PURDUE
UNIVERSITY®
School of Materials Engineering

Shingle Adhesive Specification Setting

Student Names: Emily Jones, Rahul Kurien, Abby Shelchuk, Simon Snydersmith, Ilene Trach
Faculty Advisors: Dr. Paul Mort
Industrial Sponsors: MaryBeth Tran

Abstract: Owens Corning is a global building-products leader that manufactures construction materials such as doors, insulation, and roofing shingles. The shingles rely on an asphalt-based modified laminate adhesive to bind the double-layered shingles together during the production process. The plants, while able to vary MLA handling by controlling temperature, filler percentage, and application quantity, do not currently have a quantitative specification to best regulate this process and maximize their profits. This project aims to investigate the effect of varying filler percentage and application quantity on the bond strength of the adhesive.

This work is sponsored by Owens Corning®, Compton, CA

Background & Goal

Asphalt roofing shingles are fiber-reinforced composite laminates made by saturating and coating a fiberglass mat with hot, filled asphalt, applying ceramic-coated mineral granules to the exposed surface, and then bonding shingle layers together with polymer-modified asphalt adhesive beads before cutting the sheet into individual shingles.

The laminate adhesive and sealant have high temperature-dependence, and non-Newtonian behavior whose application depends on the interaction of filler loading, and shear during processing.

The properties of the **modified laminate adhesive (MLA)** can be adjusted in plant by changing the temperature, filler percentage, and bead width.

Goal: To reduce Owens Corning's material costs by varying the limestone filler percentage and measuring the MLA bond strength.

