

THE FUTURE OF COMPOSITE REPAIR



Matthew Green, CSNRI,
USA, explores using today's
technology and testing
know-how to make a better
repair option.

Pipeline integrity repair is a critical component to the safe and effective operation of pipeline assets, and composite repairs play an ever-increasing role in providing repair options. This article will discuss composite repairs and how design methodologies, experience, and testing continue to fuel more widespread acceptance, additional

defect scopes, and continuous improvement of the composite repair implementation process.

New technology

For almost four decades, composite repair technologies have provided valuable alternatives to operating companies in maintaining the integrity of their

high-pressure gas and liquid pipeline systems. Early adopters of the technology helped to push the usage of these beneficial materials to where they are today. As with all technology, increased usage drives increased scope of usage, and there have been extensive and comprehensive full-scale testing programmes dedicated to pushing the boundaries and opening new defect repair options. These have been funded jointly by industry and manufacturers, and have yielded successful results, further showcasing the full range of benefits that composite materials can provide. This is valuable as it provides a strong foundation for using composites as a repair material in this manner.

The benefit of this history and background is that we can build a better repair option based on experience and lessons learned. Why settle for the same old technology with no updates, current testing, or product improvements, when you can use the latest in innovation and performance with composite materials? While it might be a unique experience to drive a Ford Model T to a car show and have some fun, you aren't going to use that for your everyday travel and work needs. I'll take my F-150 King Ranch for that, thanks. But on the other hand, you also want the 'latest and greatest' to be proven, and that's where the testing, validation, and verification come into play. At CSNRI, our company is proud to be at the forefront of innovation and improvement for ECRSystem™ (engineered composite repair systems) and composite technologies for the oil and gas industry.

While composites are not new in and of themselves, relative to traditional welding repair techniques, composites are still considered a 'new' technology for most pipelines. There have been mixed adoption rates from the industry, with some pipeline operators using them for a wide range of repair needs, while some companies still have yet to embrace the beneficial repair alternative as everyday integrity tools. Whatever the reasons, many of the testing programmes completed to date have proven their success and benefit time and time again, and following those, a new wave of composite repair systems development and testing has been underway to take them to the next level of performance. Even so, usage and acceptance has been on

a steep incline over the past decade, spurring a significant growth of the composite repair industry.

Enhanced performance

With the relative boom in composite materials being utilised as an acceptable means for repairing anomalies commonly found in pipelines, the need for improved performance and an in-depth knowledge of what makes these technologies work has also increased. Since the early 2000s, there have been dozens of industry-sponsored test programmes, research endeavours, and industry collaboration on the proper use and design of these materials. With a growing demand for improved performance and products within the pipeline market, it has spurred the need to develop a newer generation of testing for these materials to demonstrate performance in more and newer defect types. One specific area of focus has been to test the burst capacity of composite repair technologies. While this is a useful test to conduct, the end result does not generate a sufficiently encompassing metric for evaluating the true performance of the system in operation. Further, burst testing alone does not sufficiently identify limitations in the composite repair system. In essence, a burst test alone does not give the user sufficient guidance as to effectiveness of a design or product performance; and this test can be gamed.

Long-term considerations

Recognising the need to further validate and quantify the bounds of composite repairs for use in real-world scenarios, a host of testing programmes were embarked upon. One such programme was an industry joint testing programme conducted to validate the long-term effectiveness of composite repairs. This programme, funded by pipeline operators and repair system manufacturers, together with Pipeline Research Council International (PRCI) backing and executed by Stress Engineering Services, focused on all aspects of a full-service repair, with multiple repair systems remaining in the test programme for 10 years (reference MATR-3-4 'Long-term repair of corrosion performance study'). This study (focused on corrosion defects) included not only burst testing of repaired defects, but also

