Structural Adhesive Behavior – Experimental and Computational Study

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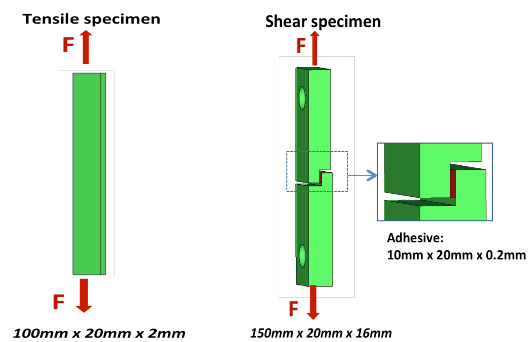
In this brief, an experimental and computational study aiming to investigate the structural adhesive behavior at different loading scenarios is presented. Structural adhesive mechanical property has been characterized under tensile and shear loadings, at low and high rate (static and dynamic). Test data was used to build a representative material model that can mimic adhesive's behavior and can be utilized in numerical models for computational studies. Finally, a material model was validated experimentally and computationally at coupon level and sub-system level, under quasi-static and dynamic loadings.

Problem Statement

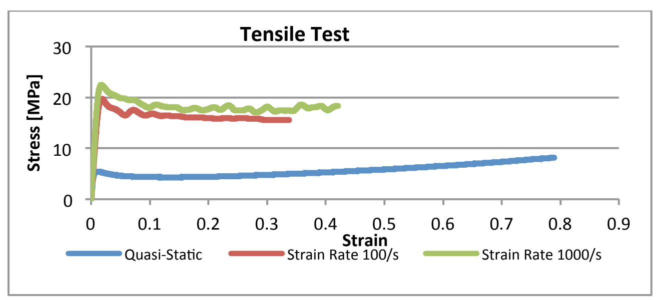
Recycled plastic composite materials (mainly High Density Polyethylene) are increasingly used in railroad applications due to their advantageous material properties. However, HDPE material components are difficult to connect using the traditional joining methods, such as bolting and riveting, due to the brittle fibrous nature of the materials. Railroad applications have seen the use of adhesive for rehabilitation and for joining load-bearing components as an excellent candidate for replacing the traditional joining due to their unique characteristics such as: high strength, light weight, dimensional stability, and ease of use. In order to utilize adhesives bonding, it is crucial to understand their behavior and strength and to be able to predict it for a given geometries and loads. The objectives of this research are: i) investigate the behavior of structural adhesive by characterizing their mechanical properties, and ii) establish a representative material model that can mimic their behavior and can be used in numerical models for computational studies.

Experimental Program

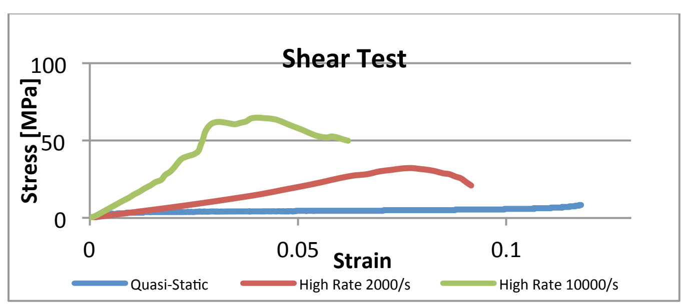
Adhesives are viscoelastic materials; their mechanical properties depend upon loading modes and rates. Tensile and shear testing have been conducted under quasi-static and dynamic loadings at coupon level:



Tensile and shear test results are presented below.



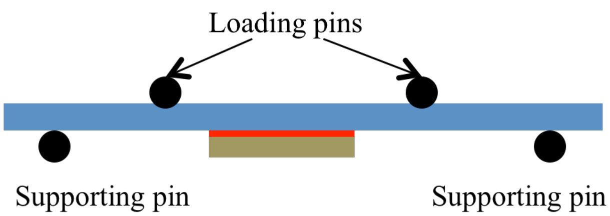
Tensile stress-strain under different loading rates.



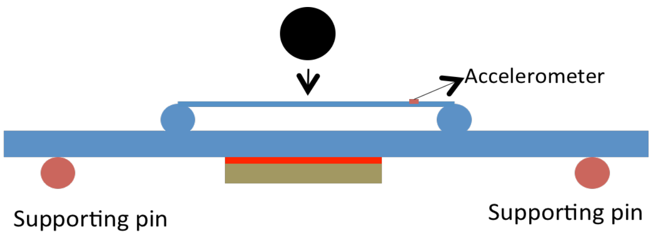
Shear stress-strain under different loading rates.

