

## 1. SCOPE

This document provides an introduction to the use of composite materials as a methodology for repairing pipelines

## 2. BACKGROUND

The use of composite systems as a repair methodology in the pipeline industry has grown in recent years. However, there are still no widely accepted standards governing the design and installation of such systems but the potential cost savings can be significant. Whilst composite repairs are gaining acceptance and approvals they do not as yet have full regulatory approval and this should be considered during the repair assessment process.

There is no general agreement on what validation testing a repair system should have undergone prior to use on a pipeline. It is not the aim of this document to set those standards and so it is recommended that the method of supply and installation of each system be considered on its own merits. Each supplier should be able to provide test reports sufficient to demonstrate the performance of their repair system in a similar situation and application to that being considered. A track record of use in similar repairs is desirable. This note highlights critical areas that should be addressed if composite repairs are to be used.

Composite material systems currently in use broadly consist of two types. The first is a pre-cured composite that is bonded into place using a structural adhesive and this is used for applications of simple tubular shapes i.e. pipe diameters. The other system consists of a flexible woven cloth of fibre that is impregnated with resin and cured at the repair site. This is most suited for repairs involving an irregular shape or fitting, or if the repair is in a bend with a radius less than three times the diameter of the pipe. Regardless of the system chosen it is advisable to consult the manufacturer.

## 3. TYPES OF REPAIRS

Composite repairs can be used as a permanent repair for external, blunt defects and to reinforce dents. They can also be used for the repair of internal defects if the defect mechanism has been arrested. If the defect mechanism has not been arrested then the repair will be temporary, and duration based on growth factors developed by the operator. The advantages of composite repairs are cost, speed and safety.

The composite repair must have mechanical properties and composite architecture appropriate to the repair task, the design of the repair must follow a proven methodology and reliable engineering tests and analyses should have been completed to show that this methodology can be used.

For a typical blunt defect such as external corrosion, firstly the defect should be assessed to establish whether the repair will be effective. In the case of external corrosion, the defect area should be thoroughly cleaned to bare metal. The pipe surface should be prepared to the specification required by the repair supplier, typically NACE #3 finish. (Clean, bare pipe with a slight anchor pattern. Commercial grit blasting is the recommended surface preparation). The defect area is filled with a hardenable filler material to enable load transfer from the pipe to the composite. The composite is then wrapped around the damaged pipe and held in place with an adhesive.

Where wall thinning has occurred for example by grinding a gouge or arc burn from the pipe wall then composite wrap repairs are acceptable, provided the following steps are taken:

- The scrape, gouge or arc burn is ground to a smooth contour
- The damaged area is inspected to verify that any cracks have been removed
- The residual indentation is filled with a hardenable material under the sleeve
- The ground area is inspected to ensure that there are no residual hard spots

An appropriate engineering assessment of the defect should be conducted to ensure that the repair will be effective and permanent. The defect should be assessed as metal loss in a manner similar to that used for external corrosion.

Composite repairs can be used to reinforce plain dents as long as the void between the composite and the pipe is filled with a hardenable material. Stress concentrators or blemishes within the dent must be removed by grinding and the area inspected for cracks.

Non-leaking pipes are most suitable for repair but some success has been reported on leaking pipes. In the latter case, the hole is plugged with a polymer putty before the application of the composite wrap.

#### **4. ISSUES WHICH SHOULD BE ADDRESSED BY VALIDATION TESTING**

Mechanical properties of the repair will determine both its effectiveness and durability. The properties to consider are tensile strength and modulus of the composite, strength (lap shear) of the adhesive and compressive strength filler material. Testing should be done to national or international standards.

Mechanical properties of composites can degrade over time. The composite should have durability data that demonstrates adequate strength at the end of the design life of the repair. This durability testing should be done in accordance with national or international standards.

Validation testing should be conducted on the same materials and under the same service conditions as would be expected of the repair in operation.

