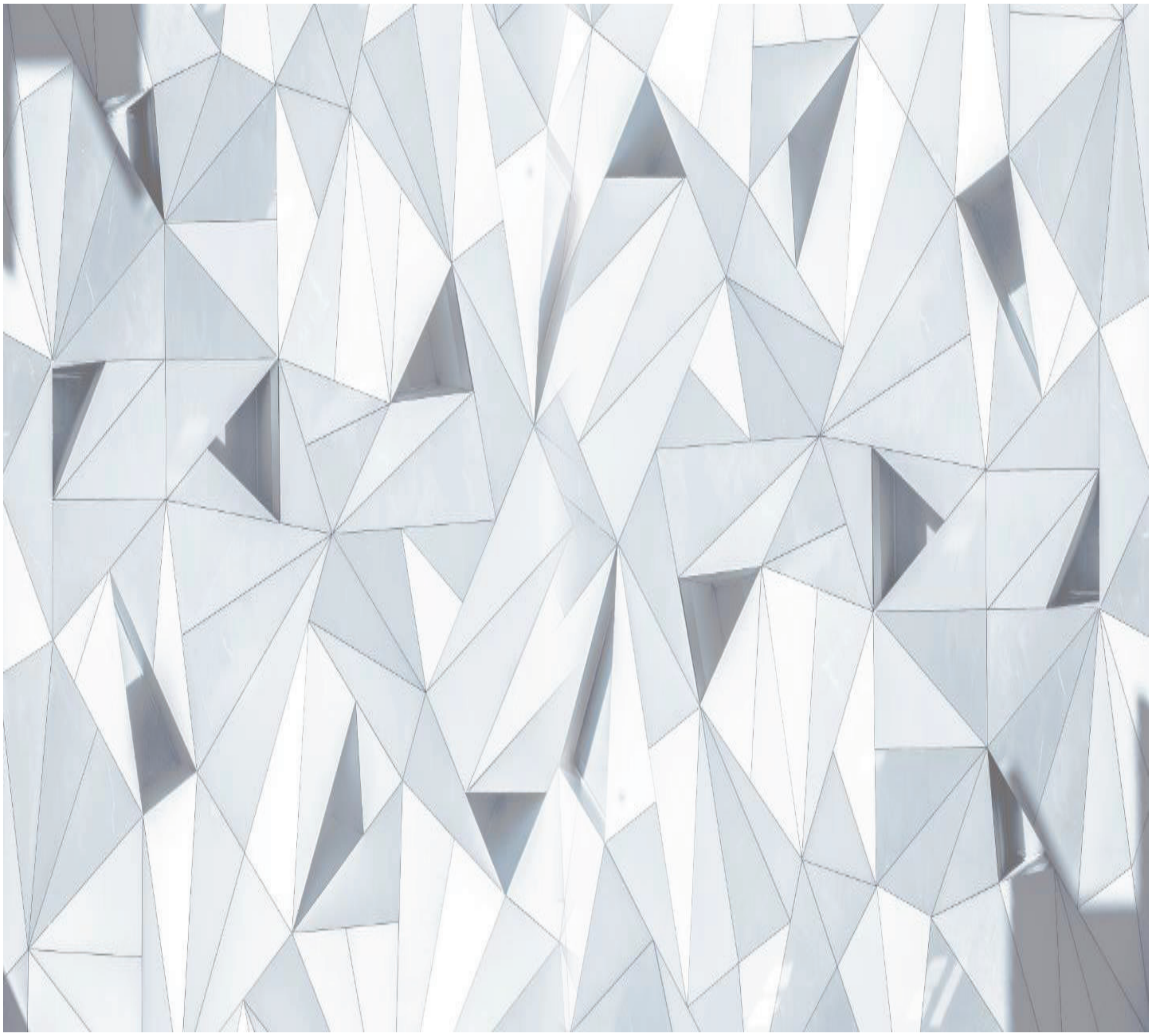
MARCH 2024



EXPANDING CAPABILITIES OF LINERS FOR PIPE REHABILITATION PROJECTS

BROUGHT TO YOU BY: INNOVATIONS AMPLIFIED

THE ACCEPTANCE OF RELINING PIPES is expanding as a reliable solution for aging infrastructures. In recent years relining project costs have experienced some dramatic increases in raw material costs. The aging infrastructure of municipalities has increased the number of needed projects and every dollar assigned to these projects is being stretched. A good way to stretch every dollar to cover the increased number of projects is to generate sustainable and repeatable cost saving measures. This is challenging with the give and take nature between low pricing and high-quality materials that provide a reliable performance in keeping with current technology and engineering requirements. How