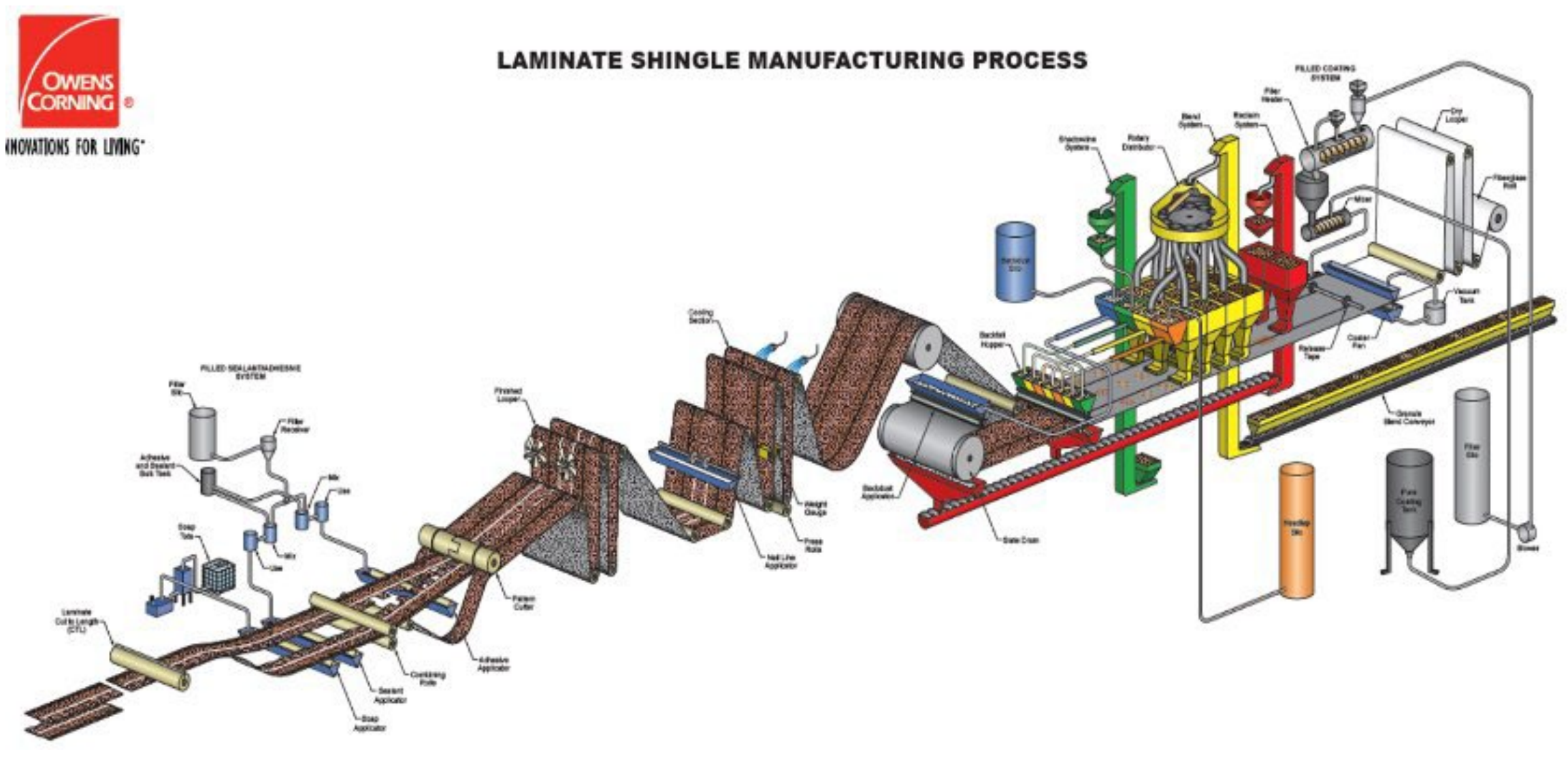

Figure 1. Diagram of the laminate shingle manufacturing process provided by Owens Corning

Experimental Procedures

Design of Experiment

Filler Content (wt.%)	20%, 25%, 30%, 35%, 40%
Bead Width (in)	0.25 – 0.60
Tank Temperature (F)	300 – 310
Roller Separation (in)	3/16