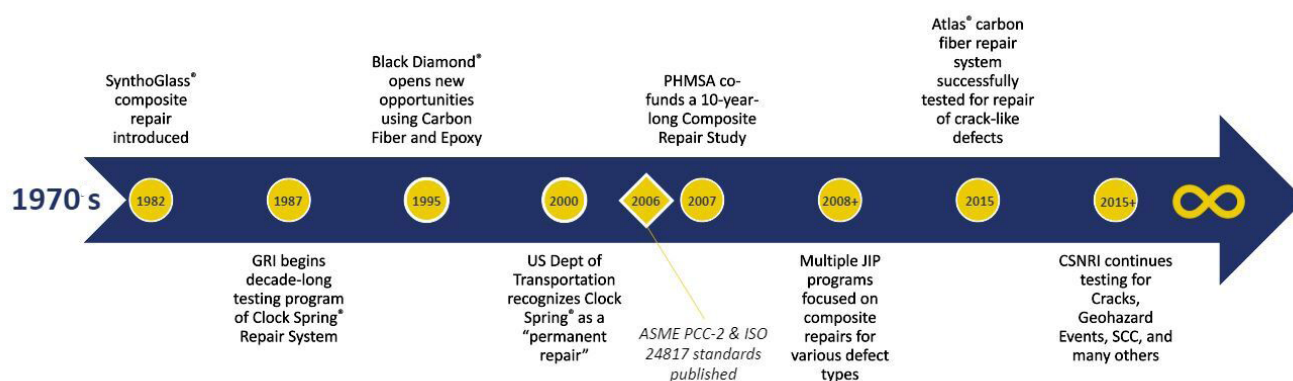


Figure 1. Brief history of composite repairs.



Figure 2. From left, clockwise: 1 million lbf tensile load frame; 3 million ft lbf four-point bending load frame; before and after composite repair bend test. (Pictures courtesy of ADV Integrity, Inc.)

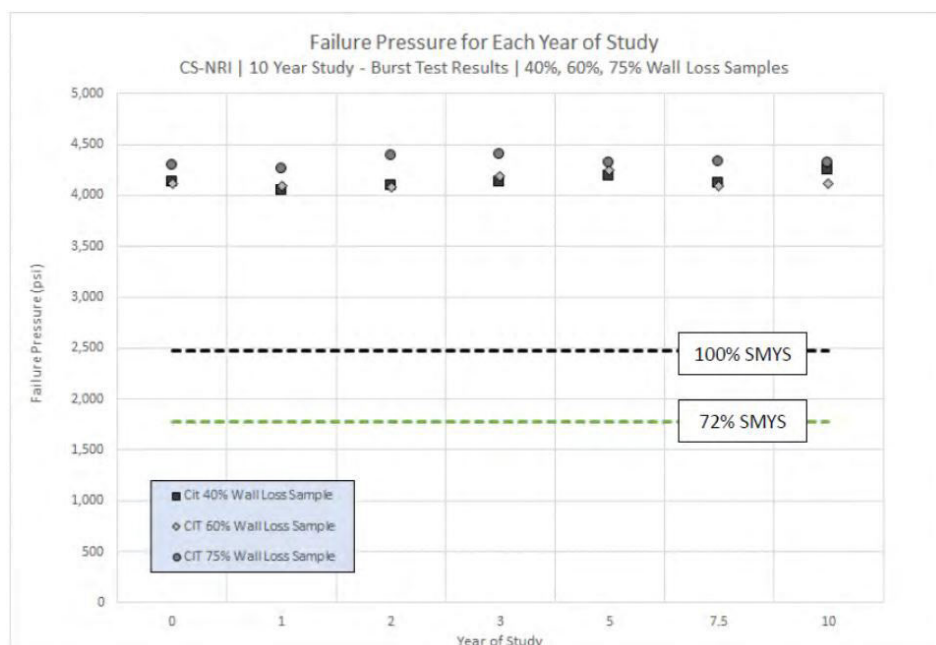


Figure 3. 10 year testing programme showed tremendous results in long-term effectiveness for composite repairs.

subjected the repairs to the same conditions as normal operations: buried repairs, cathodic protection system installed, and pressure cycling based on typical pipeline operation. These repairs were monitored over the course of years, removing samples at established intervals to perform a burst test after operation. This programme proved undoubtedly that composite repairs are capable of long-term usage and can successfully be designed for decades of use.