well these choices are implemented determines the longevity of the cost savings. One aspect that can be a driver for combating costs is the type of liner used for a relining project. There is a direct correlation between the thickness of a liner and the amount of resin that is required to saturate the liner. A thinner liner allows for use in small diameter pipes. While most of the strength of a relined pipe is achieved through the resin, there is a need to retain the strength thicker liners provide.

In this paper we will discuss:

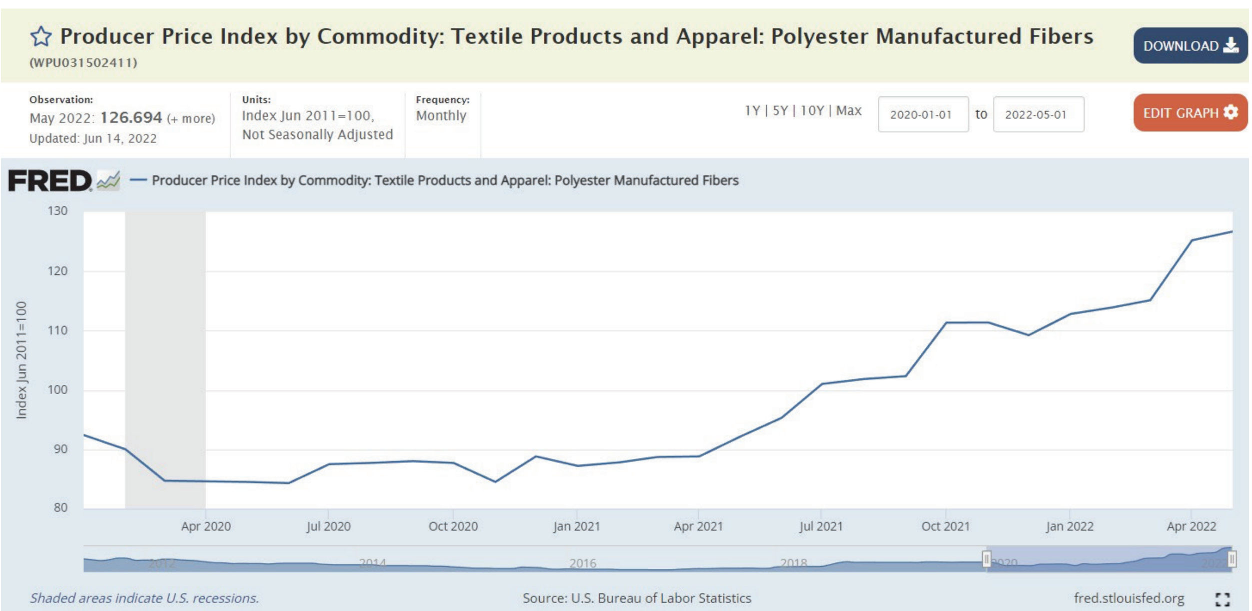
- Driving costs of raw materials used for relining pipes
- Differences between hybrid layered liners and hybrid homogenously blended liners
- Cost saving analysis using hybrid homogenously blended liners
- Conclusions and future use of reclaimed fiberglass in liners