Sample Preparation

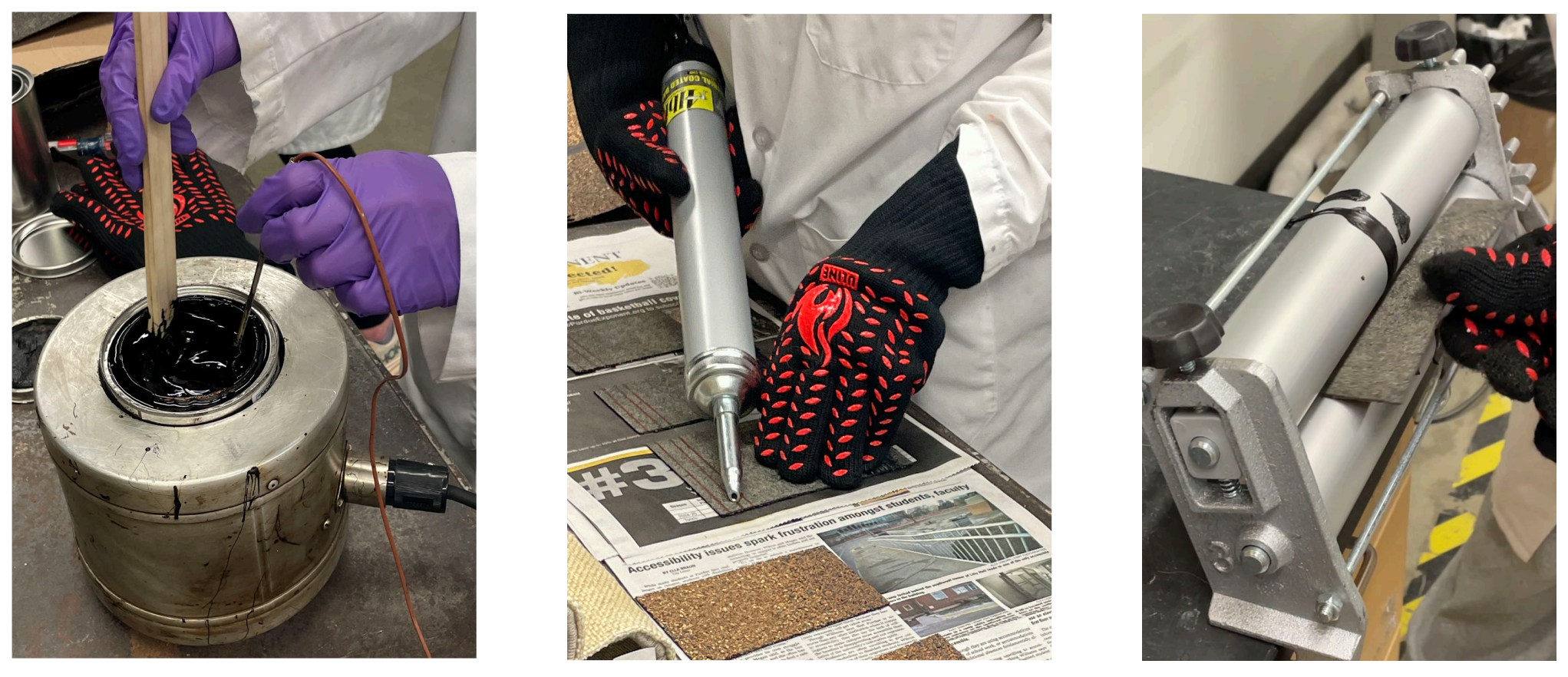

Figure 2. Mixing, Application and Squish Procedures

- MLA mix was heated up to 300-310 °F using a Glas-Col® heating mantle system, ensuring continuous agitation
- Filled sausage gun with MLA mix via suction or pour method
- Applied a bead of MLA mix at a size of ~0.25-0.6" on the shingle
- Placed head lap piece overlaying applied MLA
- Rolled sample through pasta roller (3/16"), applying slight compression to sample

