# Fatigue performance of adhesive joints in engineering structures: the impact of temperature and loading mode

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## Introduction

Understanding the behaviour of adhesive joints under different conditions is fundamental since it is a key factor in the design of vehicles structures. By incorporating adhesives with high fracture energy into joint designs, engineers can enhance the overall durability and reliability of structures, specially if those are under mixed mode conditions. The aim of this work is to bridge the research gap and gain a comprehensive understanding of the fracture and fatigue behaviour of polyurethane adhesives under diverse loading rates and temperatures.

## Experimental Methodology

A ductile polyurethane-based adhesive with mechanical characteristics adapted for industrial purposes was employed throughout this study. The adhesive's glass transition temperature is -5 ºC.

Table 1 – Summary of test conditions

| | | Temperature | | |
|---|---|---|---|---|
| | | Low Temperature -30 ºC | Room Temperature 23 ºC | High Temperature 60 ºC |
| Loading Rate | Quasi-static 0.2 mm/min | Mixed mode test (45º) | Mixed mode test (45º/60º) | Mixed mode test (45 º) |
| | Intermediate Speed 200 mm/min | Mixed mode test (45 º) | Mixed mode test (45º) | Mixed mode test (45 º) |
| | High Speed 6000 mm/min | Mixed mode test (45 º) | Mixed mode test (45º) | Mixed mode test (45 º) |

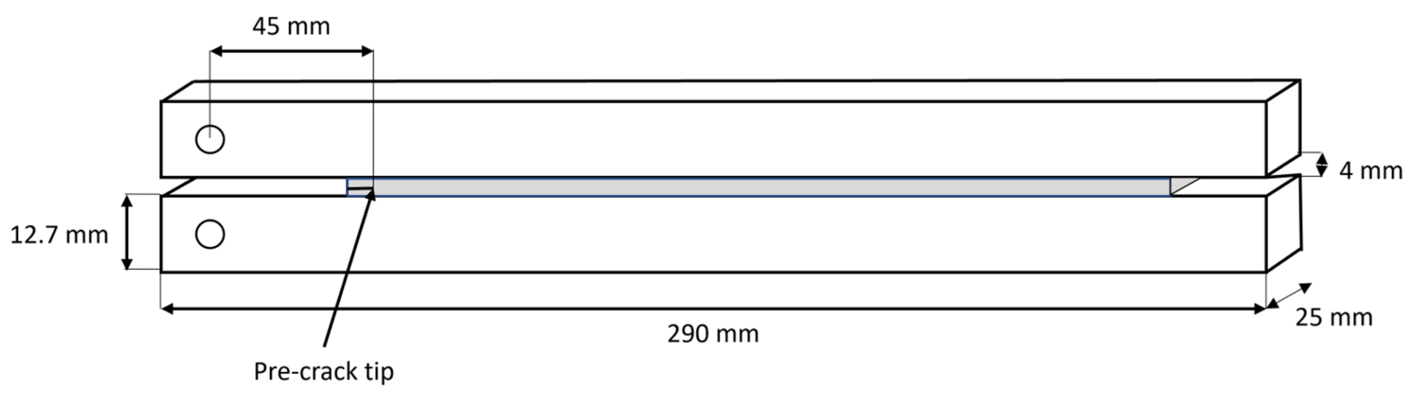


Figure 1 – DCB specimen.