DRIVING COSTS OF RAW MATERIALS USED FOR RELINING PIPES

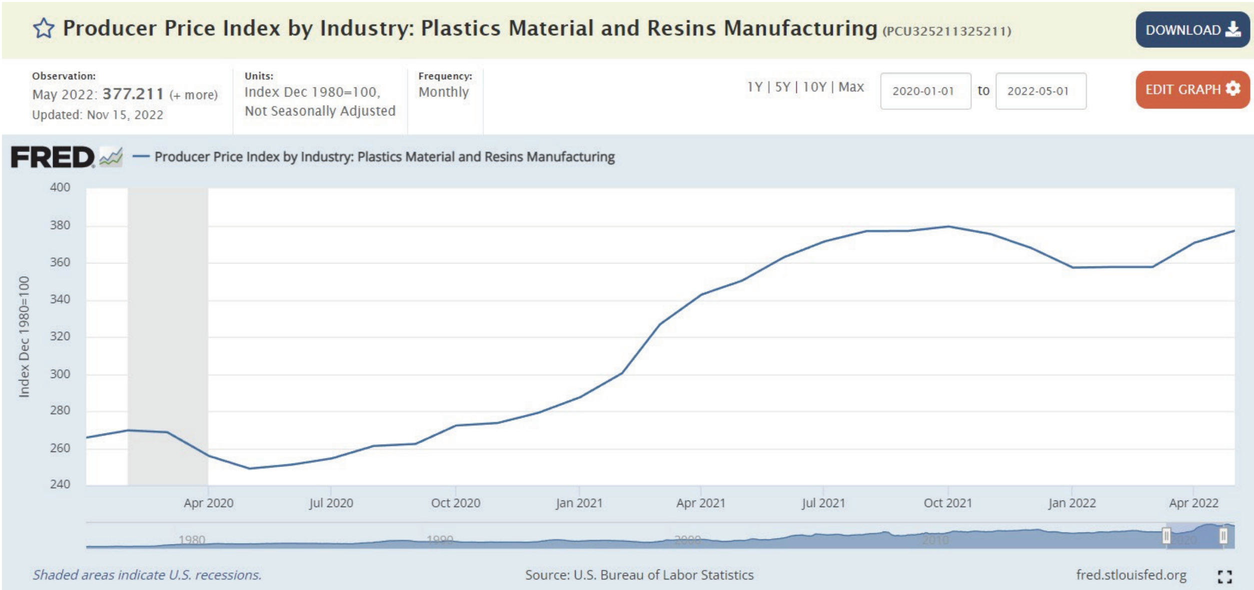
The two constituent raw materials in **C**ured **I**n **P**lace **P**ipe relining are polyester felt and resin. Resin infused liners are typically pulled through large diameter pipes or inverted into small diameter pipes before curing. Structural strength of a relined pipe is mainly provided through the resin. Incorporation of strength into liner materials was introduced with the use of woven fiberglass liners. While the use of woven liners answered the need for additional structural strength, they are difficult to invert. Layered hybrid liners occupy the middle ground between 100% polyester felt and 100% woven fiberglass liners, however, layered hybrid liners are also problematic to the inversion process.

Raw material trends: Rising Costs are rampant

The charts below show the pricing tend for the two constituent raw materials that are the building blocks of CIPP, Polyester fiber & plastic resins.



Polyester pricing realized an increase of ~37% between January 2020 and May 2022



Plastic resin pricing increased ~42% between January 2022 and May 2022

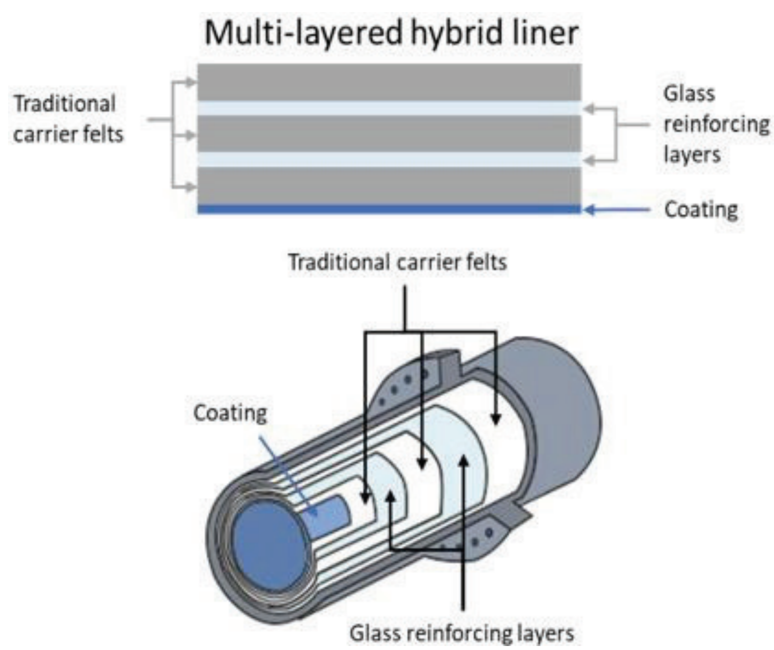
Woven and hybrid layered liners using glass and glass products have also experienced rising prices.