Tensile Testing

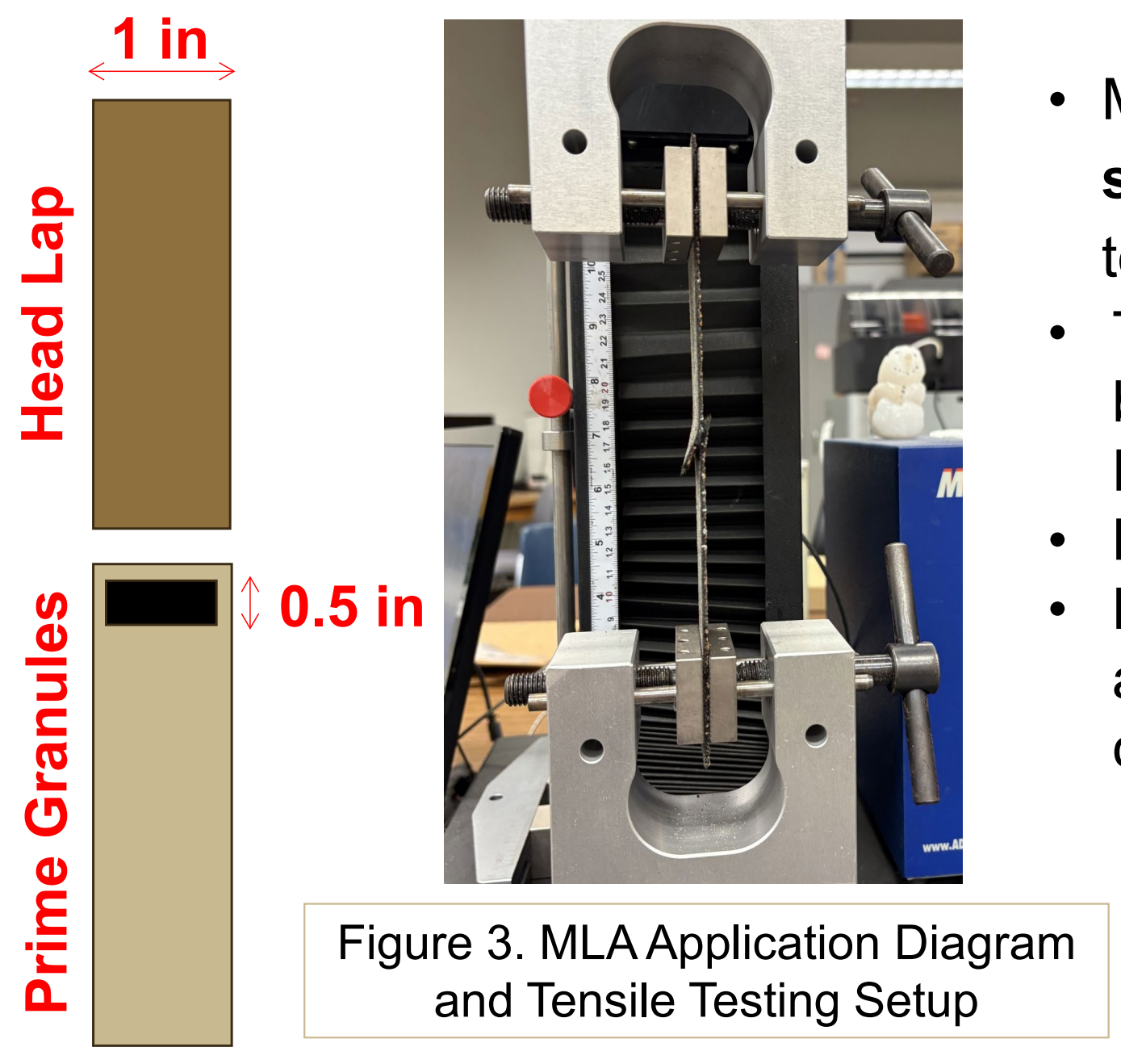

Figure 3. MLA Application Diagram and Tensile Testing Setup

- Measuring **bond strength** (maximum force to break adhesive bond)
- Testing procedures were based on ASTM standard D5868 [1]
- Load cell: 1000lbf
- Measured bead width after tensile testing was completed

