ZEUSNUMERIX

FRP Property Calculator

USER MANUAL

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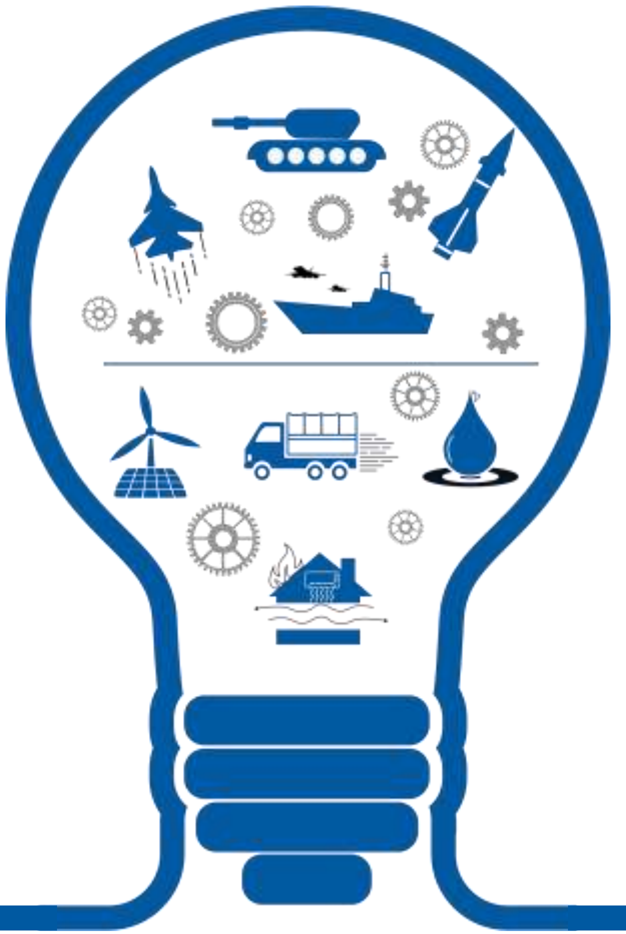


Contents

Introduction

- FRP Property Calculator is useful tool for preliminary estimation of mechanical properties of composite laminates.
- In this tool, User needs to input fiber and resin physical properties in provided format. For different type of fiber mats , user can input material properties and no. of layers.
- Code takes input file and extracts data from it. Input data is used to solve the equations to obtain equivalent mechanical properties for the laminate.
- Various parameters like equivalent elastic constants , allowable loadings and equivalent physical properties are obtained as results.

APP Usage guide

INPUTS:

- Download Sample input file
- Edit it as per requirements
- Upload to input file to App webpage

EXECUTION:

- Run the App by hitting Run button
- App will perform the background calculations as described later in this manual

OUTPUT:

- After execution , output will be shown on the screen.
- To download output file, hit the Download Button

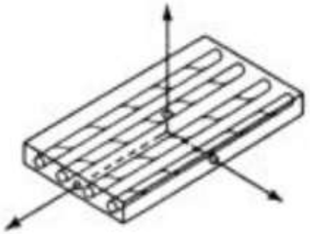
Abbreviations

Following abbreviation are used in Input and Output files:

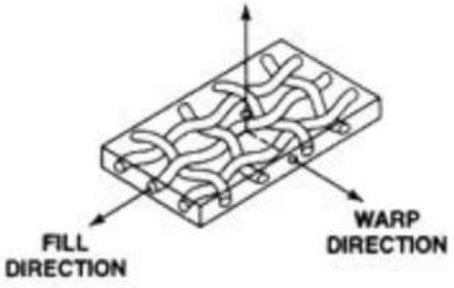
- E11 – Tensile Modulus/Strength in 1-1 direction i.e. fiber direction
- E22 – Tensile Modulus/Strength in 2-2 direction i.e. transverse direction
- E33 – Tensile Modulus/Strength in 3-3 direction i.e. out of plane direction
- G12 – In-plane Shear Modulus
- G23 – out of plane Shear Modulus
- G33 – Inter-laminar Shear Modulus