Glass & glass products have increased ~13% between January 2022 to May 2022

DIFFERENCES BETWEEN LAYERED LINERS AND HOMOGEMOULY BLENDED LINERS

Traditional CIPP methods & materials

Traditional CIPP felt uses 100% polyester as the carrier fiber and adds little to no strength to the liner yet is flexible and works well with the inversion process.
Woven glass or glass mat layers are used to meet strength requirements where appropriate. The stiffer liners are difficult to invert for small diameter pipes. The diagram below shows the aspects of a hybrid layered liner.



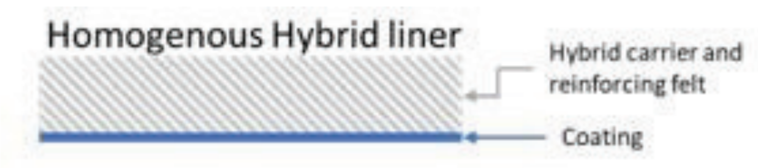
The common reinforcement layer used with multi-layered polyester felt liners is fiberglass. Hybrid felt is not limited to glass alone and can use other fibers to meet engineering specifications for unique relining projects. Other fiber materials can be layered or homogenously blended with polyester to meet strength requirements for unique industrial applications.
Adding reinforcement fibers in layers changes the handling characteristics of the liner which

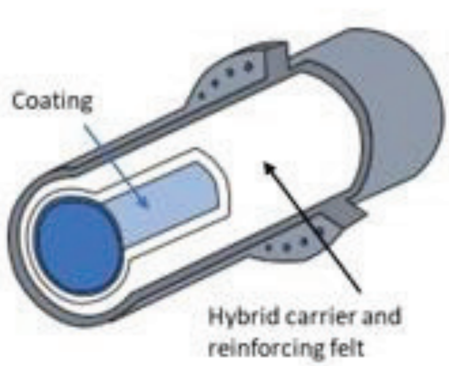
limits common methods used for wet out and installation.

An alternative option is to homogenously blend less-expensive staple glass fiber with the polyester fiber during the needle-punching process creating a hybrid felt material.

Homogenously Blended Hybrid Felts and their benefits

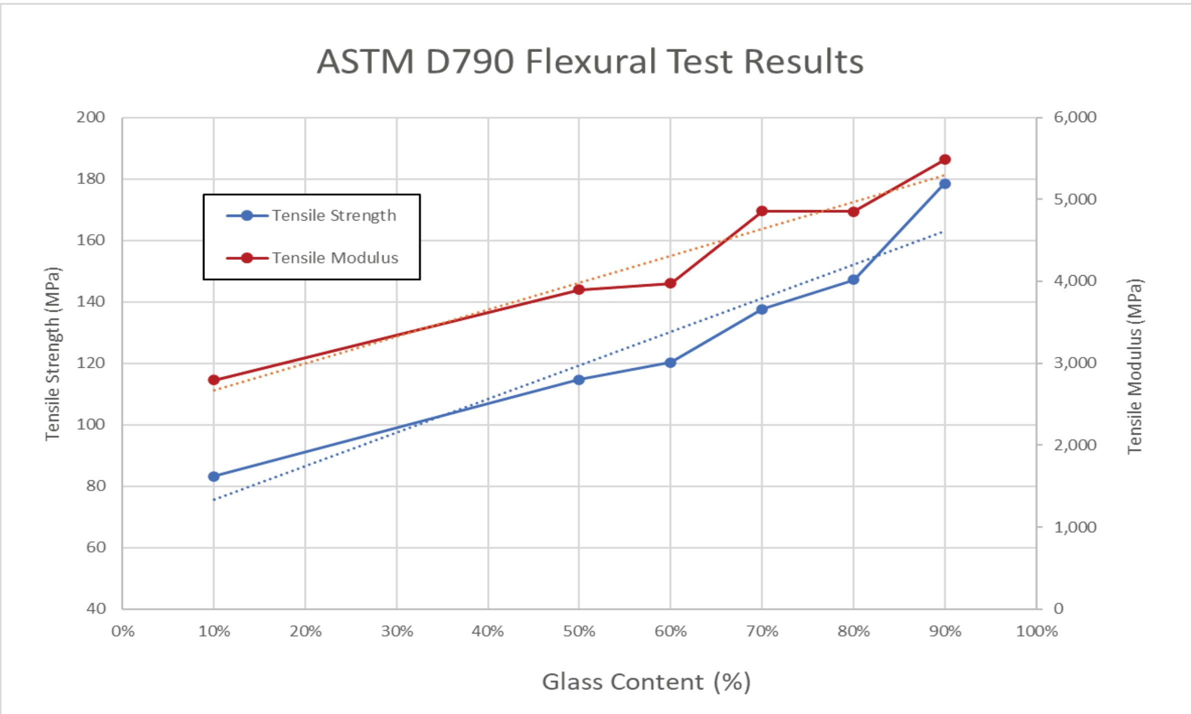
The distinctive qualities of homogenously blended hybrid felt material is accomplished through a manufacturing process using In-line blending. This process eliminates bulky layers that are difficult to invert. In-line blending forms a single layer combining polyester and reinforced fibers creating a thinner more flexible hybrid felt material that is structurally strong and flexible for inverting. The thinner liner makes it the ideal choice for small diameter pipes. The in-line blending can be used to create various thickness of liner to meet engineering requirements for large diameter pipes as well.