5 mm/min	x 3
13 mm/min	x 7

Results & Discussion

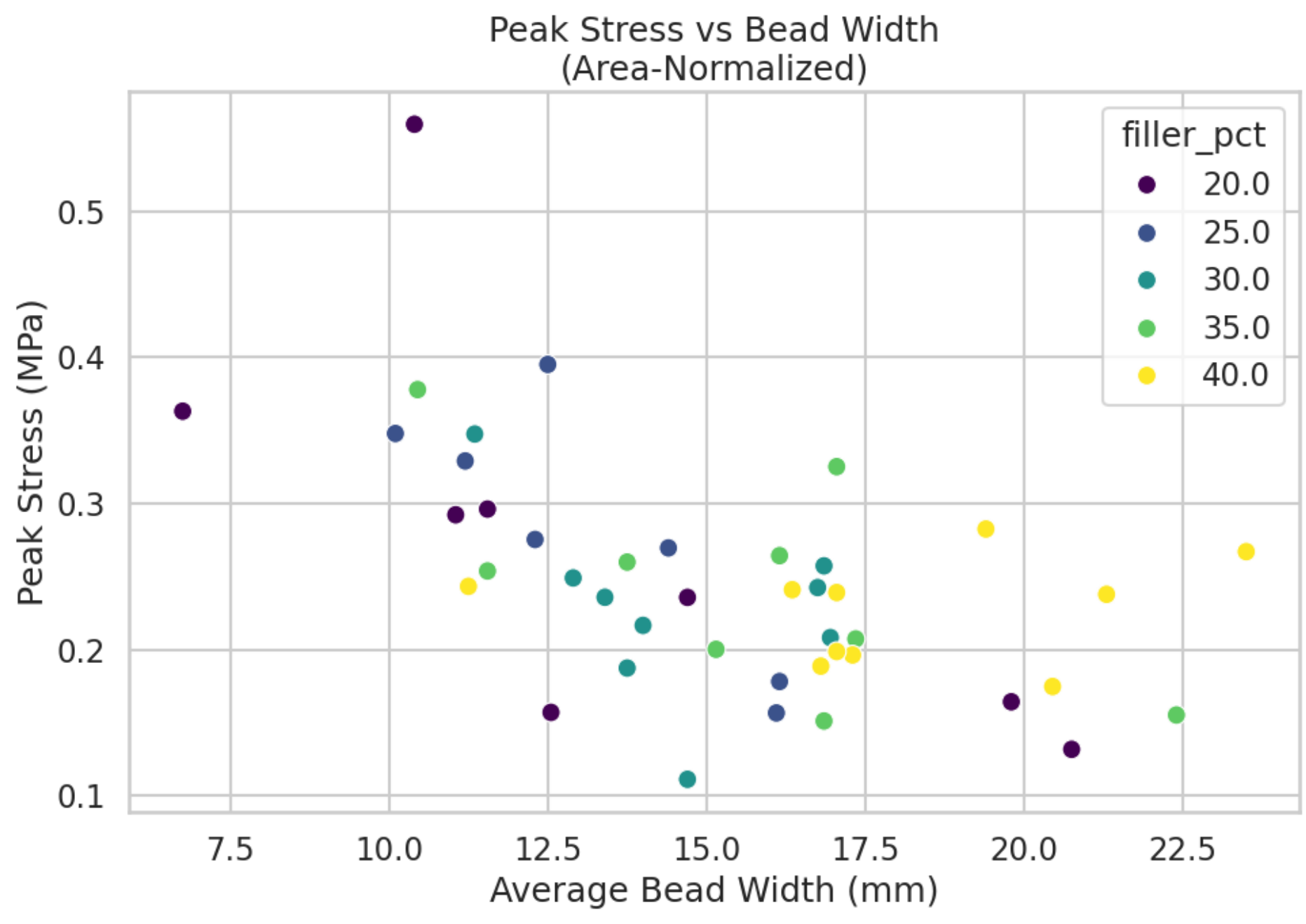

Figure 4. Effect of bead width on peak stress, separated by filler percent

- The bead width generally shows a negative correlation with normalized strength
- At 40% filler, there is no significant correlation between bead width and strength

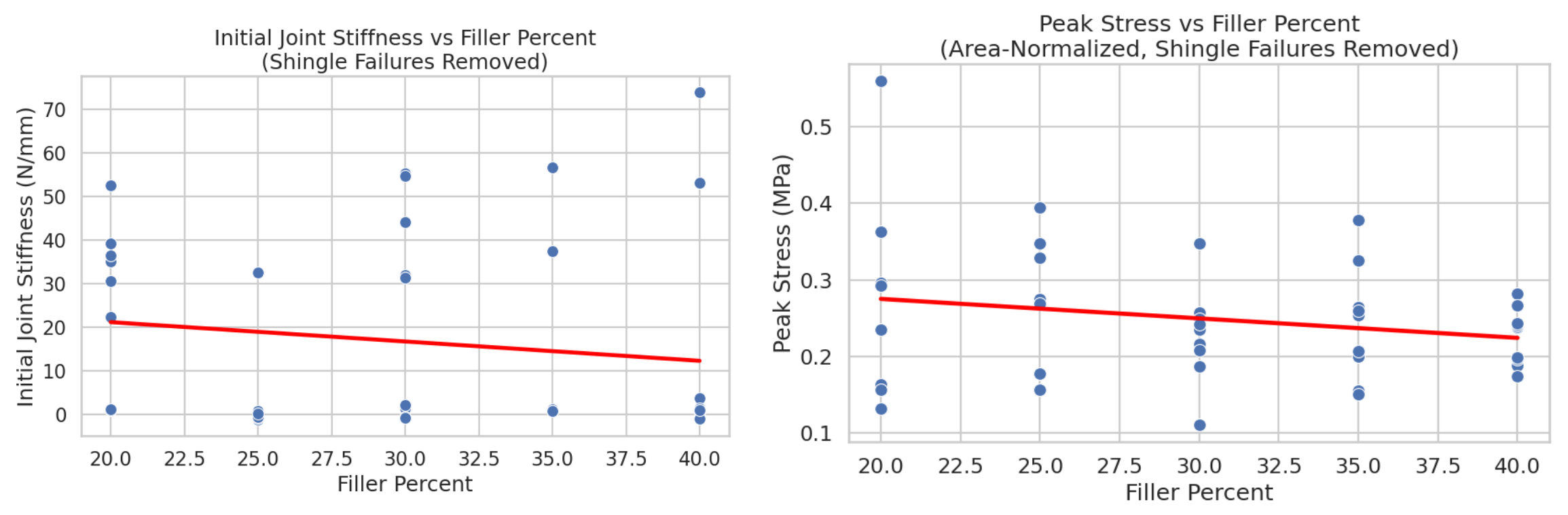

Figure 5. Effect of filler percent on stiffness (left) and peak stress (right)