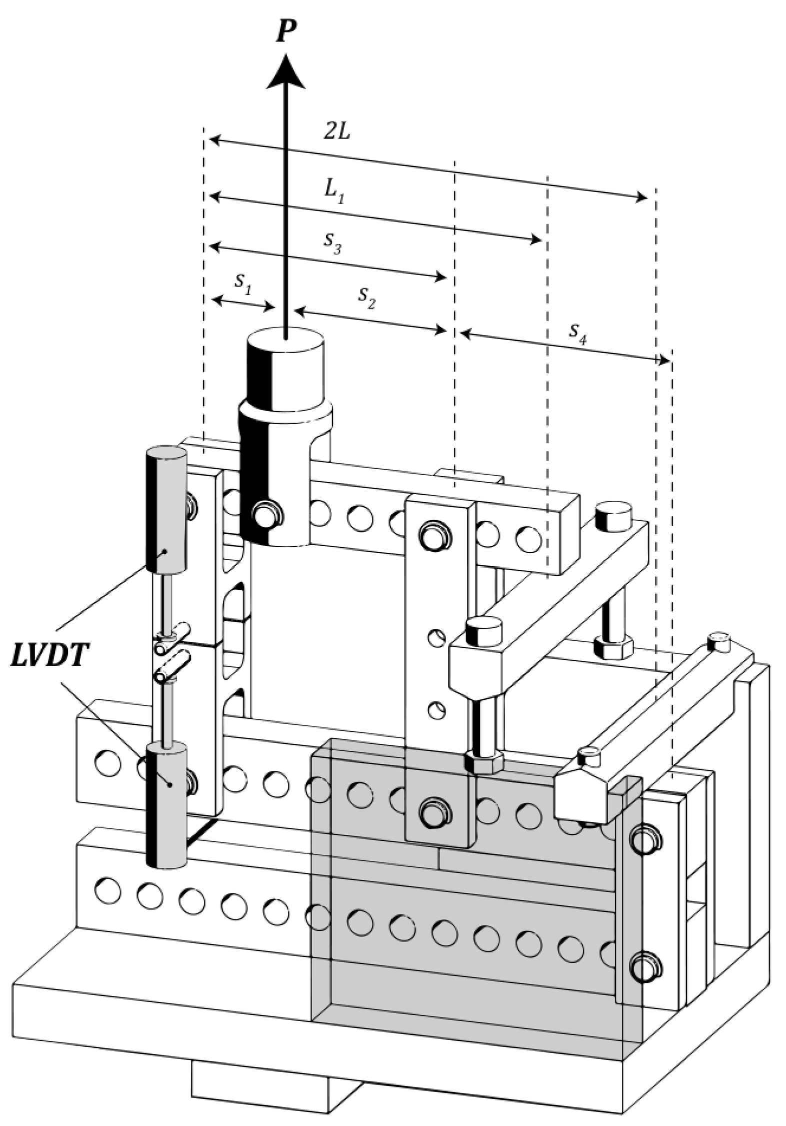


Figure 2 – Apparatus used for the mixed-mode conditions [1].

## Results and Discussion

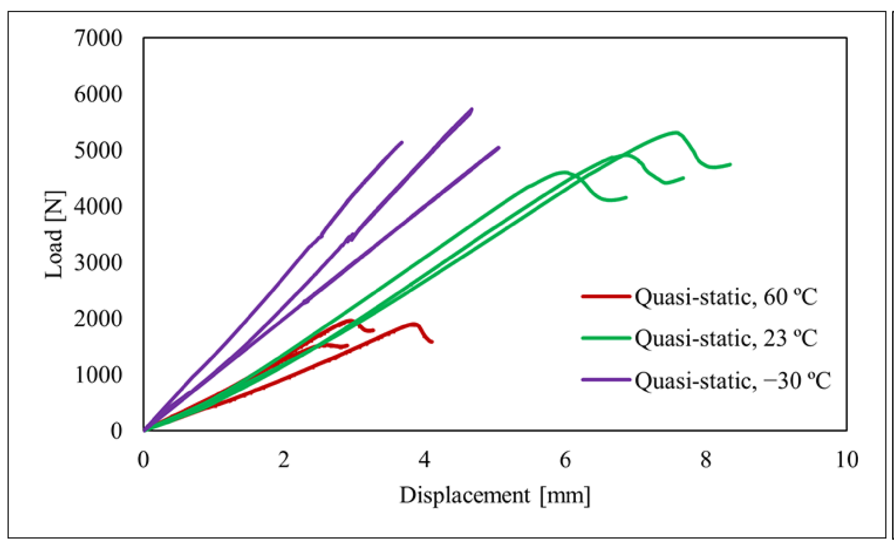


Figure 3 – Load-displacement of the machine for test submitted to quasi-static conditions for a mixed mode apparatus set up at 45º.

