CASMaT

Villum Center for Advanced Structural and Material Testing

Material properties of FRP materials and sandwich panels at elevated temperature

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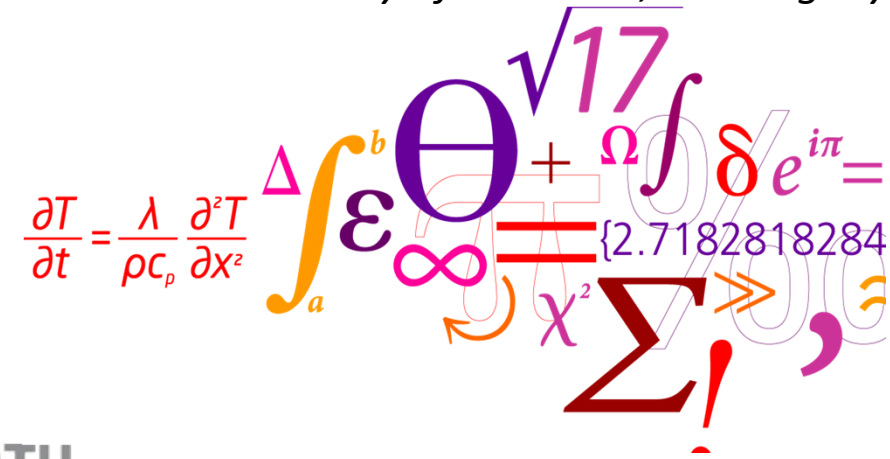


DTU Mechanical Engineering

Department of Mechanical Engineering

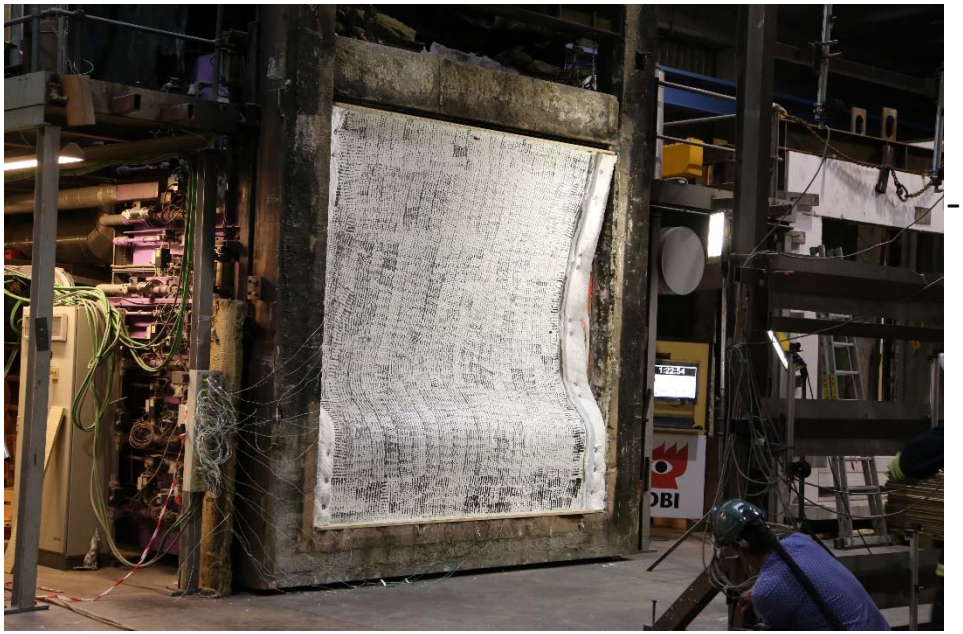
Outline

- Characteristics of composite materials
- Determination of the mechanical properties at elevated temperatures
  - ✓ Tensile, Compressive and shear Properties of E-glass/epoxy Composite Material
  - ✓ Core Shear and compressive Properties of Sandwich Structure
- Results
- Conclusion

Characteristics of FRP Composites

M80 Stiletto – America's Largest Carbon Fiber combat Ship, 2016

-**Lightweight**
-**High specific strength/stiffness**



- **Limited performance at elevated temperatures, combustible**

Determination of the mechanical properties at higher properties

The composite structure was designed using:

- GBX450L-1250 E-glass Stitched
- Fabric fibre orientation of $0^o/90^o$
- Prime 20LV epoxy resin
- Sandwich core PET Divinycell P100 (DIAB)

- Test were performed on an Instron servo-hydraulic testing machine with a 100 kN capacity.

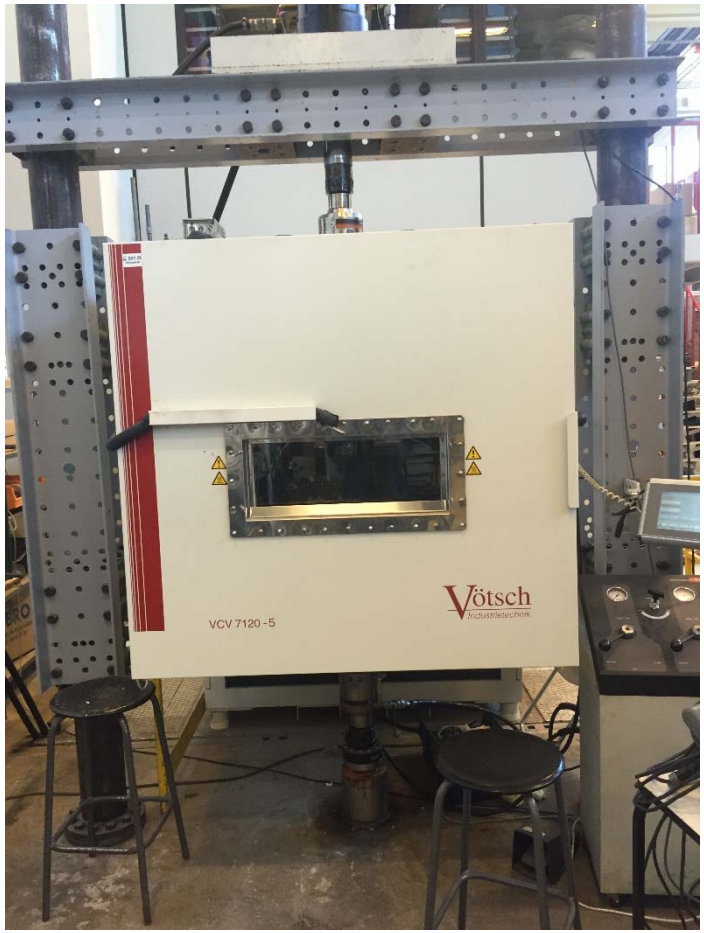
- A circulating air oven was mounted to the testing machine.

