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Technical Note

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Subject: 1978 FRP History of Anchors and Supports

Background

In 1976 Rust Engineering, Birmingham, Al, had just completed the design of a bleach plant for Champion Paper where major piping systems were designed using FRP pipe. Stainless pipe that had been used in another Champion facility had not performed well and Champion management decided to select FRP for the new bleach plant. Rust selected a commodity pipe and followed the manufacturer's recommendation for pipe supports.

During startup of the bleach plant there were several piping failures. Repairs were made and during restart other parts of the piping system failed. Champion stopped the operation and Rust was called in for analysis and re-engineering of the bleach plant piping systems. The retrofit took almost two months to complete and in review of the design several issues were presented to Champion as possible cause:

1. Piping engineers and designers were not familiar with FRP piping and used steel piping methods for routing and supporting the pipe.
2. The supports suggested by the manufacturers of the FRP pipe were inadequate.
3. Stress analysis was not considered necessary because of the low operating temperatures and pressures and because formal stress programs did not address FRP.
4. The modified steel pipe supports were widely used for FRP pipe but were found to cause some of the failures due to heavy clamping forces, poor fit and support spacing based on steel pipe.
5. Many of the failures occurred and joints at elbows and probable cause was poor joining technique.
6. Valves and components were not supported and caused excessive bending and stress.
7. Piping failures near pump outlets were attributed to shock at startup of pumps.
8. The movement of the pipe due to thermal expansion was more than expected and may have contributed to failures.

Retrofit and repair began after the analysis of failure was completed. The resulting action included:

1. Stress analysis using accepted manual calculations using FRP properties.
2. Design of a family of supports, anchors and guides to match FRP pipe dimensions and properties. All supports were lined with natural rubber to avoid metal contact with pipe.
3. Pipe guides were added and special anchors were installed on pump discharge piping.
4. Anchors were specified to reduce and control thermal expansion.
5. All adhesive joints were overwrapped with FRP to improve the connection.

After all modifications and repairs were made the bleach plant was started without further problems and remained trouble free during the next year of operation. Rust was responsible for all retrofit work.

In 1978 Rust began a project for Shell Chemical, Norco Louisiana. This Shell facility was producing a new vinyl ester resin called **Epocryl 322 (now Ashland 922)** where an effluent treatment plant was mandated by EPA to handle all chemical waste. Shell selected FRP as the piping material for all piping handling this corrosive waste. To insure compliance with the EPA mandate Shell engineers were assigned to Rust office to monitor the design of the facility.

Pipe supports. After an extensive review of all FRP manufacturers **Fibercast** was selected to supply the pipe. Because of the experience Rust had at Champion Paper a new family of pipe supports was to be designed with overview by Shell. Coordinating the design with **Fibercast** and Shell a complete set of new supports were designed by Rust. The designs were approved by Shell and were used on this project.

Stress Analysis. Each of the pipe fabricators in the review was asked to provide their method of stress analysis for evaluating stress for their particular pipe-- filament wound, centrifugally cast or contact molded. Fibercast was the only company to offer a program for analysis of their pipe. After Shell and Rust personnel visited several job sited where Fibercast pipe had been installed and in operation the pipe and method of analysis was approved by Shell. The Fibercast analysis used equations for spacing, guides and lateral off set design but did not include an analysis for anchors or anchor loads. The supports suggested by Fibercast were not load rated.

Anchor Analysis. The anchor analysis came very early in the project when designing a 16 inch diameter effluent line that was to be routed on the top of a 50 ft. tall bridge. The pipe was the source of effluent to the treatment plant. The pipe was a straight run of pipe with an operating temperature of 170^{o} F and operating pressure of 50 psi. The total expansion of the run was calculated to exceed 22 inches where the line made a direction change to drop down on a lower bridge. The offset could not handle this expansion.

There seemed to be only two solutions to accommodate the expansion; use of expansion joints or expansion loops. Approximately 5 expansion joints or three expansion loops would be required. Shell immediately vetoed the expansion joints because of the possible damage to the facility, and danger to personnel in case of failure. The expansion loops posed a problem because of the other parallel pipes on the bridge. A vertical loop was not possible because of the high bridge elevation. Horizontal loops were not feasible because of the surrounding lines and need for added bridge structure. The only solution was to install a complex loop that required an elbow up and another elbow to route the pipe over the existing lines and then drop down the side of the bridge and looped back to the top. Several versions of the loop were reviewed but all presented problems. The main concern was the need for 8 elbows, 16 joints that could be a source of failure and the need for supports for each loop. Shell then considered expansion joints but these would require many guides and anchors and did not resolve the safety issue.