Manufacturing trials were performed using In-line blending of staple polyester and staple glass at various percentages. ASTM D-790 Flexural testing was performed on the cured 100% polyester felt and homogenously blended hybrid felt laminates. Flexural strength represents the highest amount of stress the material will experience at the moment the material yields and breaks. Modulus testing indicates the ratio of applied stress and the amount of displacement or deformation in the linear elastic area of the object material.

Initial test of In-line blending was conducted and the results were very positive.

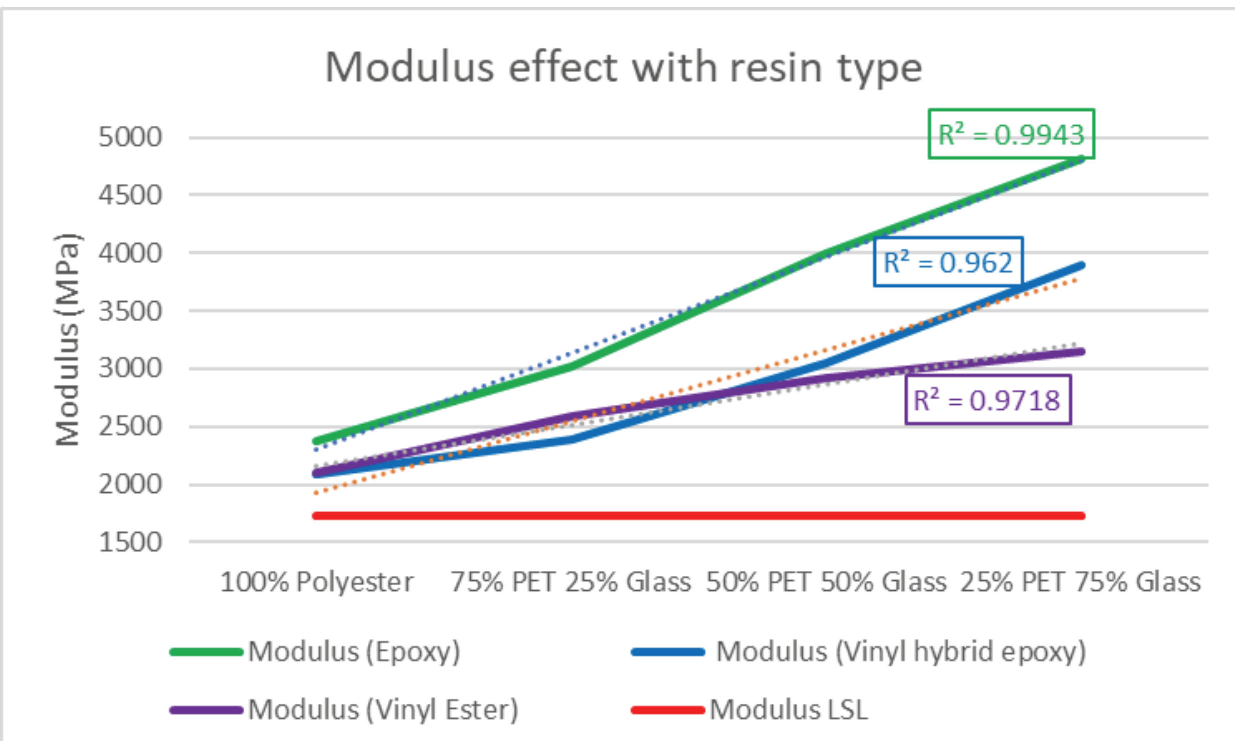


The flexural strength showed ~ a 2X improvement with 50% glass blended and the modulus showed ~60% improvement with 50% glass blended.