Composite Fibers and Laminate

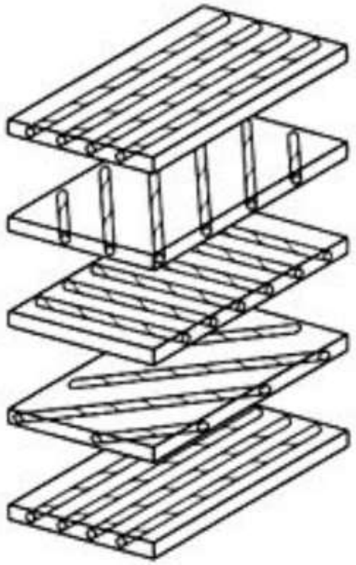
- **Composite Lamina = Fibers + Matrix**
- Matrix or Resin is a bonding material e.g. Epoxy , Phenolic.
- Fibers or Fillers are reinforcing members e.g. Glass, Carbon.



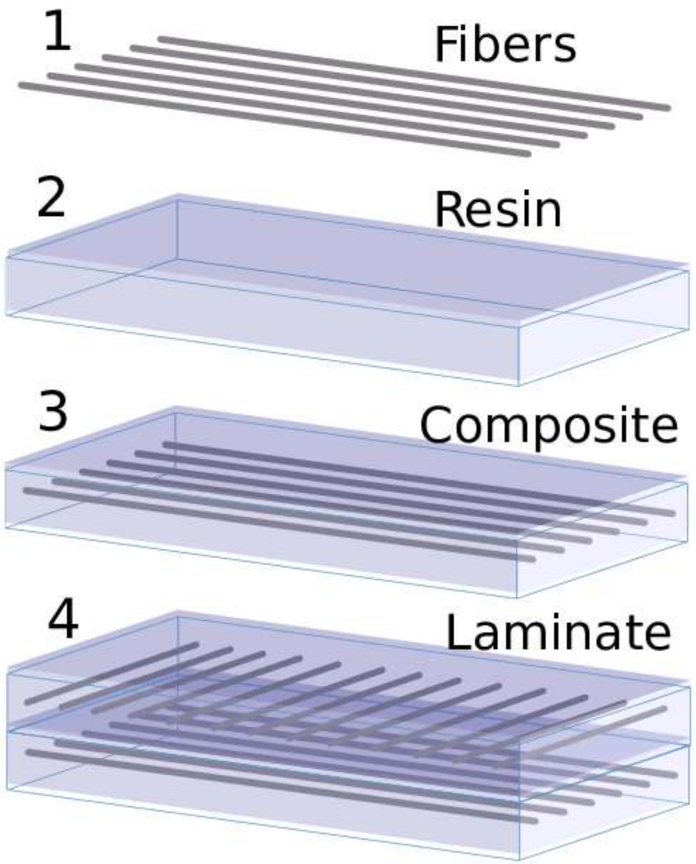
LAMINA WITH
UNIDIRECTIONAL FIBERS



LAMINA WITH
WOVEN FIBERS

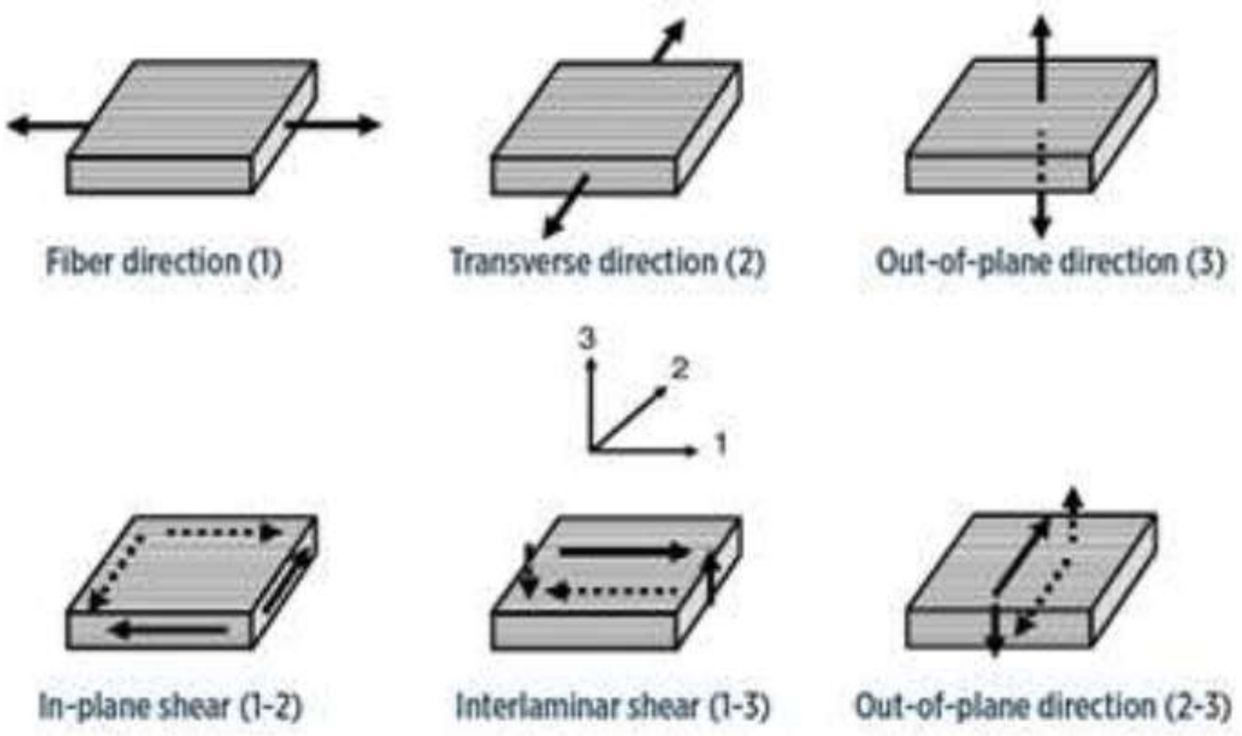


Unbonded View of Laminate Construction



Composite Fibers and Laminate

- The following figure shows the sign conventions used to analyze and understand physical significance of the results obtained from the code.



Input file Information

Input file needs following data: SI unit system is used

- Select Layup process with identifier as shown below

  "Select Hand Layup(0)/Pultrusion(1) Process" : 0

- Fiber Properties are requested as follows

  "Young's Modulus of the Fiber MPa" : 77500

  "Poisson's Ratio for Fiber" : 0.22

  "Specific Gravity of the Fiber" : 2.68

- Chopped Strand Mat Properties as follows

  "Number of CSM Layers in Laminate" : 1,

  "Fiber Content by Percent Mass in CSM" : 35,

Input file Information

"Surface Mass Density of CSM Mat kg/sq.m" : 0.45,

"Tensile Unit Modulus for CSM N/mm per kg/sq.m" : 14000,

"Ultimate Tensile Unit Strength for CSM N/mm per kg/sq.m" : 200,

- Woven Roving data is requested as follows:

"Number of WR Layers in Laminate" : 0,

"Fiber Content by Percent Mass in WR" : 50,

"Surface Mass Density of WR Mat kg/sq.m" : 0.6,

"Tensile Unit Modulus for Bidirectional WR N/mm per kg/sq.m" : 16000,

"Ultimate Tensile Unit Strength for Bidrectional WR N/mm per kg/sq.m" : 250,

Input file Information

- Unidirectional Woven Roving data is as follows:

  "Number of Unidirection WR Layers in 1-1 direction" : 0,

  "Number of Unidirection WR Layers in 2-2 direction" : 0,

  "Fiber Content by Percent Mass in Unidirection WR" : 75,

  "Surface Mass Density of Unidirectional WR Mat kg/sq.m" : 0.6,

  "Tensile Unit Modulus for Unidirectional along the Length WR N/mm per kg/sq.m" : 28000,

  "Ultimate Tensile Unit Strength for Unidirectional along the Length WR N/mm per kg/sq.m" : 500,

  "Ultimate Tensile Unit Strength for Unidirectional WR Normal to the Fibers N/mm per kg/sq.m" : 60,

Input file Information

"Tensile Unit Modulus for Unidirectional WR Normal to the Fibers N/mm per kg/sq.m" : 4000,

- 45 deg Woven Roving data :

  "Number of +/-45deg WR mat Layers in Laminate" : 0,

  "Fiber Content by Percent Mass in +/-45deg mat" : 40,

  "Surface Mass Density of +/-45deg Mat kg/sq.m" : 0.3,

  "Tensile Unit Modulus for +/-45deg Mat along the Fibers N/mm per kg/sq.m" : 28000,

  "Ultimate Tensile Unit Strength for +/-45deg Mat along the Fibers N/mm per kg/sq.m" : 28000,

Input file Information

"Ultimate Tensile Unit Strength for +/-45deg Mat Normal to the Fibers N/mm per kg/sq.m" : 60,

"Tensile Unit Modulus for +/-45deg Mat Normal to the Fibers N/mm per kg/sq.m" : 4000,

- Resin /Matrix properties are as follows

"Young's Modulus of Resin MPa" : 3600,

"Poisson's Ratio for Resin" : 0.35,

"Rupture Strain of the Matrix Design" : 0.038,

- Laminate Physical properties requirements:

"Specific Gravity of the Resin" : 1.2, "Thickness of Gel Coat mm" : 0.8,

"Factor of Safety" : 6

Useful Equations with sample calculations

The thickness of the lamina *per kg of the glass reinforcement per sq. meter* is given as

$$t_i(m_g) := \frac{1}{\rho_g} + \frac{(100 - m_g)}{m_g \cdot \rho_r}$$

$$t_{csm0.3} := 0.3 \cdot t_i(35)$$

$$t_{csm0.3} = 0.576 \quad \text{mm}$$

where $\boldsymbol{m_g}$ is the reinforcement content by % mass and $\boldsymbol{\rho_r}$ is the resin specific gravity.

$$V_g(m_{gper}) := \frac{m_{gper} \cdot \rho_r}{\left[100 \cdot \rho_g - m_{gper} \cdot (\rho_g - \rho_r)\right]}$$

where $\boldsymbol{m_{gper}}$ is the mass content of glass in percent.

Shear modulus of glass $G_g := \frac{E_g}{2 \cdot (1 - \nu_g)}$

Shear modulus of the resin $G_r := \frac{E_r}{2 \cdot (1 - \nu_r)}$

Allowable strain

For CSM $\varepsilon_{csm} := \frac{200}{14000 \cdot K}$ $\varepsilon_{csm} = 2.381 \times 10^{-3}$

$$\varepsilon_d := min(\varepsilon_{ar}, \varepsilon_{csm}, \varepsilon_{uwrL}, \varepsilon_{uwrN}, \varepsilon_{45})$$

$$\varepsilon_d = 2.381 \times 10^{-3}$$

Useful Equations with sample calculations

Parameters

$$\eta := \frac{1 + \frac{G_r}{G_g}}{2} \qquad P_r := \frac{1}{G_r} \qquad P_g := \frac{1}{G_g}$$

$$P(m_{gper}) := \frac{\left[P_r \cdot \left(1 - V_g(m_{gper})\right) \cdot \eta + P_g \cdot V_g(m_{gper})\right]}{V_g(m_{gper}) + \eta \cdot \left(1 - V_g(m_{gper})\right)}$$