- Analyzing the correlation between peak stress and filler percent, there are R^2 values of 0.151 at the 13 mm/min testing speed and <0.01 at the 5 mm/min testing speed when outliers are removed
- This aligns with visual analysis of the graph indicating no significant correlation between filler percentage and peak stress

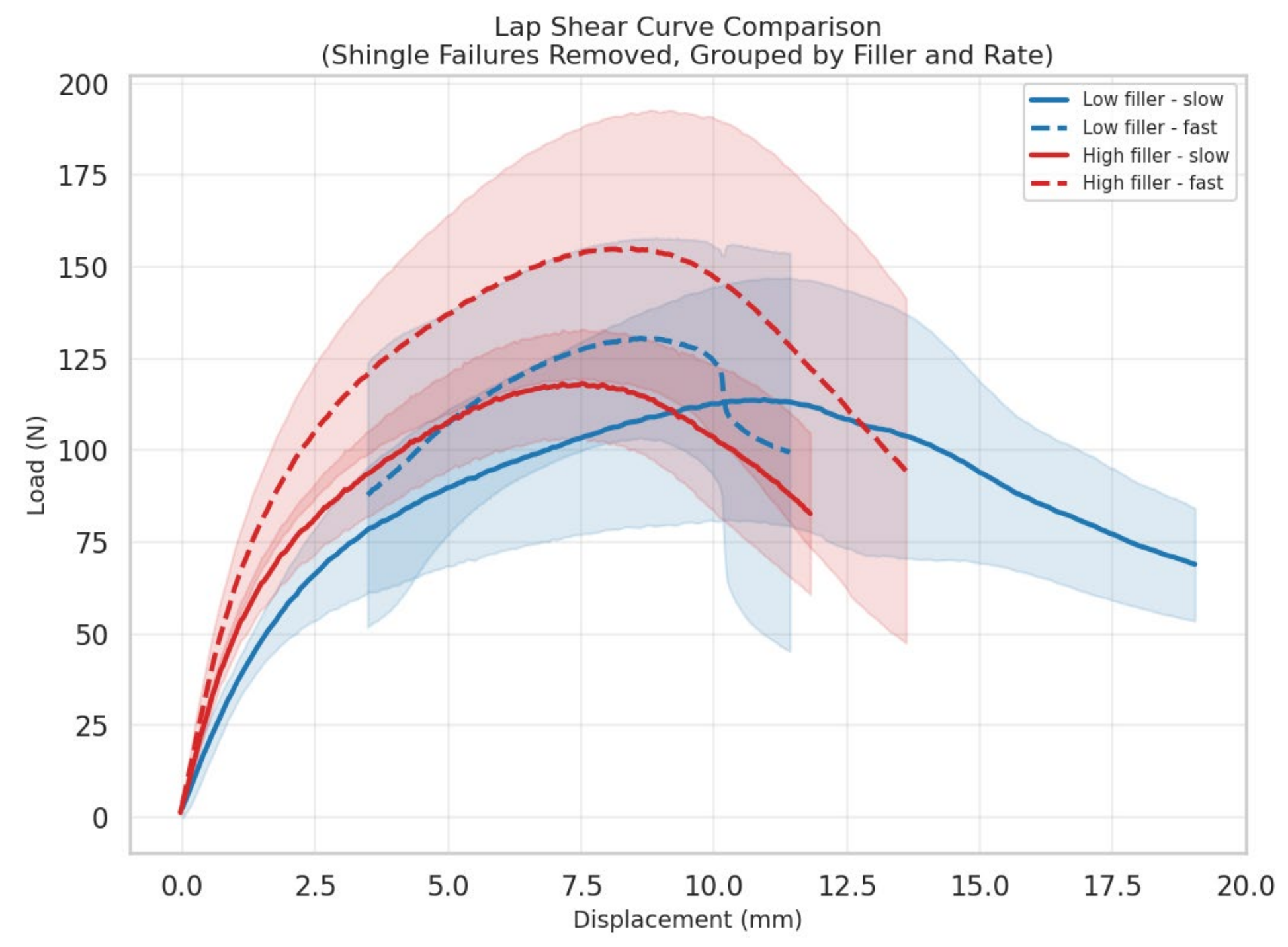

Figure 6. Effect of shear rate on lap-shear curves (dashed is fast, solid is slow)