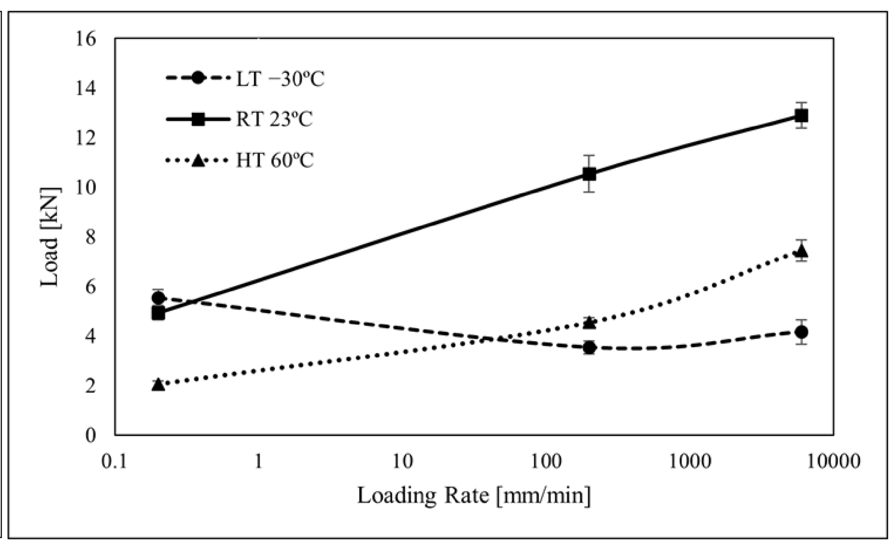


Figure 4 – Maximum load of the machine as function of loading rate and temperature for a mixed mode apparatus set up at 45º.

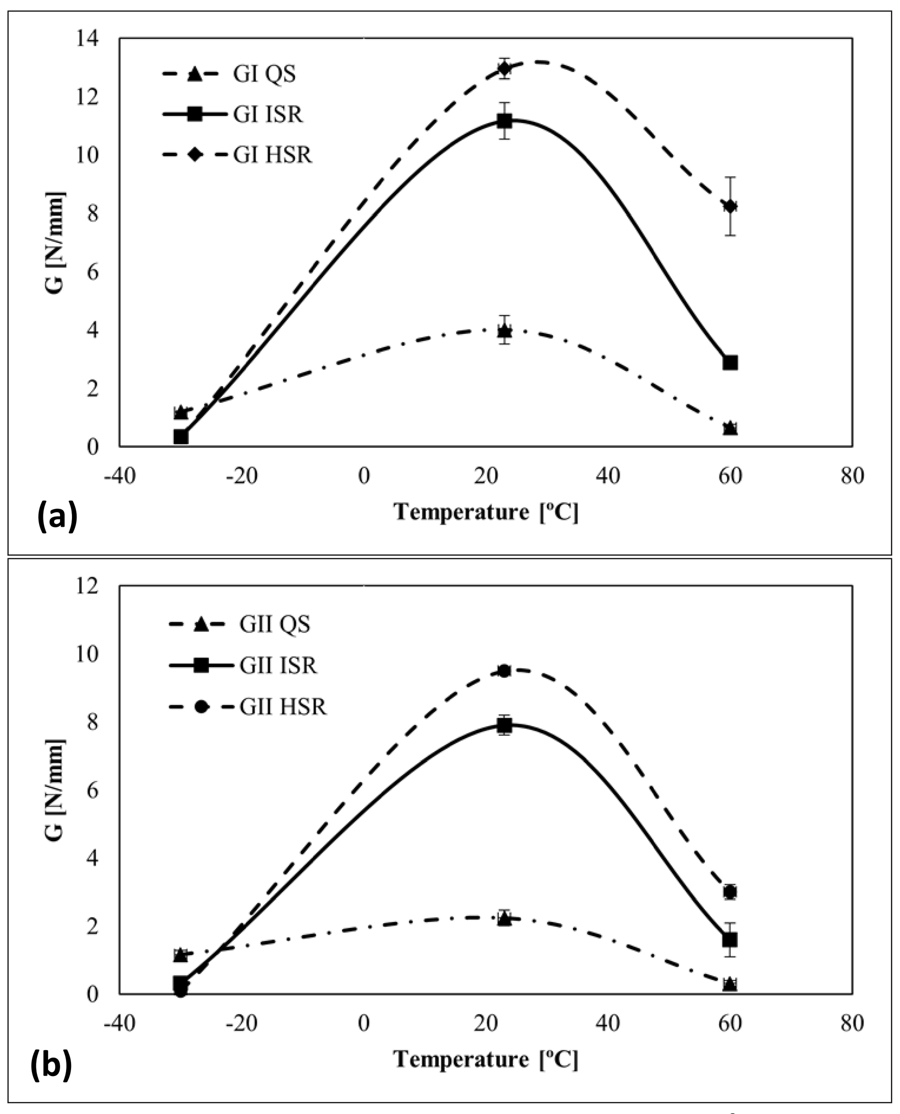


Figure 5 – Fracture energy modes as a function of temperature: (a) Mode I part (b) Mode II part.

