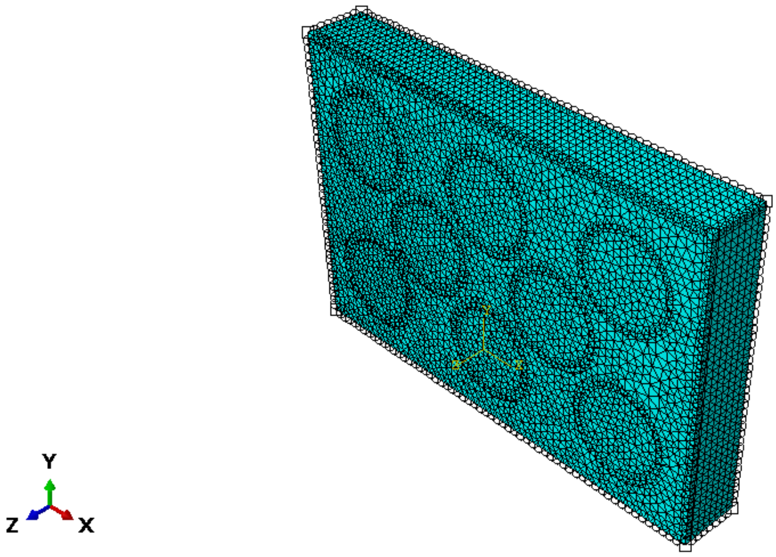

Figure 26: Meshed assembly for Skudra Stress concentration prediction

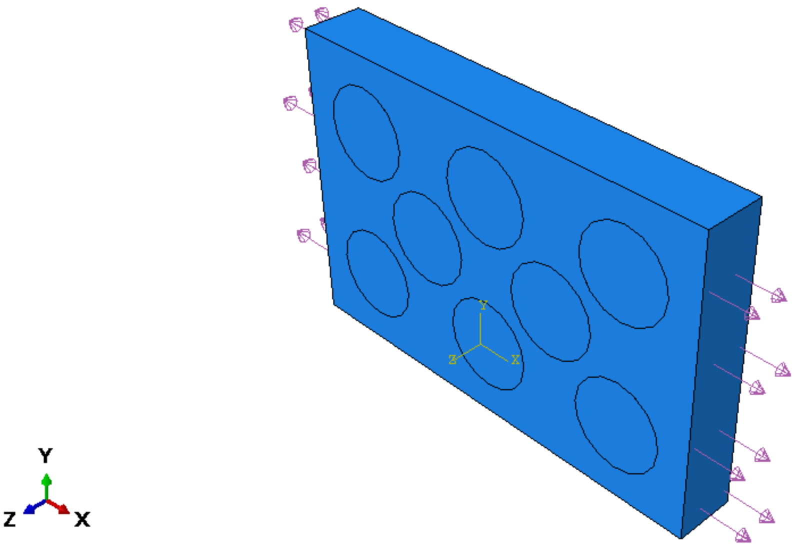

Figure : Loaded assembly

FEA result and Skudra chart comparison

- The distribution of S_{11} is shown below
- For Stress concentration, we take the stress value near the interface [in matrix] or just outside the fibre, on matrix we take the value.