Determination of the mechanical properties at higher properties

- specimens were exposed at the prescribed temperature up to the point that thermal equilibrium achieved.

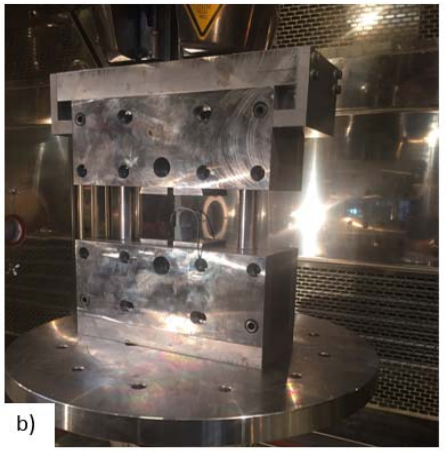
- Specimens were tested with intervals of 25^{o}C starting from room temperature to 100^{o}C. Tensile test were continued till 175^{o}C.

- At least 3 specimens were tested for each interval.



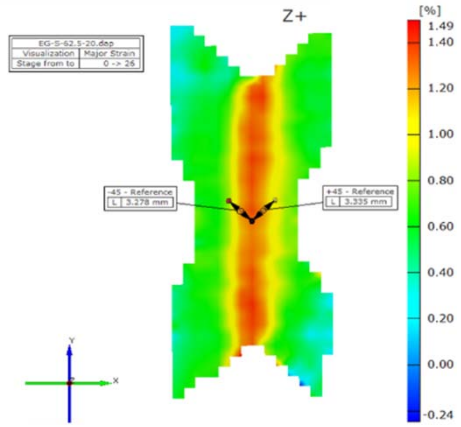
Material Properties of E-glass/epoxy Composite

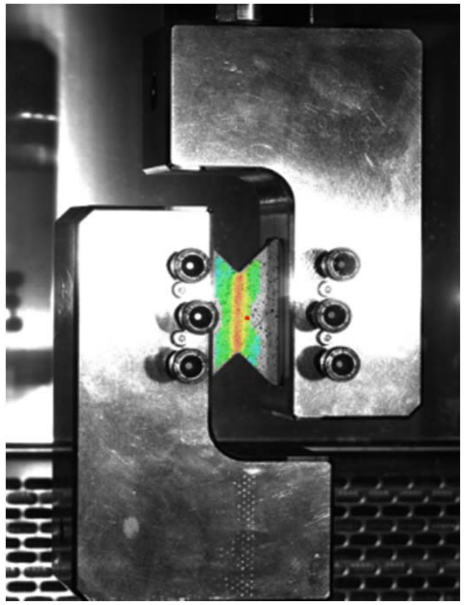
- Modulus and ultimate strength in:
- Tensile (using extensometers)
- Compression (using strain gauges)
- Shear (using 12M DIC system)
- According to existing ASTM standards



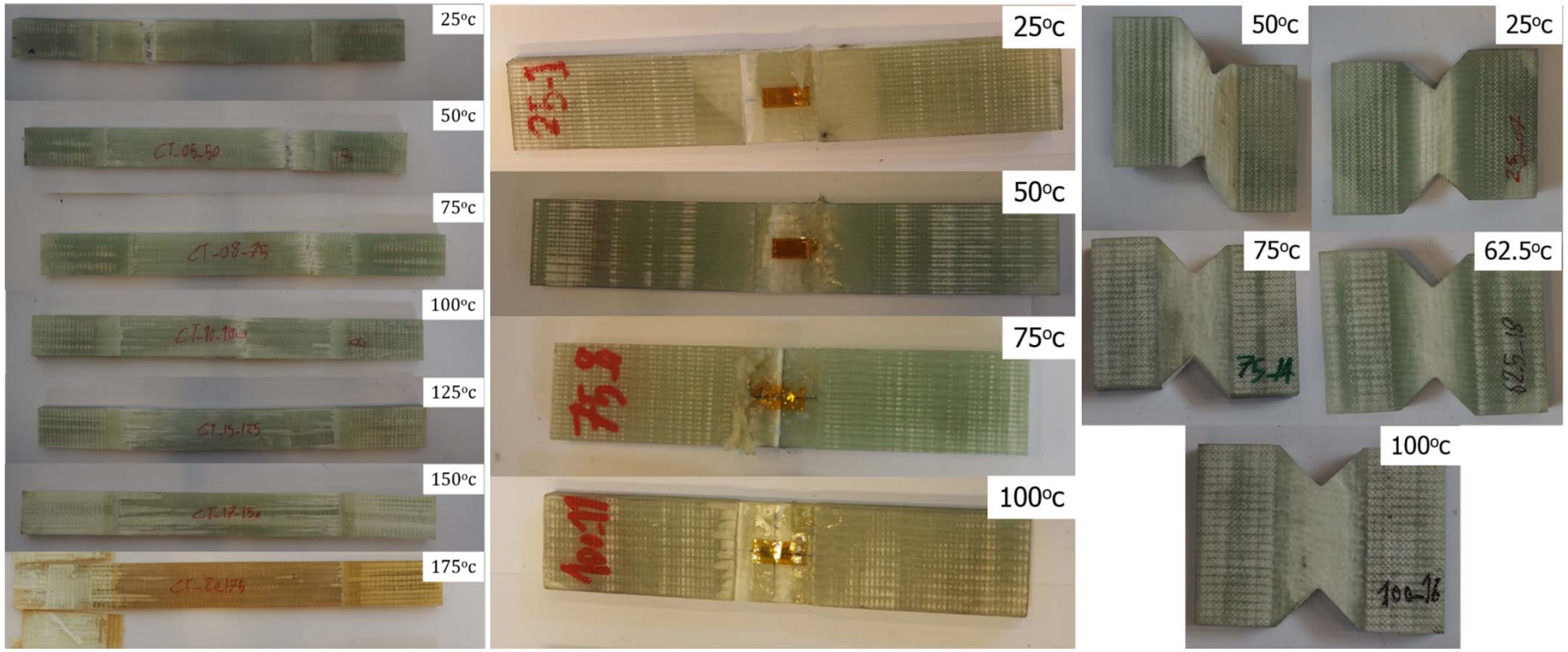
b)