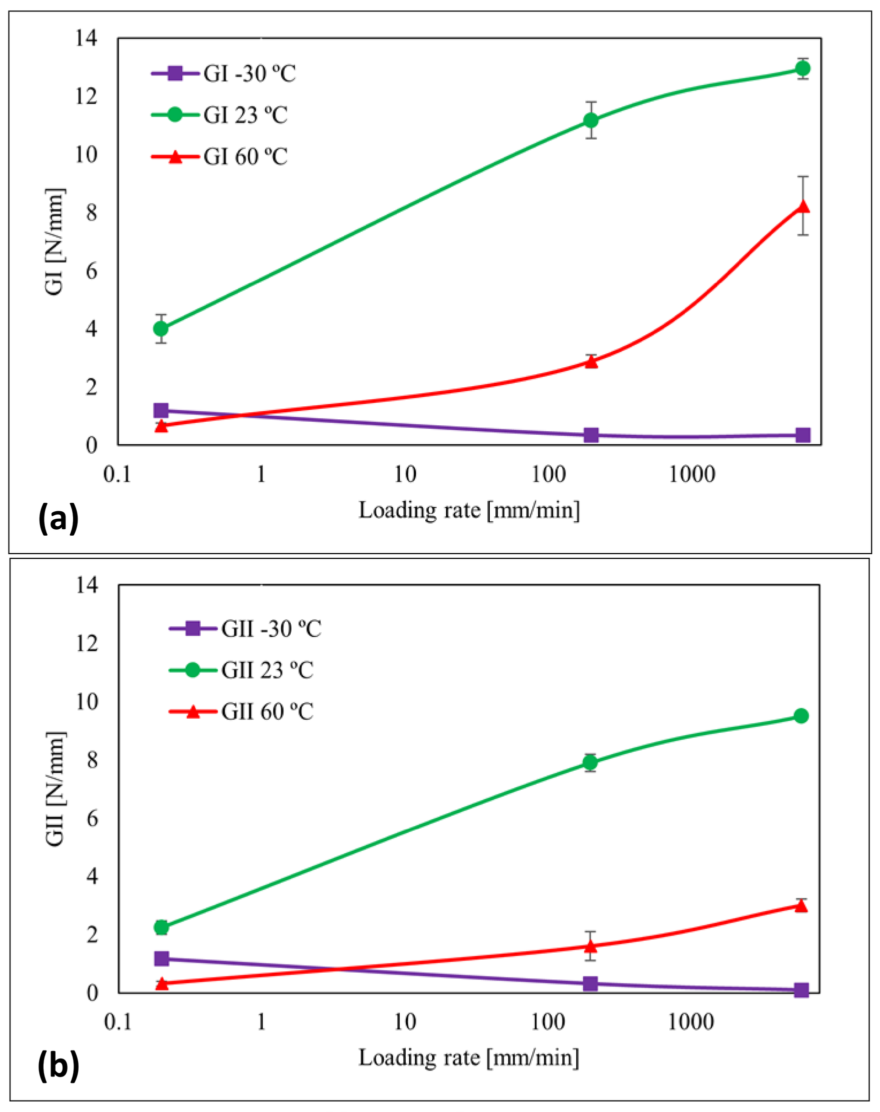


Figure 6 – Effect of temperature on fracture energy as function of loading rate: (a) Mode I part (b) Mode II part.

