

Matthew Green, Director of Technical Service, CSNRI, considers the past, present and future of engineered composite repair systems for pipelines.



pipe is a pipe, and they all look the same. But national transmission pipelines and piping networks within processing facilities and refineries are critical components of a country's infrastructure. Transporting essential resources

Catching up with **COMPOSITE REPAIR**



such as oil, gas, and water across vast distances, pipelines serve to provide a safe and successful journey for their contents. Maintaining pipeline integrity is paramount to ensuring safety, efficiency, and environmental protection remains at the highest levels. Traditional repair methods often involve extensive downtime, costly materials, and significant labour. However, for the past three decades, engineered composite repair systems have emerged as a solution, offering advantages in durability, cost-effectiveness, speed, and ease of application. CSNRI continues to push the boundaries on the capabilities and understanding of these highly beneficial materials.

Understanding engineered composite repair systems

The history of engineered composite repair systems for pipeline repair dates back to the late 20th century, when the need for more effective, durable, and non-intrusive solutions became evident as ageing infrastructure began



Figure 1. Pipe sample set up for a large-scale bend test to determine the effectiveness of composite repairs for reinforcement in bending such as in geohazard events.

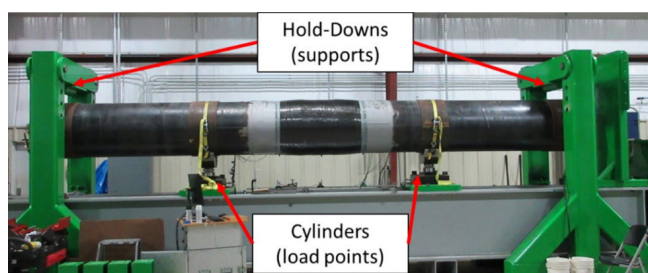


Figure 2. Composite repair and set up for a large-scale bend test.

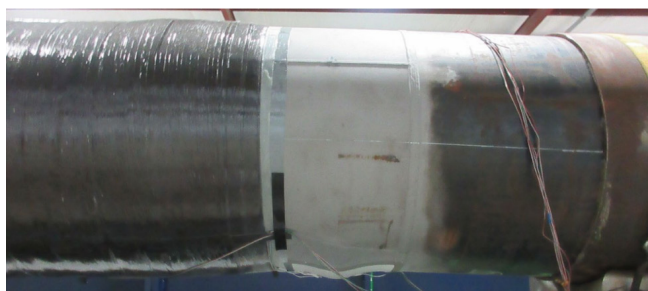


Figure 3. Results show good contributions of the composite repair system to the point that deformation occurred outside of the repair area.

to pose significant challenges in various industries. Initially, traditional repair methods like welding and cut-and-replace were common, but these approaches often resulted in extended downtime and increased costs. In the 1980s, advancements in composite materials, particularly fibre-reinforced polymers, began to transform the landscape of pipeline repair. These engineered composites offered superior strength-to-weight ratios, corrosion resistance, and the ability to conform to complex shapes. By the 1990s, standardised repair systems emerged, enabling operators to address pipeline integrity threats efficiently while minimising disruption to services. Followed in the next decade by the formalisation of industry standards such as the ASME PCC-2 Article 4 and ISO 24817, and the acceptance and use of these materials began to rapidly increase. Today, composite repair systems are widely recognised for their effectiveness and longevity, and they continue to evolve with advancements in material science and engineering, further enhancing their role in pipeline integrity management.

Engineered composite repair systems consist of high-performance materials designed to restore the integrity of damaged pipelines. These systems typically utilise a combination of advanced fibres, resins, and adhesive technologies to create a composite material that is both strong and flexible. The most commonly utilised materials for these systems include:

- Fibreglass reinforced polymer (FRP): Offers a high strength-to-weight ratio and excellent corrosion resistance.
- Carbon fibre reinforced polymer (CFRP): Provides superior tensile strength and modulus, making it ideal for high-stress or high-strain applications.