Other defect types

This provides a great foundation and confirms the effectiveness of composite repairs, but another question remained. What about other defects that are not just

corrosion? From this, many more testing programmes have been born to continue to test and validate the viability of composite repairs for a host of other defect concerns, especially where fatigue and pressure cycling become critical factors for the composite repair design methodology to address. For many of these defect types, such as dents, wrinkle bends, crack-like defects, and others, this becomes the driving factor which must be addressed not only in the validation testing, but in the design methodology for the repair as well. It is not the same as a simple burst repair calculation to show that the material is strong enough, but now must address the long-term effects of other stress/strain states within the defect and composite repair system.

Significant work has gone into creating not only the testing programmes to begin to address this question, but in the materials, methodologies, and testing equipment as well. As these have continued to advance, so has the ability to expand the use of composite repair systems for a wider range of defect types mentioned.

Cracks

By working with industry experts at testing organisations, and with pipeline owner/operators, the amount of testing and validation has increased significantly. This increase has led to a multitude of test programmes for defect-specific needs, which has in turn increased the understanding of how composite repairs can be safely and successfully used,



Figure 4. Burst test result of crack repair after cyclic pressure testing.

and consequently increased the overall acceptance of composites in general. Dents and wrinkle bends were some of the first non-corrosion focused defects that the industry looked at. But it wasn't long before new defect scopes were introduced, such as cracks and crack-like defect testing, and some of the most recent work on reinforcing girth welds to protect against geohazard events.

In 2015, the Atlas™ product was thoroughly tested on seam weld cracks at 33% and 75% deep. This programme, which included testing labs and industry regulatory involvement, led to the repair of several dozen permanent repairs on an ethylene line with low crack depths – close to the 33% depth tested. This line could not be easily welded on or de-pressurised without incurring a major expense, but with the use of composites, conservative repairs could be on the live line with minimal expense. Further testing was performed on the Atlas system in a joint industry project examining cracks of 15% and 50% depth. Again, the results here showed tremendous success in not only burst pressure restoration but also demonstrated the composites' ability to greatly reduce a crack's propagation rate – essentially increase the cyclic life of the pipe. Beyond just demonstrating pass/fail scenarios, CSNRI has gone further and developed a predictive tool utilising classical fracture mechanics and composite theory to determine the remaining capability of a repaired crack defect.

A third major test programme provided an ideal scenario to test the prediction of this programme to actual results. Before testing the pipe samples, material properties such as fracture toughness were determined. After testing and

comparing nearly 60 samples in both burst and cyclic failures, this tool has been shown to be very conservative in its assumptions. Now composite repairs can be installed on crack-like seam weld defects with more confidence than ever, knowing that a tested fracture mechanics model supports the engineering design.

Conclusions and future work

Based on multiple industry testing programmes and material knowledge gained over the course of 20 years, composite repairs have proven, both in testing programmes and real-world execution, that they are a safe and reliable repair option for pipeline integrity. Qualification testing according to the ASME PCC-2 Article 401 and ISO 24817 standards is a great foundation, and significant work has been completed above and beyond these standards to validate the methodologies for composite repairs across a variety of defect types.

CSNRI remains at the forefront of this work, and continues to validate and expand the boundaries for composite repair materials. Unique and independent test programmes, along with the work done in concert with many pipeline operators and joint-industry programmes, have provided for this continued advancement and understanding of the specific needs of the composite materials and defect types. With more than 40 years of repair design, qualifications, field experience, and track record, the future is bright for composite repairs and their successful implementation into pipeline integrity programmes. 