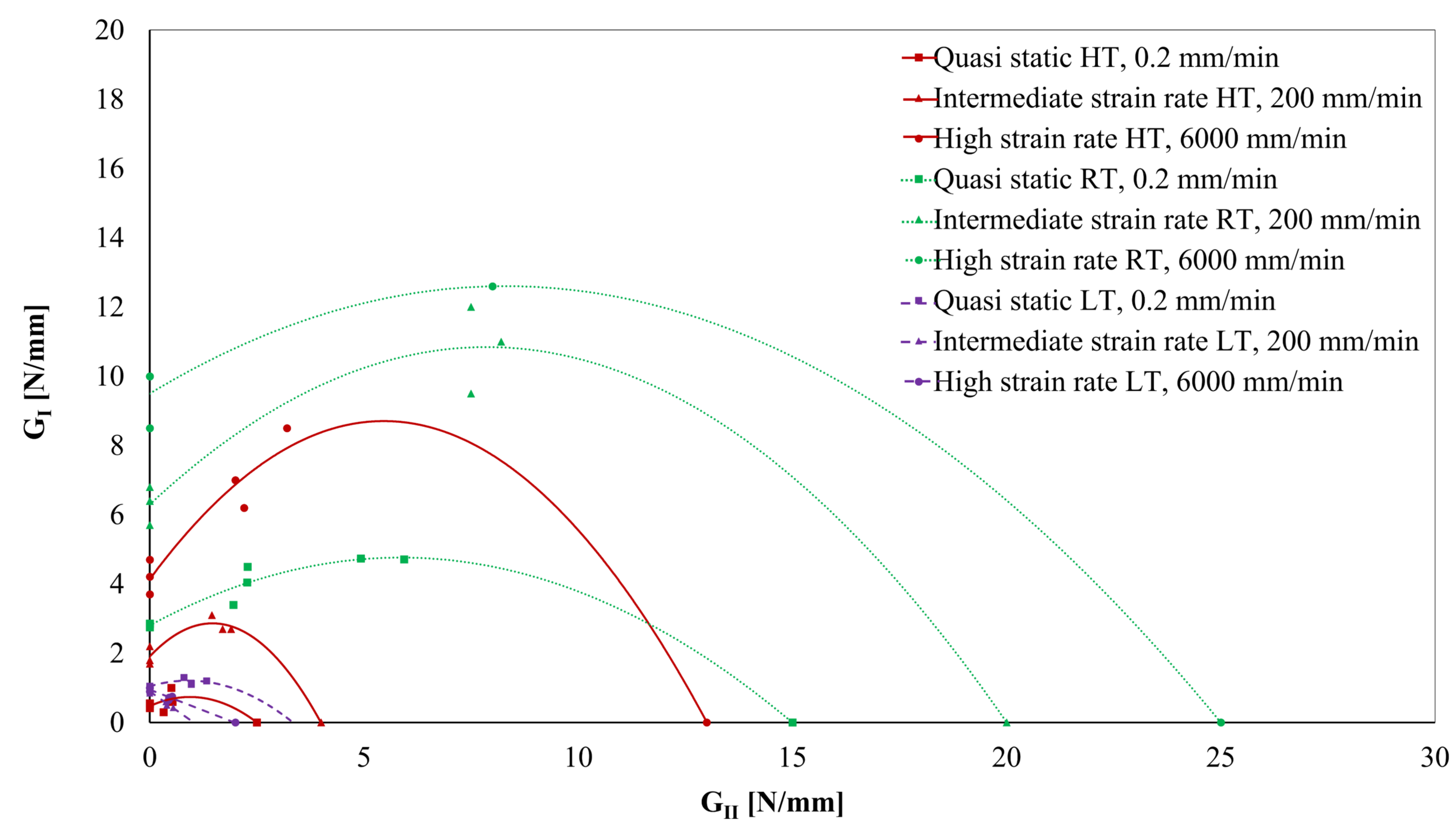


Figure 7 – Fracture envelope.