b)





Material Properties of E-glass/epoxy Composite



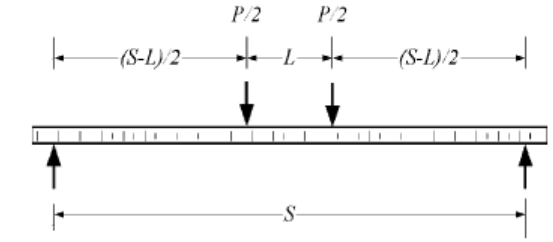
Failure surface of specimens after different exposure temperatures in tensile, compression and shear test (one specimen per exposure time)

Core Shear Properties of Sandwich structure

- According to standard C393/C393M–11

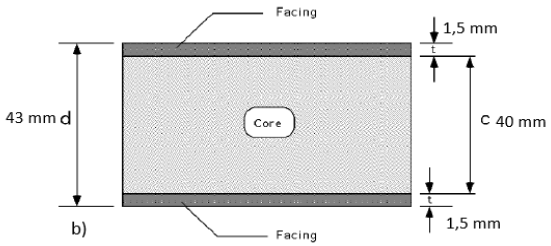
Test Setup:

- Displacement control mode- 3 mm/min
- Core Shear modulus were measured according to the standard. The beam mid-span deflections were measured using Aramis system.



a)

S=450 mm, L=160 mm



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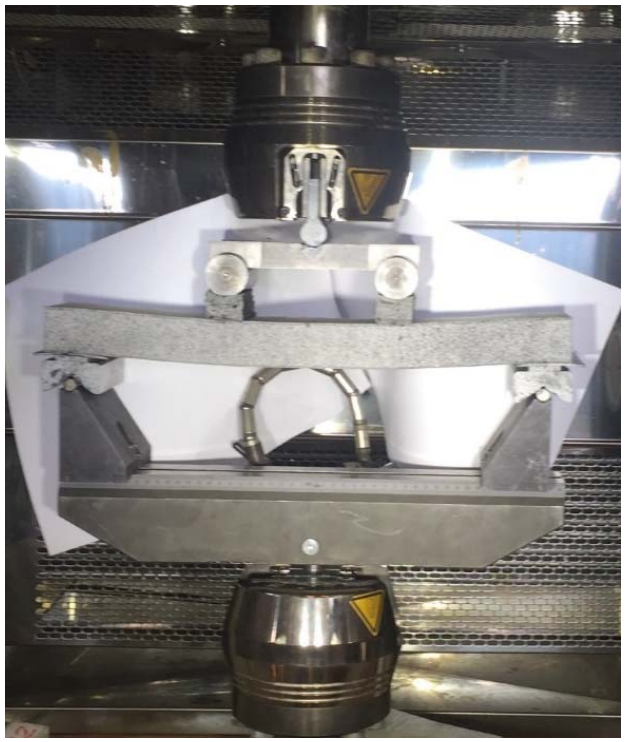
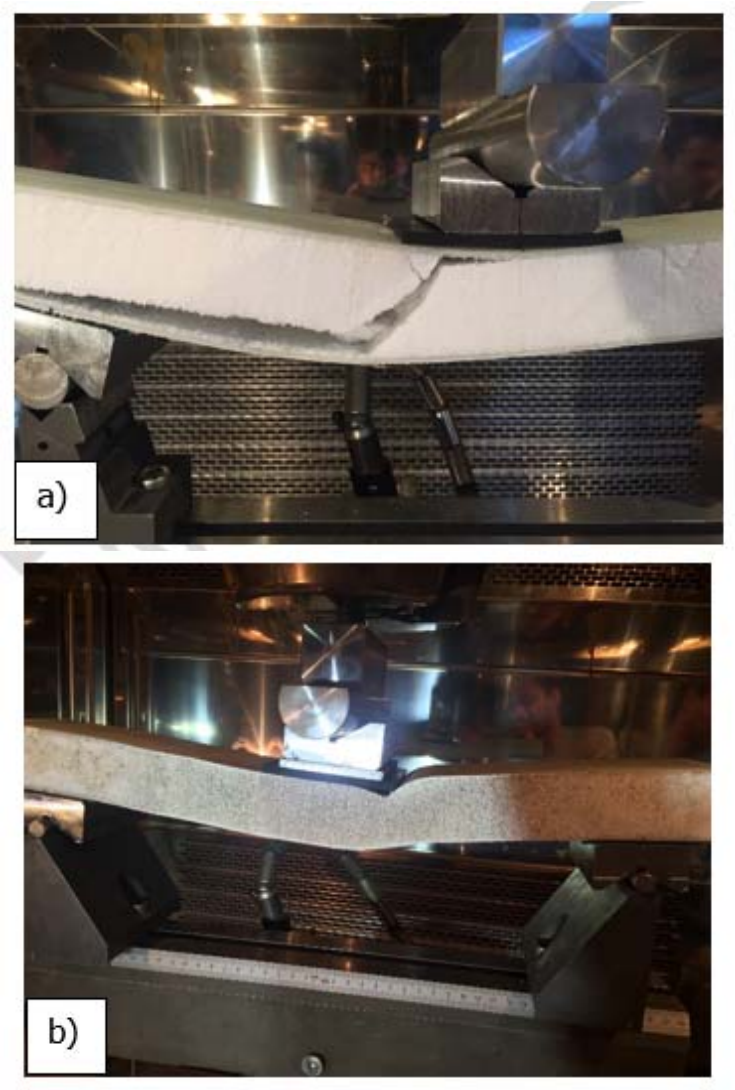