The composite systems are engineered to bond to the existing pipeline substrate, effectively creating a new load-bearing structure that can withstand operational stresses. The bonding agents vary depending on the need of the repair system, but typically include polymers such as epoxies, urethanes, or polyesters.

Advantages of composite repair systems

Composite repair systems offer a range of significant advantages that make them increasingly popular as a staple in the toolbox of pipeline integrity programmes.

- Rapid deployment: One of the primary benefits of engineered composite repair systems is their quick application. Unlike traditional repair methods, which may require extensive excavation and replacement of pipeline sections, composite systems can often be applied directly in situ. This reduces downtime and allows for expedited restoration of service.
- Cost-effectiveness: Engineered composite repairs can be more economical than conventional methods. The materials and processes used can lead to significant cost savings, especially when factoring in reduced labour and operational disruption. Additionally, the longevity

of composite materials often translates into lower maintenance costs over time.

- **Durability and longevity:** Composite materials exhibit excellent resistance to corrosion, chemicals, and environmental factors. This inherent durability enhances the lifespan of the repaired pipeline, reducing the frequency and cost of future repairs, and in many cases, are considered permanent.
- **Versatility:** Composite repair systems can be applied to various types, sizes and geometries of pipelines, including those made of steel, fibreglass, and concrete. They are suitable for a range of environments, including offshore, underground, and industrial applications.
- **Environmental safety:** Composite systems are often less invasive than traditional methods. Their application typically requires minimal excavation, which reduces the risk of environmental disruption. Furthermore, many composite materials are designed to be environmentally friendly, contributing to safer operations.

A history of testing and validation

With three decades of testing and experience behind them, composite materials are continuing to prove their value. There have been a variety of ways in which today's commercially available products have had their origins. Many have funded significant independent testing on their systems, but also the industry at large has had a hand in many testing programmes over the years. Multiple Joint Industry Programmes (JIPs) have been held and either fully or partially funded by pipeline owners, as well as repair system suppliers.

While the previously mentioned standards from ASME and ISO have a good basis of qualification testing, for the repair of transmission pipelines, there are a variety of defect-specific needs that are not fully addressed. Many of the testing programmes held over the years have been to validate the usage of composite repairs on these defect-specific scenarios, and in many cases, including the use of pressure cycling as part of the test method to determine the real-world effects on the repair system as it would be in service. This is especially critical for regulated pipelines. One such large programme was the PRCI (Pipeline Research Council International) research study, "Assuring the Permanency of Composite Systems for the Repair of Corrosion and Mechanical Damage (MATR-3-3) (MATR-3-4)" which was conducted to validate the long-term usage of composites. This project subjected a multitude of composite repairs to a 10 year study in full operational conditions, where many of the repairs maintained the integrity of 75% deep metal loss defects under 900 annual pressure cycles and then were subjected to a burst test where failure initiated outside of the repair.

Many other similar such programmes have been executed to either determine the viability of or quantify the effectiveness of composite repairs for specific defects.

These have included:

- General external corrosion.
- Internal corrosion.
- Corrosion in weld seams.
- Mechanical damage.
- Cracking and crack-like defects.



Figure 4. Sections of pipeline with crack-like defects sent to CSNRI for testing.



Figure 5. Repaired crack-like defects ready for pressure testing.

- Axial reinforcement (geohazard, girth weld, and wrinkle bend).

While there have been significant programmes for corrosion and mechanical damage, some of the more recent testing mentioned has focused on crack-like defects, and axial reinforcements, specifically for reinforcing girth welds to prevent failure in potential geohazard events.

Composites in the real world

Theory and testing are a great foundation for technologies, but without real world usage, what good are they? Many independent testing programmes have been funded or co-funded by the pipeline operators who are looking to qualify or in some cases expand the scope of usage of composite repairs within their operations.