#### **5. DESIGN CONSIDERATIONS**

Pipelines are designed to operate at a pressure that limits the stress in the pipe wall based on various safety factors. Typically, the pressure carrying capability of a pipeline is:

$P = (2 \cdot S \cdot t / D) \cdot F \cdot E \cdot T$  where;

P = Design pressure

S = Specified Minimum Yield Strength (SMYS) of the steel

t = Wall thickness

D = Pipe diameter

F = Design factor

E = Joint factor

T = Temperature factor

The pressure inside a pipeline acts at right angles, in all direction on the wall of the pipe causing the steel in the pipe wall to be in tension. At a defect location (wall thinning) the steel in the thin ligament of the defect will be under a higher stress level than the sound pipe and may therefore yield beyond its safe limit. A composite repair works by sharing the hoop load at the defect site thus limiting the strain in the pipe, and therefore the stress, to a level that is safe for the Maximum Allowable Operating Pressure (MAOP) of the pipeline. The steel will still yield but the extent of yielding will be controlled by the externally applied composite so that the MAOP can be maintained safely. To accomplish this the mechanical properties of the repair must be known.

Non-leaking pipelines are most suitable for repair by composite materials. The steel and composite will share the load due to internal pressure provided a suitable, non-compressible material is used between them, such as a two-part, filled epoxy resin. The load will be shared in proportion to the stiffness of the two materials. The repairs will be most effective if applied to a depressurised line.

The stiffness of composite material is generally lower than that of steel. The working strain in the repair will be controlled by the combined steel and composite stiffness and, since the modulus of the composite is less than steel the stress in the composite will be limited. The full properties of the composite will only be used if the steel is allowed to yield. It is the designer's responsibility to ensure that this is acceptable.

Glass fibre and carbon fibre based repairs are acceptable. The supplier must demonstrate, however, that no galvanic couple can form between a carbon repair and the pipe. This is usually achieved by including a glass fibre inter layer between them.

For pipelines designed to temperatures above 45°C the installer must be able to demonstrate that the resins and adhesives will be suitable. It would be normal to ensure the glass transition temperature or heat deflection temperature of the materials as installed exceed the design temperature by at least 30°C.

Stress concentrations can develop at the edges of repairs. A taper should be included in the repair if possible, or, as a minimum, the bond line filleted at 45°C.

## **6. MECHANICAL PROPERTIES OF COMPOSITE REPAIRS**

Each composite repair will have mechanical properties and durability specific to that repair. The mechanical property and durability data collected cannot necessarily be used to assess another similar repair.

One of the primary factors in the degradation rate of composites is moisture. Each composite repair should be reviewed to ensure that it is designed to minimise moisture absorption. Durability data must confirm that the repair will be effective over its full design life.

All composites are not equal and the data used must be appropriate to the system used. The data required will be specified in the approved methodology used for design.

## **7. INSTALLATION CONSIDERATIONS**

The installer should provide a written method statement detailing how the repair will be applied. This should detail all steps in the repair and follow equivalent procedures to those used to complete the validation test reports presented to support the repair. A record of the repair and copies of completed procedures should be retained.

The materials used in the repair and the method of application (including surface preparation) should be the same as those used to complete the validation test reports.

## **8. INSTALLATION GUIDANCE**

Installation of a repair system should be covered by a Method Statement which describes each of the main procedures to be carried out.

Input to the Method Statement comes from the following:

- Risk assessment (supplied by owner)
- Working conditions (supplied by owner)
- Design information
- Line operating conditions, layout etc (supplied by owner)
- Design of repair (supplied by repair system supplier)
- Materials information for repair system (supplied by repair system supplier)

Repair system suppliers should provide full installation instructions. These instructions should include (where appropriate):

- Environmental conditions of site at time of repair
- Material storage
- Surface preparation
- Resin mixing
- Laminate lay-up
- Laminate consolidation
- Cure
- Key hold points

The key hold points to be observed during a repair are summarised in Table 1 below:

Table 1.

<b>HOLD POINT</b>	<b>CHECKED BY</b>
Method statement	Installer
Material preparation <ul style="list-style-type: none"> <li>• Reinforcement</li> <li>• Resin</li> </ul>	Installer
Surface preparation <ul style="list-style-type: none"> <li>• Inspection</li> <li>• Mechanical test</li> </ul>	Installer or supervisor
Filler profile	Installer
Stage check on reinforcement lay-up	Installer
Tests on repair laminate <ul style="list-style-type: none"> <li>• cure (hardness)</li> <li>• thickness</li> <li>• dimensions</li> <li>• external inspection</li> </ul>	Installer or supervisor
Pressure test	Inspection authority

The results of the tests on the repair laminate should be compared with the qualification data. The repair system supplier prior to repair system installation should provide acceptance values of the test results.