Table 1. Average peak stress at varying filler percentages and testing speeds

Filler %	Testing Speed (mm/min)	Average Peak Stress (MPa)
20	5	0.151
20	13	0.297
25	5	0.167
25	13	0.305
30	5	0.169
30	13	0.258
35	5	0.169
35	13	0.281
40	5	0.190
40	13	0.243

- There was a significant decrease in peak stress going from 13 mm/min testing to 5 mm/min testing
- At slower loading rates the MLA performs less elastically, preferring to permanently stretch rather than resist the pulling force
- The averages at 40% imply that higher filler amounts exhibit more elastic behavior, although there is not enough test data for a significant result

Conclusions & Recommendations

Lap shear testing of MLA samples with different filler percentages showed that there is no significant correlation between filler percentage and bond strength up to 40% filler added by weight. Based on these results, Owens Corning should be able to **increase the MLA filler content up to 40% in production without decreasing the strength of the shingle**.

The peak stress tends to decrease as bead width increases as the bonds go from being loaded primarily in shear to a cohesive failure mode. Essentially, **there are diminishing returns in bond strength as bead width increases.** Owens Corning may be able to reduce their MLA bond width without seeing significant decrease in performance thus creating material cost savings.

The peak stresses reached in samples tested at 5 mm/min were on average much lower than in those tested at 13 mm/min. This reflects the viscoelastic behavior of the MLA. **Future experiments must consider the significant effect of loading rate on strength results.**

Two methods of cost reduction may be explored based on these experiments:

1. Increase percentage of limestone filler in MLA
2. Reduce bead width

Future Work

Since these were lab scale experiments and the MLA application method was an extremely rough approximation of the shingle production line, **Owens Corning plans to test these recommendations at their Compton plant directly before a planned shutdown**. Their biggest worry is that an increase in filler percentage may lead to issues with MLA application. The viscosity increases as filler is added, and their current application system may not function properly if the viscosity is too high. If this issue arises, this may point to a need to adjust temperature as well to account for viscosity changes.

A lab scale experiment could be run in the future if the viscosity of highly filled MLA is a problem. By characterizing the rheology of filled MLA at higher application temperatures, one could **find the temperature at which the highly filled MLA will flow as well as the less filled MLA** at the current application temperature.

It may also be interesting to experiment on the effects of increased application temperature on bond strength. Work in thermoplastic injection molding has found that increased bonding interface temperature can enhance bond strength by increased interdiffusion [2, 3]. A similar result may be achievable for the asphalt adhesive.

References

1. ASTM Standard D5868-01, 2014, "Standard Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding," ASTM International, West Conshohocken, PA, 2014, DOI: 10.1520/D5868-01R14, www.astm.org.
2. Özel, A.; Soylemez, E. Experimental Investigation of Processing Temperature Effect on Adhesive Bond Strength between Engineering Thermoplastics in the Plastic Injection Molding Process. *Journal of Manufacturing Science and Engineering* **2024**, *146* (10). DOI:10.1115/1.4065847.
3. Persson, A. M.; Hinrichsen, E. L.; Andreassen, E. Adhesion between Thermoplastic Elastomers and Polyamide-12 with Different Glass Fiber Fractions in Two-component Injection Molding. *Polymer Engineering & Science* **2020**, *60* (7), 1642–1661. DOI:10.1002/pen.25408.

Acknowledgements

We would like to acknowledge and thank MaryBeth Tran and Jenny Brzezinski from Owens Corning for providing testing materials, working parameters, and plant tours. We would also like to thank Professor Paul Mort for his support and guidance throughout the project.