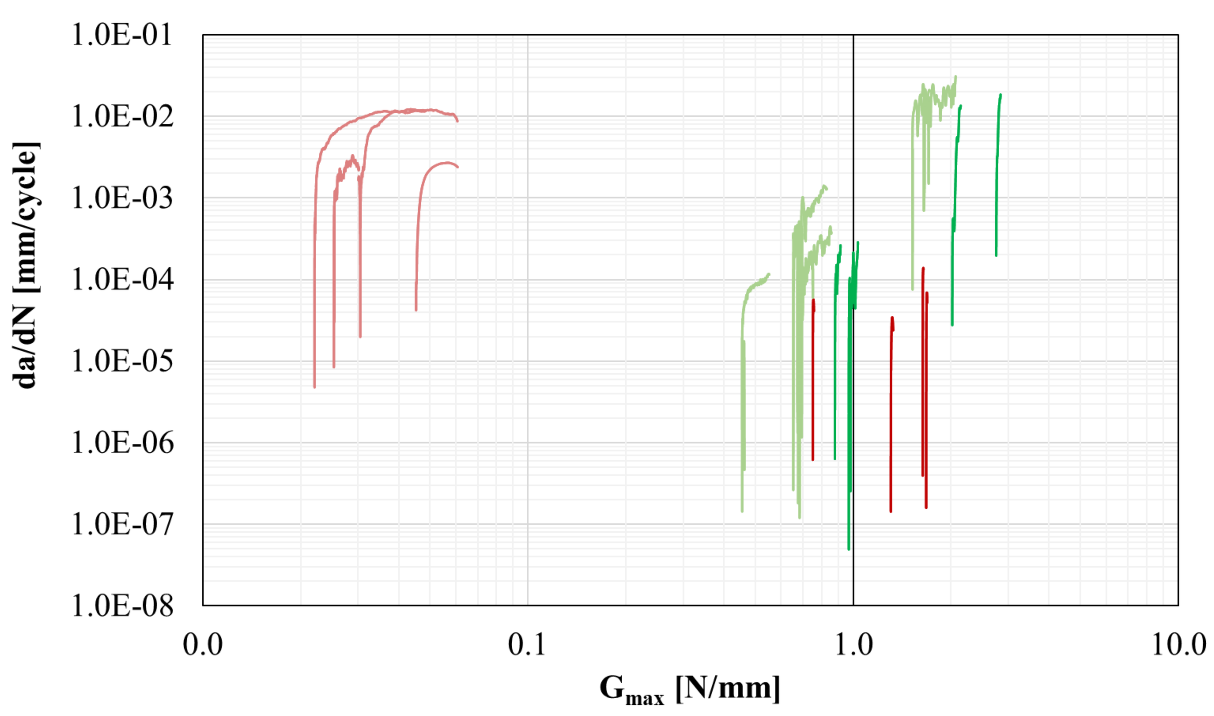


Figure 8 – Paris-law curves.

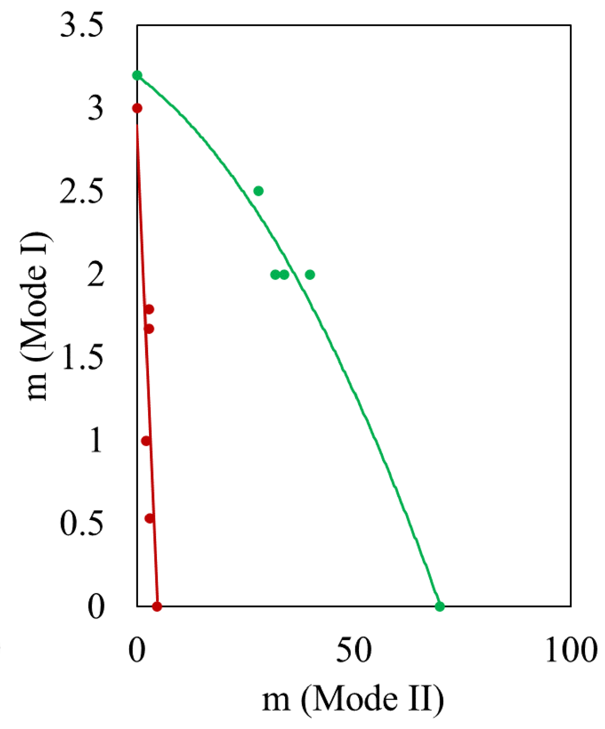


Figure 9 – Paris-law curve's slopes.

## Conclusions

The critical strain energy release rate is highly dependent on service temperature and loading rate, especially above Tg, where higher loading rates result in increased maximum load support. Temperature has a substantial impact on intermediate and high strain rates, with GI and GII increasing significantly. Both strain rate and temperature affect mixed mode I and II, but mode I is more sensitive. The best adhesive performance is at higher loading rates and room temperature, with GI at approximately 13 N/mm and GII around 7 N/mm. Crack propagation life assessment is less relevant for shear conditions, and although mixed mode is not pure Mode II, it's crucial to consider the threshold for joint design.

## References

[1] M. Costa, R. Carbas, E. Marques, G. Viana, L.F.M. da Silva, "An apparatus for mixedmode fracture characterization of adhesive joints," Theoretical and Applied Fracture Mechanics, 2017.

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