Experimental setup for four-point bending test of sandwich beams

Core Shear Properties of Sandwich structure

- Some of the Specimens at room temperature were failed due to core shear failure and some due to indentation. Core shear strength measured at room temperature is equal to 0.88 Mpa.

- All the specimens at elevated temperatures were failed due to indentation. Therefore Considering the effect of temperature on core shear strength is not achieved.



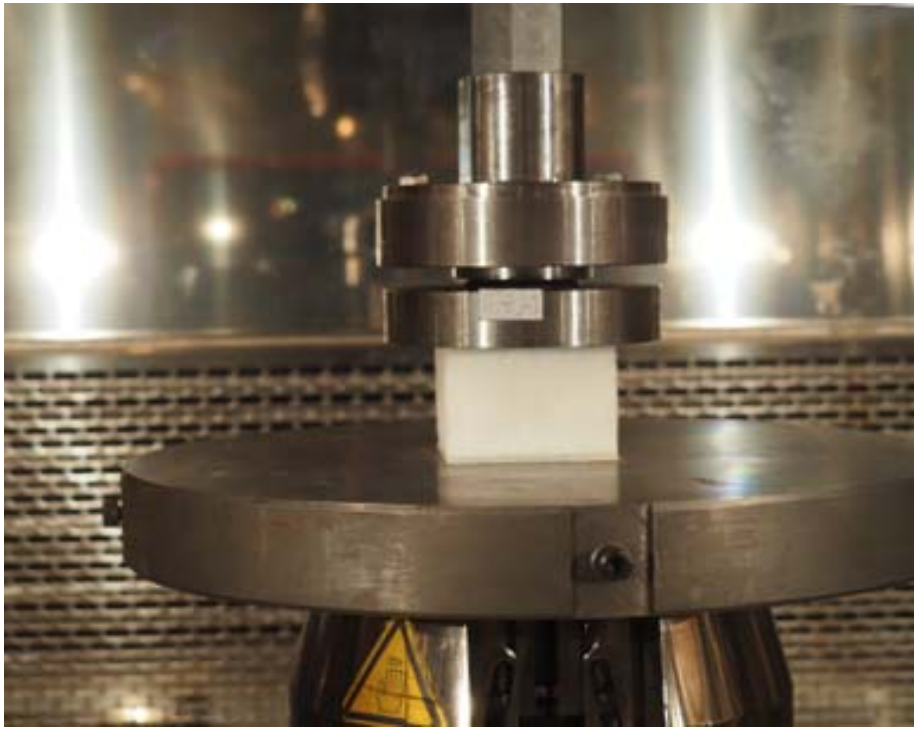
Failure due to a) core shear failure at room temperature b) indentation at elevated temperatures (50 ^{o}C and above)

Core Compressive Properties of Sandwich structure

- According to standard C365/C365M−16

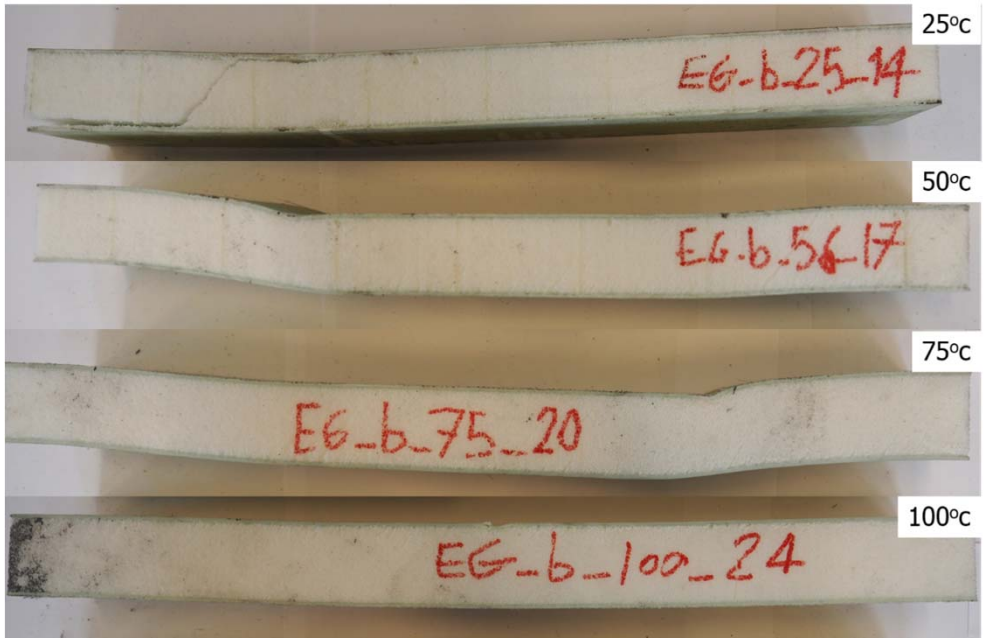
Test Setup:

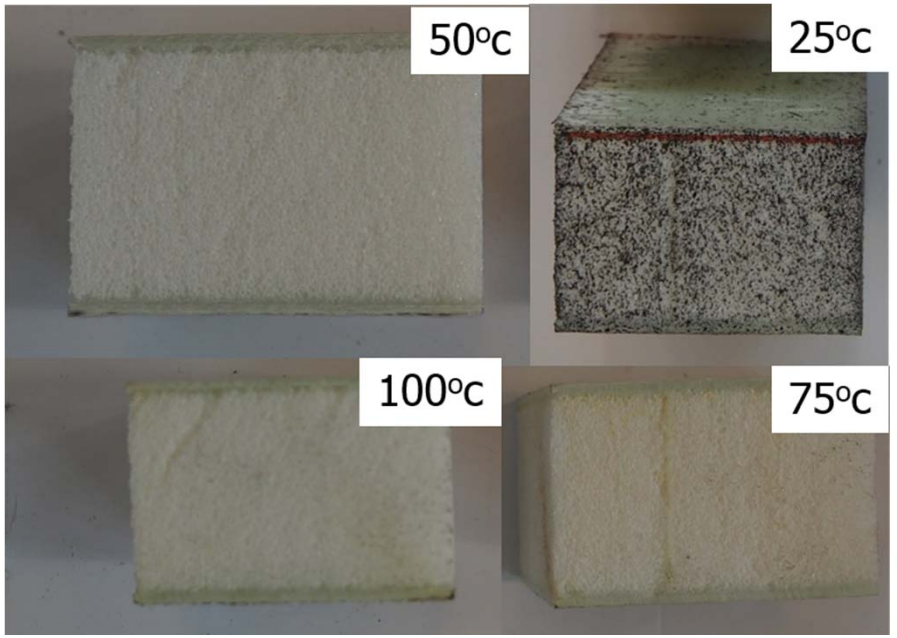
- Displacement control mode- 0.5 mm/min
- Core Compressive modulus and ultimate Strength were measured followed by standard. (The deflection of the sandwich specimens were measured using Aramis system.
- Panel is cut to the specimens with 60 mm × 60 mm dimensions.



Experimental setup for flatwise compression test of sandwich beams

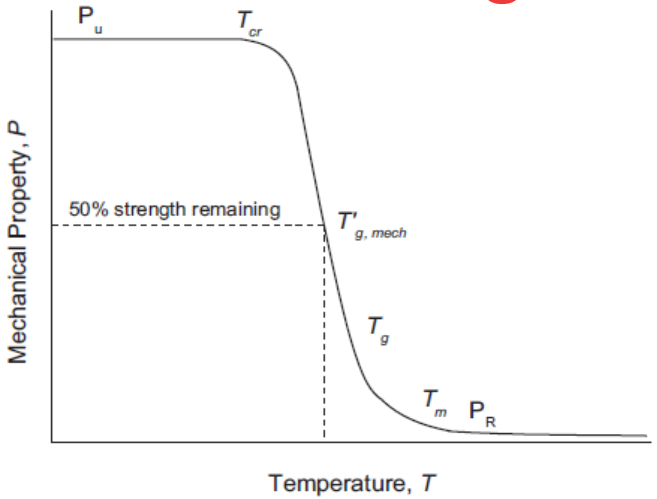
Material Properties of Sandwich Core





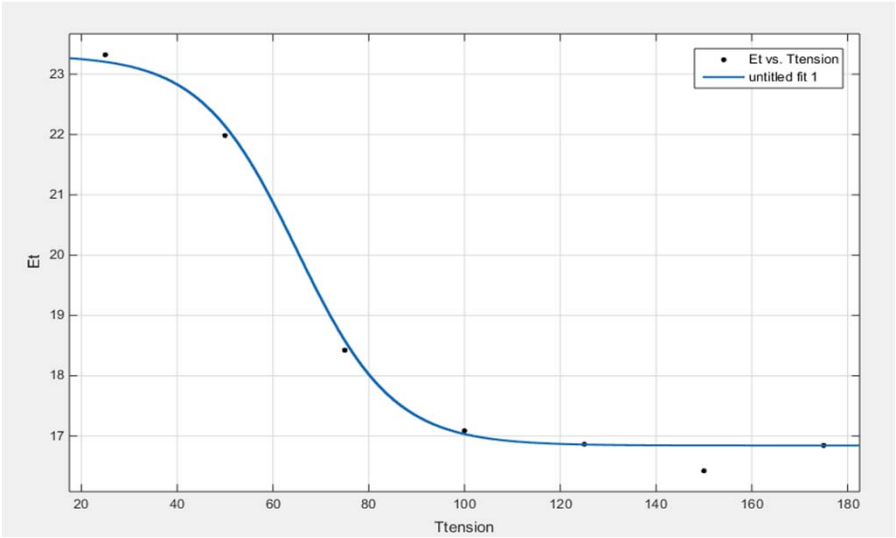
Failure surface of specimens after different exposure temperatures in core compression and core shear test (one specimen per exposure time)