Testing at sub-system level under static and dynamic rate.

Sandwich structures were constructed where the adhesive was sandwiched between two substrates (Al and PC); two configurations were considered as shown below.



Unequal-length sandwich structure under quasi-static bend



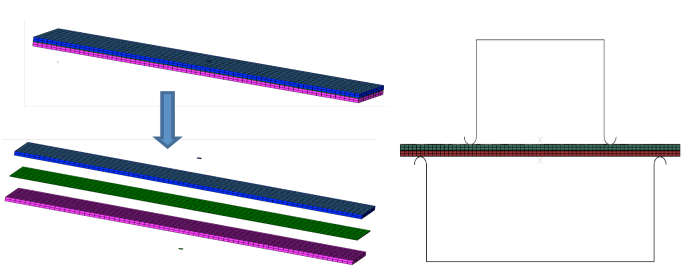
Unequal-length sandwich structure under dynamic test

Material Model

Three material models were considered for this study: linear elastic model, elastic-plastic model, and elastic-viscoelastic model.

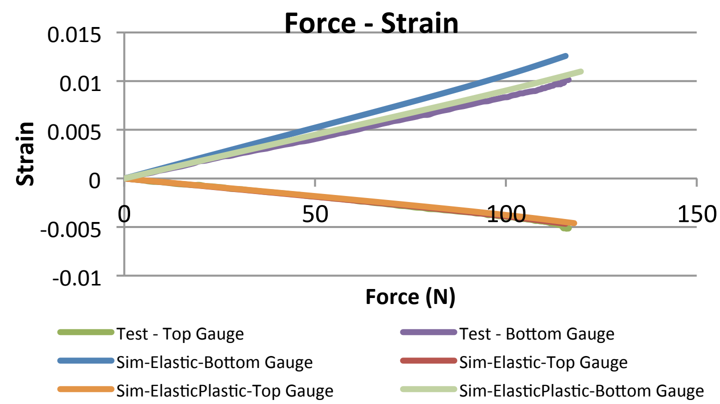
Finite Element Analysis Model

A full three-dimensional finite element model of the sandwiched structure (Al plate, adhesive and PC plate), and the supports of the four-point bend fixture were built using the modeling software ABAQUS. The plates and the adhesive were modeled with full-integration brick elements. Supports of the four-point bend fixture were modeled using analytical rigid surfaces.

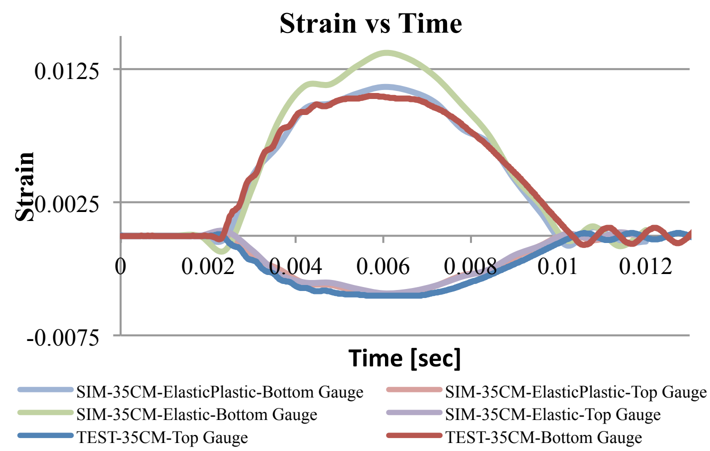


Finite element model

Quasi-static bend results: Test vs Simulation



Dynamic bend results: Test vs Simulation



Conclusion

- Unequal-length sandwich structure configuration is able to capture the sensitivity to the adhesive material modeling approaches. However, equal-length sandwich structure configuration is insensitive to the adhesive layer and failed as a configuration for capturing or investigating adhesive behavior and properties.
- Comparison between numerical and experimental results from both the quasi-static and dynamic simulation results show that the elastic-plastic material model mimics the adhesive material behavior better than the elastic and elastic-viscoelastic material models, due to the ability of the elastic-plastic model to account for adhesive plasticity.

- Although elastic and plastic phases of studied adhesive are loading rate dependent, plastic behavior has bigger impact than its elastic behavior.

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