Homogenously blended Hybrid felts & characterization – Flexural Modulus

There are many factors that can impact the performance for the flexural strength and modulus. The first factor that was investigated was resin type. Resins vary greatly in price and performance. Three commercially available CIPP resins were chosen for these tests: a styrenated vinyl ester, a non-styrenated vinyl hybrid and a 2-part epoxy system. All were cured using the manufacturer's recommended processes.

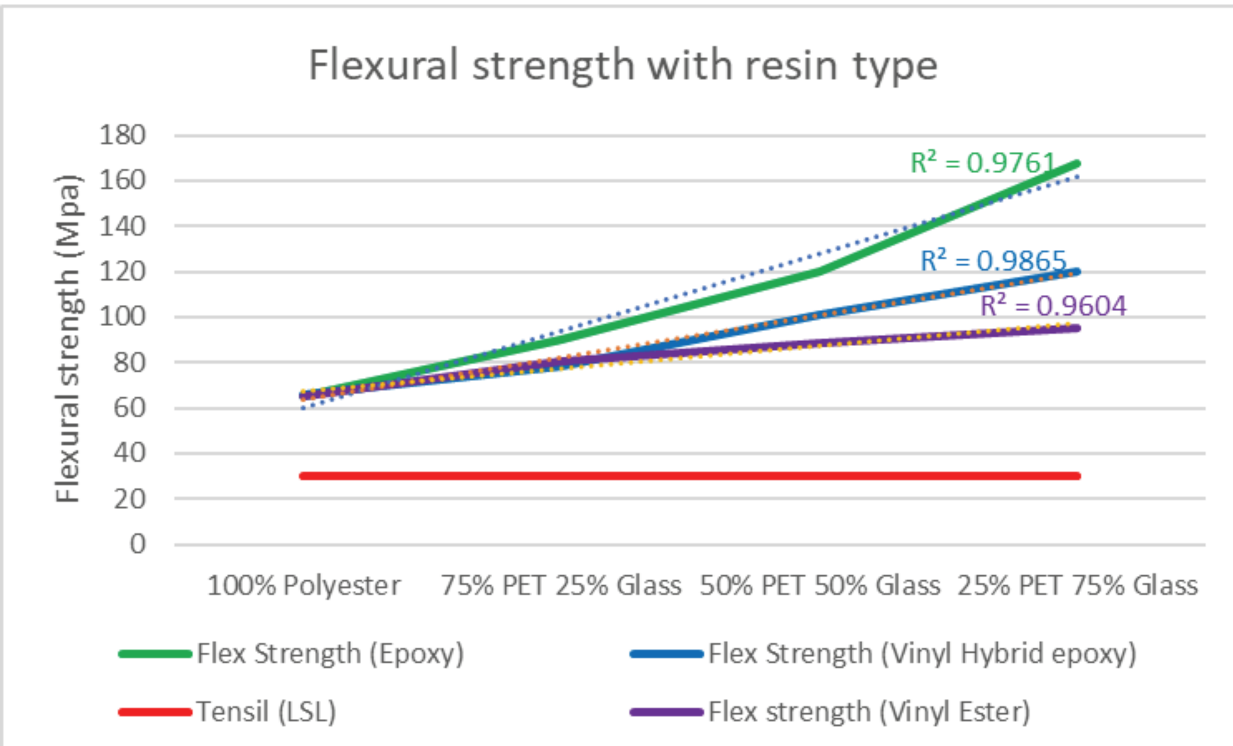
Felt consisting of 100% Polyester using each of the three resin types has the lowest result. Homogenously blended Hybrid felt consisting of 75/25 Poly/Glass, 50/50 Poly/Glass and 25/75 Poly/Glass improved in Flexural Modulus respective to the type of resin used.