Curve fittings

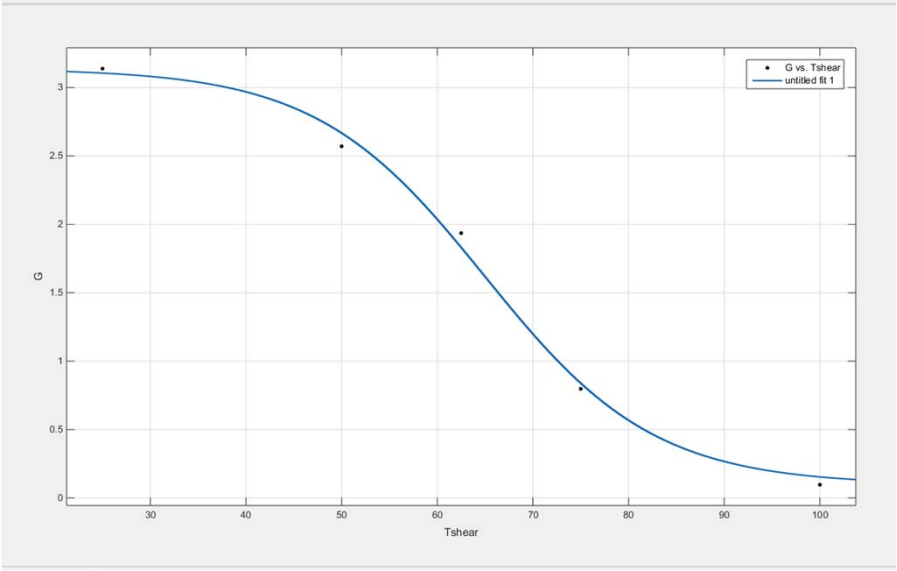


"Fire Properties of polymer composite materials", Mouritz & Gibson, 2006

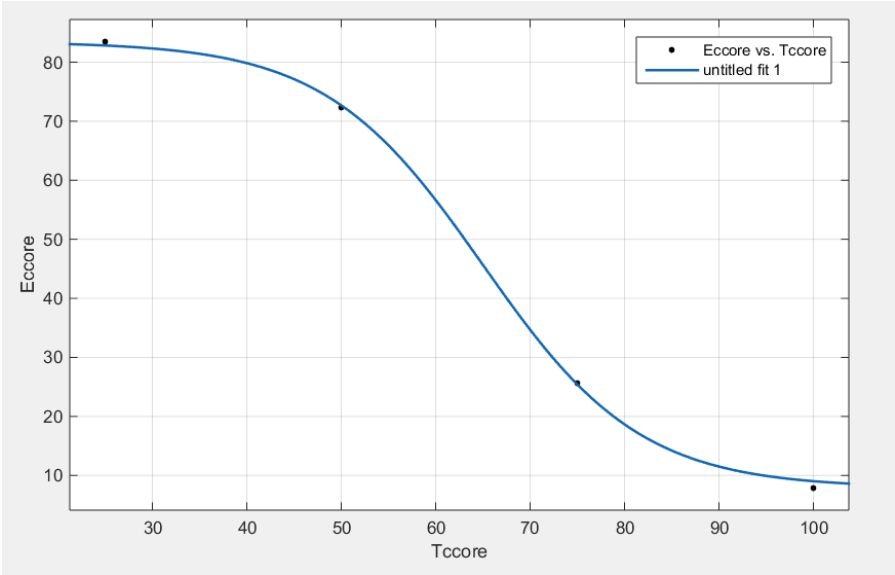
$$P(T) = P_U - \frac{P_U - P_R}{2}(1 + \tanh(k(T - T_{g,mech})))$$



Curve fitting for tensile modulus, $T_{g,mech}$=65ºc



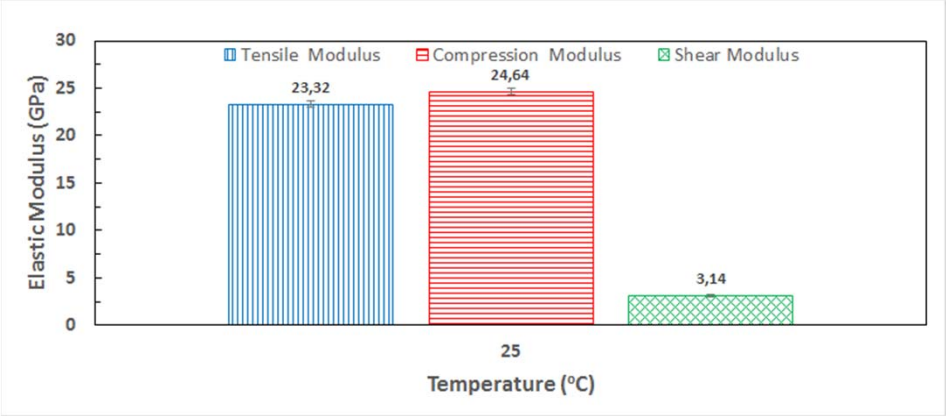
Curve fitting for shear modulus, $T_{g,mech}$=65ºc



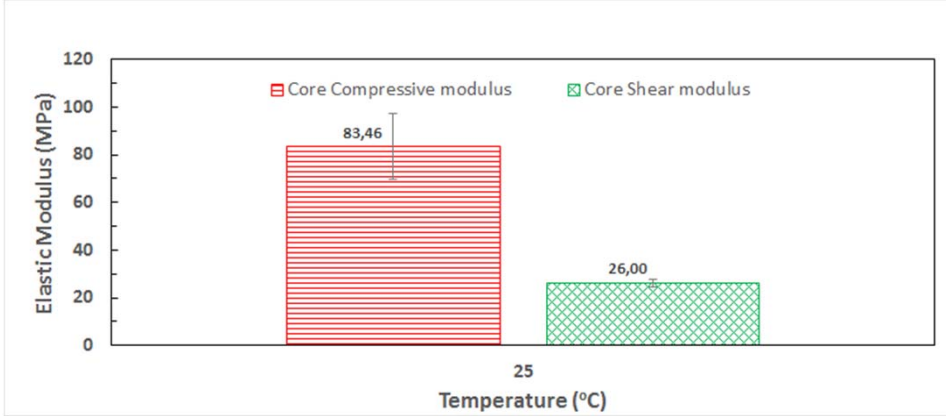
curve fitting for core compressive modulus, $T_{g,mech}$=65ºc