I recalled seeing an isometric drawing in a book by John Mallinson; Corrosion -- Resistant Plastic Composites in Chemical Plant Design, where one long straight segment of pipe was restrained at each end by anchors. There was interest in looking into the idea and I placed a call to Mr. Mallinson to see if he had used this concept in any of the FMC plants where he was the chief engineer. He said he had never used the idea but had calculated anchor loads for several conditions and believed it would work. Using the same calculations for this effluent line it seemed that this could be a very economical solution. Using pipe properties for the Fibercast filament wound pipe the calculated anchor load would be 20,000 lbs.; a load that had to be taken by the upper elevation of the bridge.

Conferring with the structural engineer it was determined that the bridge could accept these loads with minor changes and Shell made the decision to use this solution. This became the first anchor to anchor design. Fibercast opposed the anchor design at that time but Shell made the decision to use anchors.

As we began to analyze other piping systems Shell suggested that all should be checked to see where an anchored piping run might be considered. There were approximately 65 lines, 2in.” through 36in. that had anchored segments where applicable but all unanchored segments were analyzed to insure piping offsets were adequate to minimize stresses. The discharge pipes from all pumps were anchored to reduce dynamic stress. All piping components were independently supported. Support and guide spacing was in accordance with the Fibercast design method. All components were independently supported.

After all supports anchors and guides were in place each piping system was successfully hydro tested without any leaks or failures. Shell stated that this was the first successful test with FRP pipe without any incident related to FRP pipe performance and Shell decided to adopt the anchored design for all future projects.

All of the equations in the Fibercast program were used for all piping system and where anchored segments were proposed the anchor equation was used. Fibercast engineering developed the flexibility equations and credit for the anchor equation goes to John Mallinson. Britt has made minor modifications to these equations, as a result of testing,   to more closely match FRP pipe properties. Working with Fibercast and others over many years we have developed a table of allowable bending moments for FRP elbows. Many values in the table were determined by test; others were extrapolated. The allowable values have been successfully used for off set design for many years. Most formal stress programs use stress intensification values for FRP fittings that are determined using steel calculations. Validation of these values by testing has never been done for FRP pipe.

After the success of the Shell project I presented a technical paper in 1979 at a NACE conference that described the method of analysis and support designs. Design Consideration for FRP Piping Systems by William F. Britt, Jr., published by The National Association of Corrosion Engineers, Managing Corrosion With Plastics, VOL IV, 1979. Since that date we have presented several additional papers updating the procedures and support designs. This is the method being considered in Chapter II Part 3 – Pipe Stress Analysis and Pipe Support.

Summary

The procedures, equations and support designs resulting from Rust projects and discussed in this brief history are thought to be the first efforts to develop an analysis that could be used by designers and engineers to successfully make FRP pipe more reliable. At that time there were no supports available that were specifically designed for the unique properties of FRP pipe. These designs were carefully designed to prevent local piping stresses while supporting, guiding and anchoring this pipe. Each support was structurally analyzed by Rust and Shell engineers and has proven successful in more than 2,000 plants and facilities over the past 30 years.

Unfortunately today's catalogs, design manuals and literature have some of the same support illustrations and designs that have not been successful and many engineering firms are still calling out steel pipe supports for FRP pipe.

Fibercast and may other fabricators were opposed the anchored system even though many engineering firms now acknowledge and have successfully used the anchored approach. With the history of success many fabricators are now acknowledging the use of anchors.

Conclusions

1. The anchored system for FRP has been very successful but it is a method that might not be practical for every piping system. However, it is very important to consider using anchors to control excessive expansion. Unrestricted expansion can over stress fittings and joints, move pipe supports off of structural steel, induce high bending stress and can cause other parallel pipes to be overstressed. (See Figures 1-3).
2. Anchored designs must consider extreme cold conditions that might occur when the pipe is not in operation. Allowing limited anchor movement to accommodate contraction is easy to accomplish. Anchored FRP piping that has been operating in cold environments as low as 50 degrees below zero have been in place for more than 30 years without incident.
3. The equations as presented in Chapter II Part 3 – Pipe Stress Analysis and Pipe Support are the same simplified equations that have been easily used by designers and engineers for more than 30 years with great success. The anchored system has been shown to be an economical but conservative approach for FRP pipe design and properly applied will enhance the reliability of FRP pipe.
4. The pipe support designs used on the Shell FRP project were successful and were structurally analyzed by Rust and Shell Engineering before being specified and used. The family of supports has been enlarged to accommodate a wide variety of applications and is load rated. If the designer or engineer determines that piping loads exceed the rated support loads these loads may over stress the pipe.

Figure 1. Example of uncontrolled expansion.

Figure 2. Example of uncontrolled expansion and lack of guides to avoid buckling and lateral movement.

Figure 3. Support at tipping point due to uncontrolled expansion.