Modulus improved ~38% with 50% glass and vinyl ester resin.
Modulus improved ~52% with 50% glass and vinyl hybrid resin.
Modulus improved ~67% with 50% glass and epoxy resin.

Homogenously blended Hybrid felts & characterization – Flexural Strength
The flexural strength also moves significantly with glass inclusion and resin type.

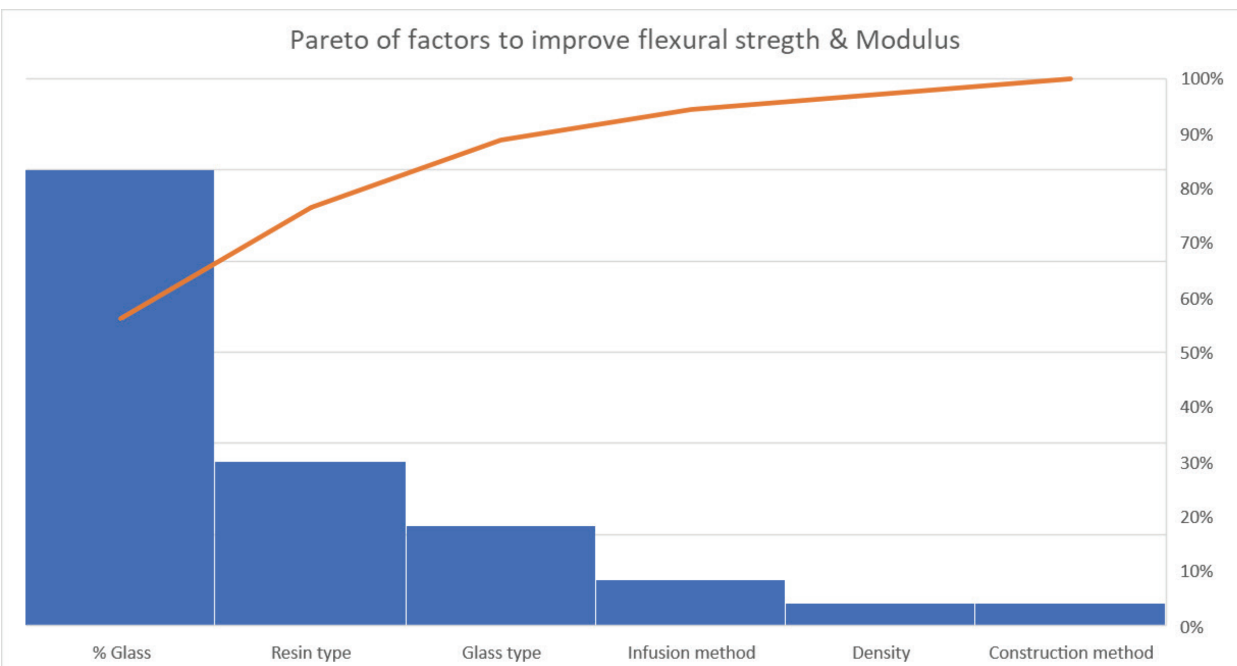
Felt consisting of 100% Polyester has the lowest result in Flexural Strength using each of the three resin types. Homogenously blended Hybrid felt consisting of 75/25 Poly/Glass, 50/50 Poly/Glass and 25/75 Poly/Glass improved in Flexural Strength respective to the type of resin used.



Flexural strength improved ~36% with 50% glass and vinyl ester resin.
Flexural strength improved ~54% with 50% glass and vinyl hybrid resin.
Flexural strength improved ~85% with 50% glass and epoxy resin.

Optimizing Homogenously blended Hybrid felts

The homogenously blended hybrid felt consists of several aspects to optimize the best combination. The controlling factors of the overall manufacturing process from raw felt to finished tube were considered. These aspects include the following areas: The ratio of glass staple fiber in relation to the felt. The type of resin used and the results of each resin in relation to the felt and glass ratio. Different glass fiber types were tested to find the optimum combination, including commonly available and glass typically specified for pipe relining. Different methods of felt wet out or resin infusion were tested. Factors of the felt density and arial weight used in the industry. The chart below shows the percentage each aspect of the homogenously blended hybrid felt has on the improved flexural strength and modulus.