Results: Material Properties at room temperature

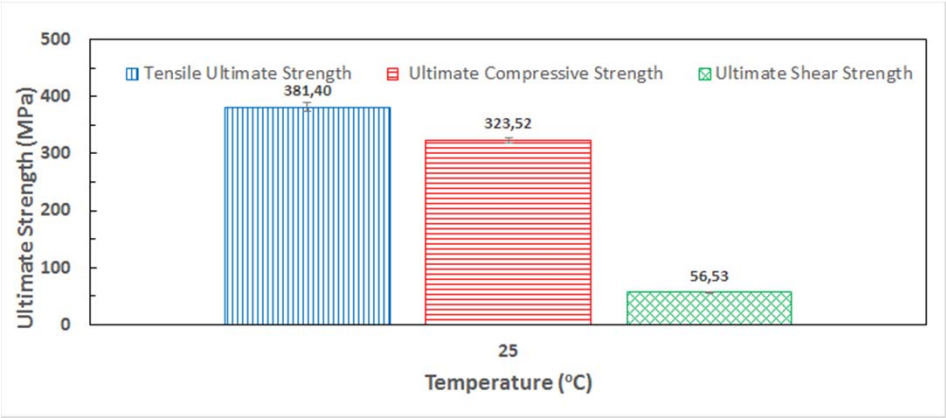
Modulus: (G/E Composite)

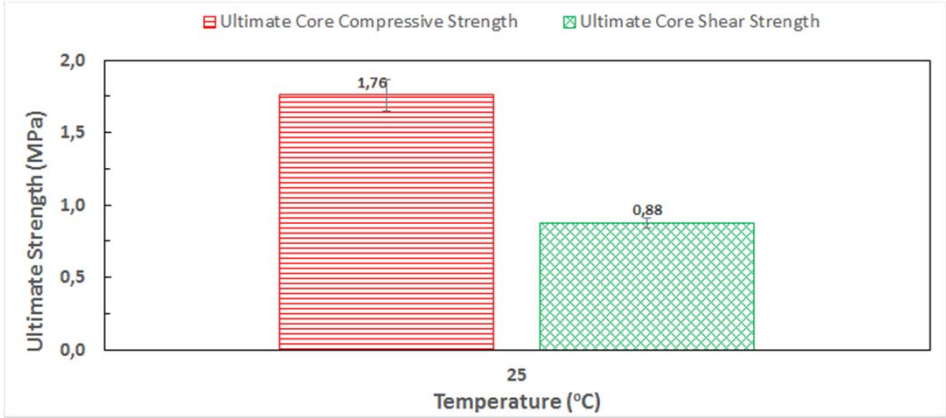


(Sandwich Core)