Figure 6. Successful testing with failure outside of the repaired area proved the effectiveness of the Atlas composite repair system.



Figure 7. Reinforcement of a girth weld with the Atlas UA carbon fibre repair system in a region with active geohazard threats.

Repair of crack-like defects

A pipeline company that had previously implemented composite repairs for various defects, including small-scale crack-like anomalies, undertook an evaluation to expand the application of composites to encompass longer defect lengths and interacting features in vintage seam welds. Composites had consistently demonstrated superior performance compared to traditional repair methods, and this extension of the application envelope for composites on seam weld anomalies was projected to yield significant economic benefits. Following a comprehensive testing programme utilising CSNRI's Atlas carbon fibre repair system, the operator revised their Standard Operating Procedures (SOP) to include specifications for longer and interacting defects. This modification facilitated the successful execution of multiple repairs, thereby enhancing pipeline integrity and optimising maintenance expenditures.

Reinforcement of girth welds for geohazard events

In a challenging geohazard area with multiple landslides occurring simultaneously, a pipeline operator successfully utilised Atlas UA to reinforce its girth welds, eliminating the risk of a rupture during a landslide. Recognising the risks posed by shifting soils and potential landslides, the engineering team implemented Atlas UA's patented advanced composite technology, which provided exceptional strength in the axial direction of the pipeline, improving the tensile strain capacity of the girth weld. This solution not only improved the welds' resistance to environmental stresses but also streamlined the repair process, significantly reducing downtime. The application of Atlas UA exemplified a proactive approach to pipeline integrity management against emerging integrity threats, ultimately safeguarding both the pipeline's operation and the surrounding ecosystem.

Considerations for composite repair

While engineered composite repair systems offer numerous advantages, there are also considerations that engineers and operators must consider to ensure their successful implementation into their procedures. Full testing validation and qualification should be a given as discussed above, but what else may need to be considered?

- Material and environmental compatibility: Composites are a versatile technology, and by implementing different types of polymers, they can accomplish a wide range of chemical and environmental compatibility. Thorough testing is essential to avoid adverse reactions that could compromise repair integrity based on the operating environment and conditions.

Environmental conditions, such as temperature and humidity, can impact the curing process and overall effectiveness of composite repairs. Proper planning and monitoring are crucial during application. Whether it is chemical or temperature, knowing the limits and functionality of the repair system and its components is vital.

- **Regulatory compliance:** Engineers must ensure that all repairs comply with industry regulations and standards. This may involve documentation, testing, and certification processes that can be time-consuming. By implementing a sound SOP around the use of composite repair systems, it can provide a working structure that allows for the effective implementation of these materials into integrity management plans.
- **Training and expertise:** Successful application of composite repair systems requires trained personnel with expertise in the materials and techniques used. Investment in time for proper training is necessary to maximise the benefits of these systems. CSNRI has pioneered this effort to provide the best training programmes and platforms for the successful training of all installers of their composite repair systems.

Conclusion

The evolution of engineered composite repair systems has transformed pipeline maintenance, offering significant advantages over traditional methods. As the demand for reliable infrastructure increases, the application of these advanced materials will play a vital role in ensuring the safety and efficiency of pipelines. The successful testing and validation of composite systems have established a solid foundation for their use in a variety of scenarios, from addressing crack-like defects to reinforcing critical welds in geohazard-prone regions. As operators continue to adopt these innovative solutions, they must also remain vigilant about the considerations necessary for effective implementation. Ensuring material compatibility, adhering to regulatory standards, and providing thorough training for personnel are crucial steps in maximising the benefits of composite repairs. Ultimately, the strategic deployment of engineered composites not only enhances pipeline integrity but also contributes to long-term economic savings and environmental protection, solidifying their place as a cornerstone of modern pipeline integrity management practices. As the technology advances, further innovations are expected, promising even greater enhancements in pipeline reliability and performance. 