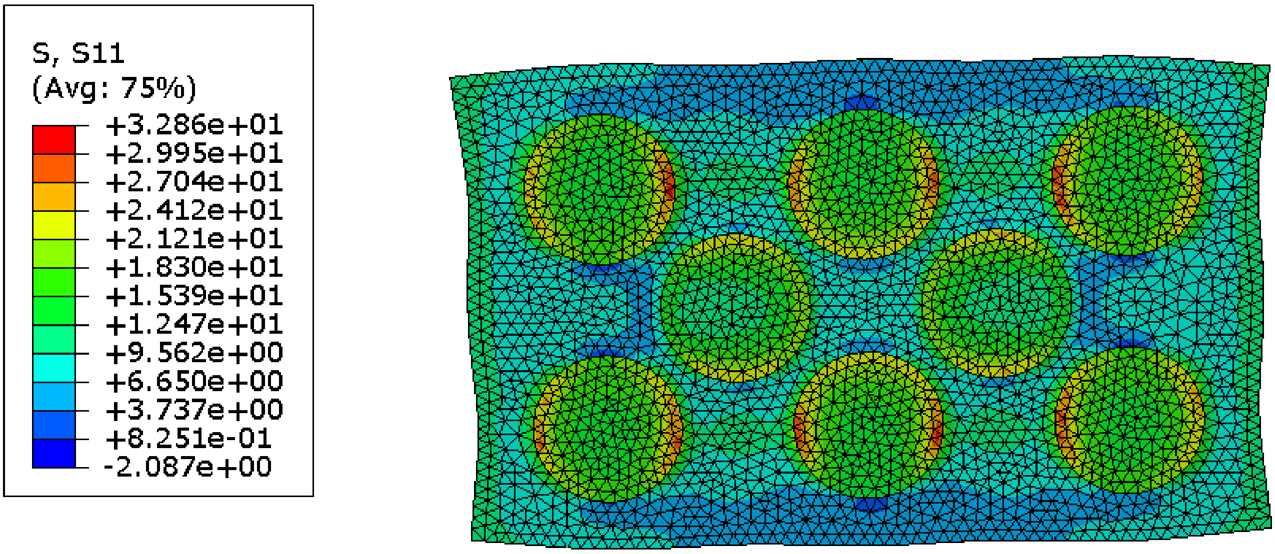

Figure 27 - S_{11} *distribution*

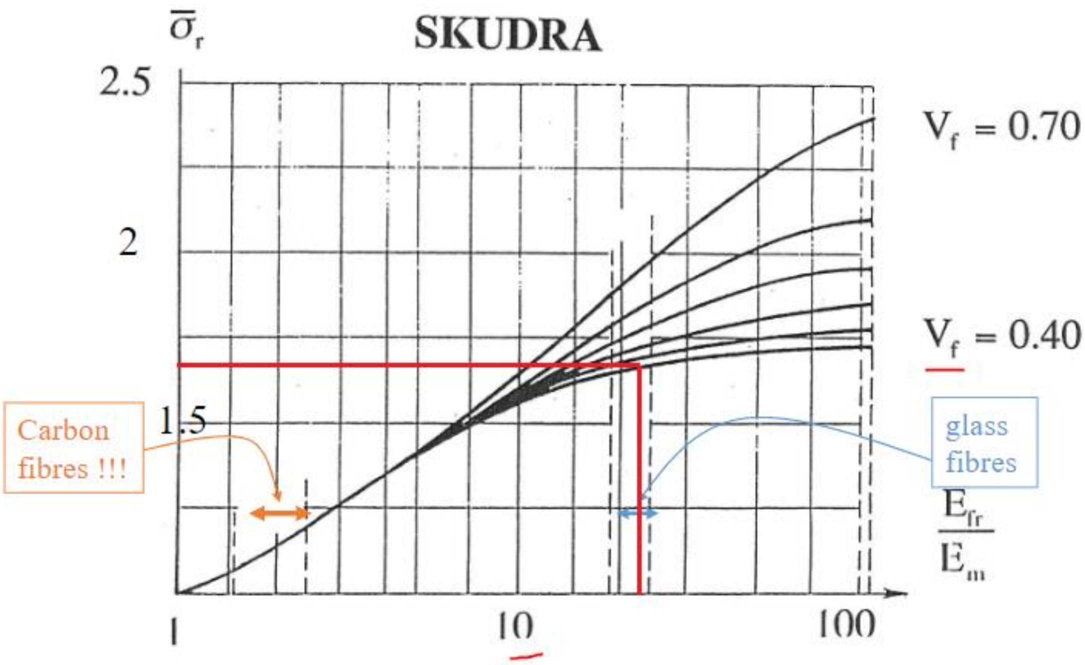

Figure 28: Skudra Chart

- From the Skudra chart , we approximately find that stress concentration factor

$$K_c = 1.65$$

- From the FE analysis,

  The stress the interface – 15.39 Mpa and 18.30 Mpa

  Taking average - $\frac{15.39+18.30}{2}$ = 16.845 Mpa.

$$K_c = \frac{Stress\ at\ interface}{stress\ applied} = \frac{16.845}{10} = 1.684$$

Conclusion

The Skudra prediction of stress concentration is nearer to FE value.