Optimizing glass percentage, resin type and glass type produces the desired performance & savings.

Homogenously blended Hybrid felts and other tangible benefits

UV-curable liners:

Glass fiber is transparent to light and typical UV-curable liners are made of higher cost woven glass fabrics. Compared to 100% polyester felt, Hybrid glass/polyester felts would add optical clarity to help speed cure and take advantage of the core strengthening given while reducing resin usage and material cost. UV curing trials and testing are planned for 2024.

Liner coatings:

Hybrid felts readily accept common coatings, such as PU and PVC in a variety of coating thicknesses and are easily sewn into tubes without modifying equipment or processes.

Liner installation and cure methods:

Hybrid felts can also be used in pull-in-place or inversion installations, making them ideal for hot water, steam, or UV curing processes.

Thinner liners:

Using hot water, steam or UV, thinner liners could be used to provide the equivalent strength with additional flow capacity of the inside pipe diameter. Thinner, stronger hybrid felt liners also lend themselves to smaller diameter pipe rehabilitation.

Hybrid felts – Repeatability and Sustainability

Hybrid felt material combines industry standard types of readily available polyester and fiberglass. Existing supply channels are utilized resulting in consistent sustainable manufacturing. Coating and seaming and sealing the homogenously blended hybrid felt material into desired tube dimensions results has a dependable repeatable supply.

COST SAVING ANALYSIS USING HOMOGENOULY BLENDED LINERS

Homogenously blended Hybrid felts – Value proposition

In the final CIPP tube product, how much of the composite is resin and how much is fiber?

In burn-off tests after infusion, the resin is generally 80-90% weight and the fiber is generally 10-20% weight.

Resin can cost up to 5X or more the equivalent of the fiber portion of the product. Reducing resin usage therefore is key.

With flexural strength and modulus being key components of the final product, this performance boost makes reduced resin usage possible.

Homogenously blended Hybrid felts – Cost example

Assumptions:

- Liner cost per foot = $2.20 (Felt, coating, seaming & sealing)
- Resin cost per pound = $9
- Resin % weight per linear foot = 85%
- Felt base weight = 12opsy

The pipe diameter for this example is 8”

Calculations:

- Felt material weight = 0.174 lbs (15% of total weight)
- Resin material weight = 0.96 lbs (85% of total weight)
- Resin cost would be = (0.96lbs x $9) = $8.62
- Total cost per linear foot = ($8.62 + $2.20) = $10.82

Homogenously blended Hybrid felt – cost example

Modulus and flexural strength improve by 50%. To get the same performance the resin content can be reduced by 33%.

- Total cost per linear foot = ($5.78 + $2.20) = $7.98
- Total savings of 26% or $2.84 per linear foot.

Conclusions

Material costs for CIPP rehabilitation have been rising constantly in recent times. Planning a response to the rising costs of the two major constituents used in pipe rehabilitation impacts how a municipality prioritizes and plans infrastructure projects effecting their citizens. Implementing the use of homogenously blended hybrid felt materials can create a pathway for funding dollars to be used towards an expanded number of CIPP infrastructure projects. Homogenously blended Hybrid felt materials have improved flexural strength up to 160% (with 75% glass content) and flexural modulus up to 95% (with 75% glass content). These results expand the use of the homogenously blended hybrid felt material to include projects with unique or complex requirements not met by traditional felt or multi layered hybrid felts.

FEASIBILITY of a repeatable and sustainable homogenously blended hybrid felt material is practical. The manufacturing process using staple polyester and glass fibers does not change the handling characteristics of the liner.

COST EFFICIENCIES of 25 to 35% on liner and resin systems materials is achievable. This is the equivalent to $3 to $4 per linear foot on an 8" CIPP project.

FUTURE GREEN SUSTAINABILITY

Further cost reductions and sustainability may be gained by using recovered glass from end-of-life wind blades. Approximately 3,000 wind turbine blades are de-commissioned each year and destined for landfills. Reclaiming these de-commissioned blades for use in a municipalities CIPP infrastructure project can be beneficial for all. Manufacturing trials and mechanical testing began in the first quarter of 2024.