The shear modulus for unidirectional layer of m_{gper} percent of glass by mass is:

$$G_{12}(m_{gper}) := \frac{1}{P(m_{gper})}$$

The Poisson's ratio of unidirectional laminate is:

$$\nu_{12}(m_{gper}) := \nu_g \cdot V_g(m_{gper}) + \nu_r \cdot \left(1 - V_g(m_{gper})\right)$$

Useful Equations with sample calculations

Extensibility of the Combined Laminates

$$X_{lam1}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}, m_{gper}) := 28000 \cdot n_{udl1} \cdot m_{udl} \ldots$$
$$+ 4000 \cdot n_{udl2} \cdot m_{udl} \ldots$$
$$+ 14000 \cdot n_{csm} \cdot m_{csm} \ldots$$
$$+ 16000 \cdot n_{wr} \cdot m_{wr} \ldots$$
$$+ X_{45}(m_{gper}) \cdot m_{45} \cdot n_{45}$$

Extensibility in the 2-2 direction(perpendicular to earlier direction) with UD,WR and CSM combination is

$$X_{lam2}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}, m_{gper}) := 4000 \cdot n_{udl1} \cdot m_{udl} \ldots$$
$$+ 28000 \cdot n_{udl2} \cdot m_{udl} \ldots$$
$$+ 14000 \cdot n_{csm} \cdot m_{csm} \ldots$$
$$+ 16000 \cdot n_{wr} \cdot m_{wr} \ldots$$
$$+ X_{45}(m_{gper}) \cdot m_{45} \cdot n_{45}$$

Useful Equations with sample calculations

Nominal Thickness of the Laminate

$$
\begin{aligned}
t_{nomHL}\left(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}\right) := \; & n_{csm} \cdot m_{csm} \cdot t_i(35) \; \ldots \\
& + n_{wr} \cdot m_{wr} \cdot t_i(50) \; \ldots \\
& + n_{udl1} \cdot m_{udl} \cdot t_i(50) \; \ldots \\
& + n_{udl2} \cdot m_{udl} \cdot t_i(50) \; \ldots \\
& + n_{45} \cdot m_{45} \cdot t_i(50)
\end{aligned}
$$

Useful Equations with sample calculations

Elastic Contas of Laminates

$$E_{11hl}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}) := \frac{X_{lam1}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}, 45)}{t_{nomHL}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45})}$$

$$t_{nomcsm450}(n_{csm}) := n_{csm} \cdot m_{csm} \cdot t_i(35)$$

$$E_{11csm450} := \frac{X_{lam1}(0,0,1,0,0,45)}{t_{nomcsm450}(1)} \qquad E_{11csm450} = 7.289 \times 10^3$$

$$v_{12}(35) = 0.325$$

$$G_{12hl}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}) := \frac{X_{lam12}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45}, 45)}{t_{nomHL}(n_{udl1}, n_{udl2}, n_{csm}, n_{wr}, n_{45})}$$

$$G_{12csm} := G_{12hl}(0,0,1,0,0) \qquad G_{12csm} = 2.803 \times 10^3$$

Output File Information

- Estimated Physical properties of Laminate will be displayed with units as follows:

Thickness of laminate with gelcoat = 1.66 mm

Fiber Volume Fraction = 0.19

Poisson's Ratio v12 = 0.324

Estimated Elastic Constants of Laminate are:

E11 = 7288.80 Mpa   E22 = 7288.80 Mpa   E33 = 5403.31 Mpa

G12 = 2803.38 Mpa   G23 = 2039.37 Mpa   G13 = 2039.37 Mpa

Allowable Design Loading:

Stress 1-1 direction = 17.35 Mpa   Stress 2-2 direction = 17.35 Mpa

Shear Stress = 6.67 Mpa   Minimum allowable strain = 0.002381

References

- The Behavior Of Structures Composed Of Composite Materials by Jack R. Vinson and Robert L. Sierakowski

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Thank You !

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