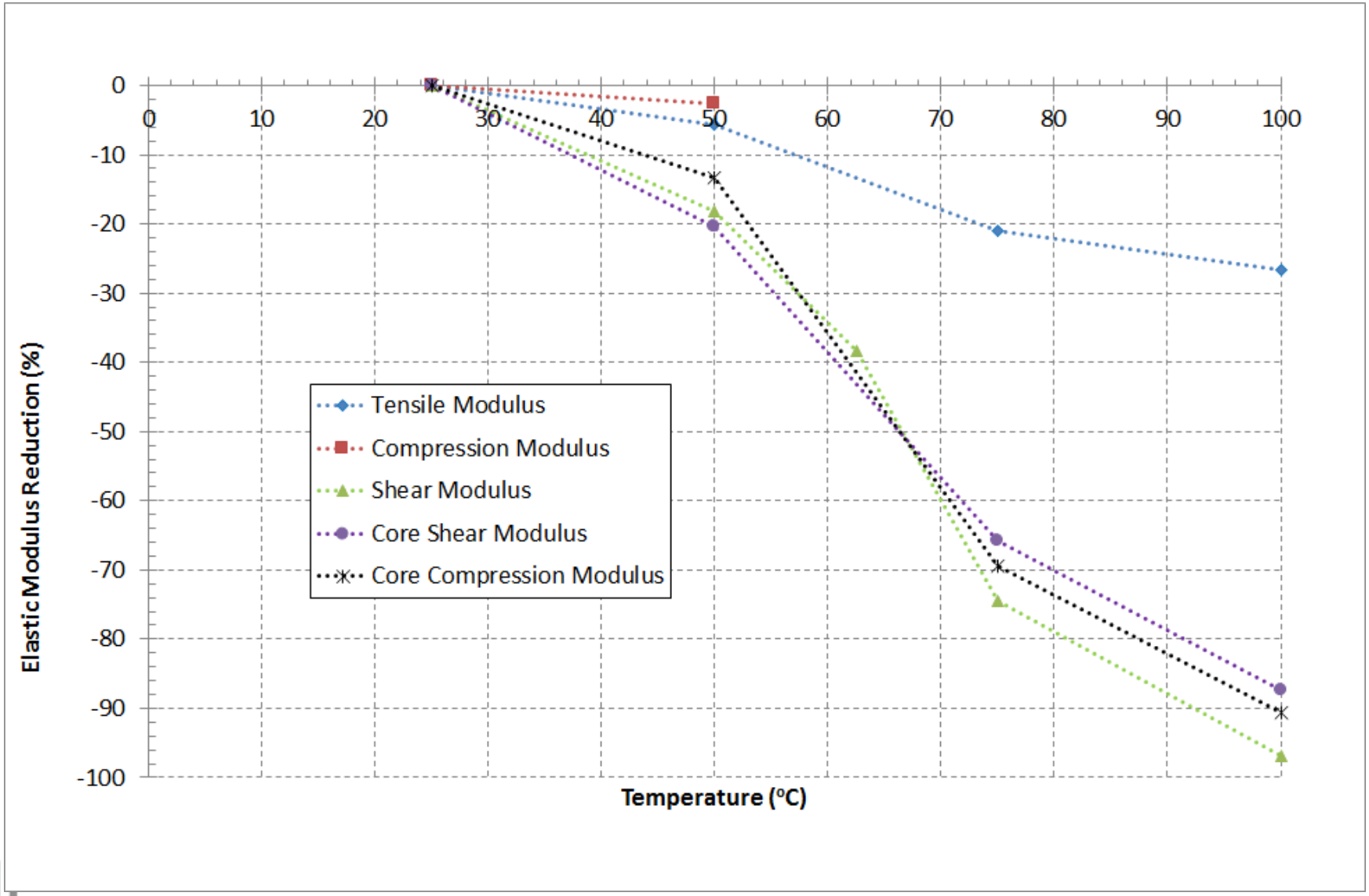


Ultimate Strength:

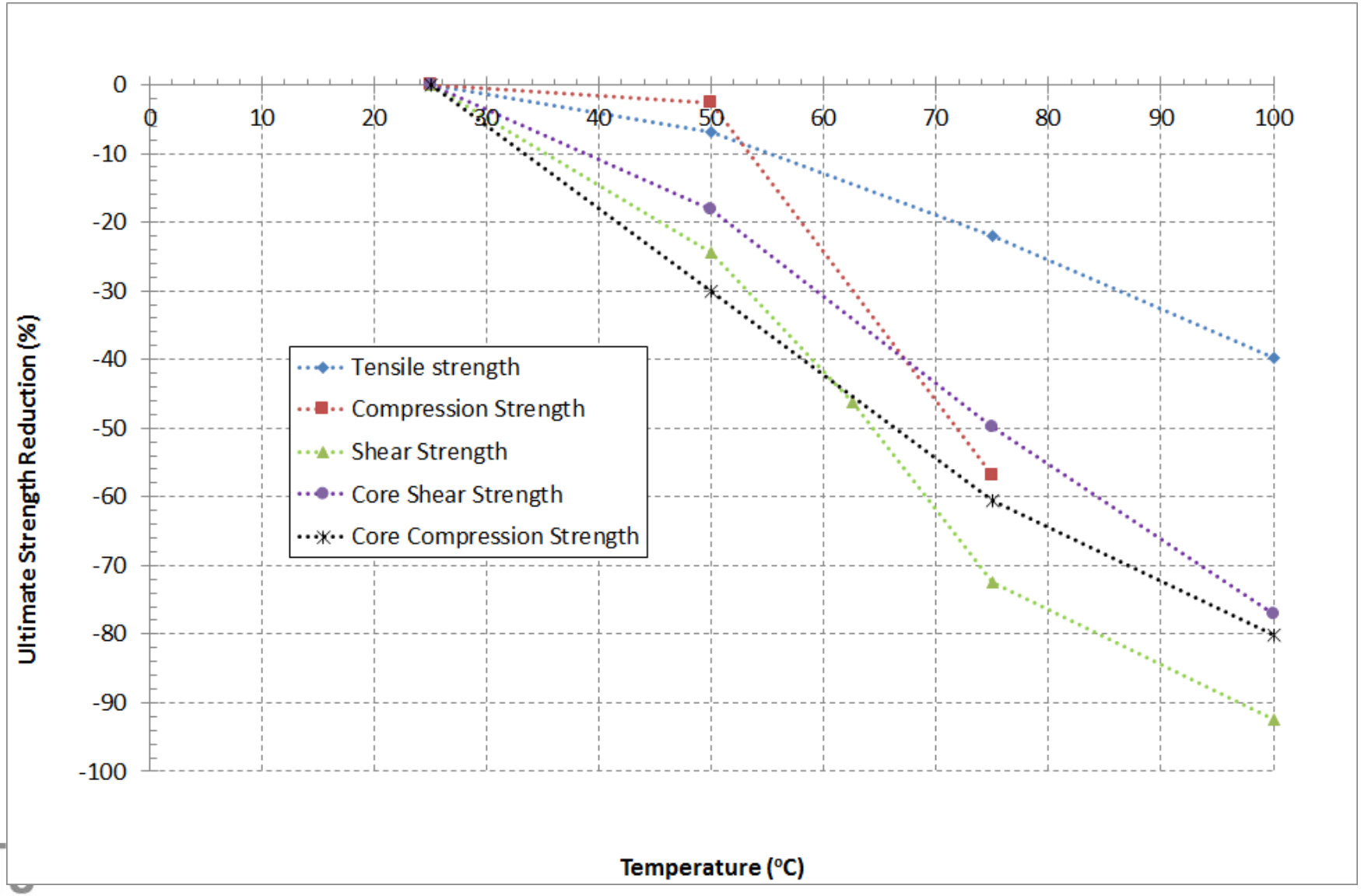




Results


0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10
20
30
40
50
60
70
80
90
100
Elastic Modulus Reduction (%)
Temperature (°C)
Tensile Modulus
Compression Modulus
Shear Modulus
Core Shear Modulus
Core Compression Modulus

Results


Ultimate Strength Reduction (%)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
10
20
30
40
50
60
70
80
90
100
Tensile strength
Compression Strength
Shear Strength
Core Shear Strength
Core Compression Strength
Temperature (°C)

Conclusion

- General reduction for both modulus and strength **f(t)**
- Compression and shear – matrix dominated – more susceptible
- Curve fitting function applied to the test results, all had good agreement with the tanh equation.
- $T_{g,mech}$ for most of the tests observed at 65^{o}C.

Remarks

- New materials (fire retardant resins, additives etc.)
- Versatility and complexity
- Experiments are necessary for the understanding of material system, lead to optimised design.

Thank you