## 9. TRAINING

All installers should be able to demonstrate competence in the operations they are completing. They should be able to demonstrate they have been on a training course to utilise and to install the repair materials. These courses should be documented and should include at least the following details:

- how to handle all materials
- how to mix resins
- how to complete surface preparation
- how to install the materials
- what site conditions need to be controlled
- what hold points should be observed
- what health and safety issues should be considered.
- how to deal with abnormal conditions

Installers will normally have two years experience in pipeline maintenance or fabrication or in laminating composite materials.

For repairs to be permanent then it is vital that close attention is paid to surface preparation. It is normal to follow the requirements outlined in the blast cleaning series ISO 8501 to 8504.

After repair, a system pressure test may be conducted. Composites do not benefit from a 1.5 times design pressure test and tests to 1.1 times operating pressure should be sufficient.

## 10. QUALITY ASSURANCE

Each repair should be given a unique reference.

After surface preparation, monitor and record surface roughness and cleanliness and ensure they compare to those used for validation testing.

Temperature and humidity at time of application should be monitored and recorded. It is normal to follow painting guidelines and ensure application does not take place if the relative humidity is above 80% or the temperature of the pipeline is less than 3°C above the dew point. This may be relaxed if the supplier can demonstrate long term performance of repairs applied in conditions outside of this.

The temperature of application should be within limits proven to be suitable for the adhesives selected.

Records of the types of materials used, the quantity and the batch numbers should be kept. Some of the materials used will have a specific shelf life and also temperature limitations for storage and use. These issues should be considered before repair.

The number of layers applied should also be recorded.

A visual inspection should be completed after application, The assessment of the repairs should be against a documented procedure and a record of the inspection should be kept. The dimensions of the repair should be recorded and compared against the design.

Cure can be checked by comparing the hardness of the adhesive against a known standard; Barcol hardness measurements are often used.

## 11. INSPECTION OF REPAIRS

There are no proven methods of inspecting the composites nor the bond to the steel pipeline. It is therefore critical that careful attention is paid to the application process. The steel pipeline can be inspected from the inside by pigging. Ultrasonic, radiography and pulsed eddy current inspection techniques have both had reported success in inspecting the steel through the composite repairs. The repair supplier should be consulted for advice.

Note: Composite repairs are normally marked e.g. with steel bands, so that their location can be seen on a pigging report, relative to the damage to the steel pipeline.

## 12. ACKNOWLEDGMENT

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	<b>NATIONAL DIFFUSION NETWORKS PROJECT TECHNOLOGY QUESTIONNAIRE Water Industry Group “Composite Repairs for Pipelines”</b>	<b>Revision No:</b> Rev 1
		<b>Page 1 of 2</b>
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As part of the WTIA National Diffusion Networks Project the Water Industry Sector has identified the need to introduce composite pipeline repair technology into the industry. The WTIA has prepared a Technical Guidance Note “Composite Repairs for Pipelines” to explain the composite repair process. As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this note. Please complete this questionnaire so that we can gauge the success of meeting this need.

**Objective 1: Identify the application of composites for pipeline repairs**

This guidance note is intended to provide the Water Industry with the types of repairs that can be made using composites plus information on the design, installation, QA and training necessary for their use. How well does the document explain the benefits of composite repair technology?

poor  average  good  very good

Comments: \_\_\_\_\_

**Objective 2: Identify appropriate technology receptors in the Water Industry**

This document was written for Designers and Maintenance Engineers in the Water Industry. Are these people the appropriate individuals we should be targeting?

yes  no

What other types of companies and/or personnel do you suggest we target? \_\_\_\_\_

**Objective 3: Identify latest pipeline repair technology**

The document was written to reflect current best practice and latest technology for composite pipe repairs. Do you envisage opportunities for the use of this technology in the industry?

yes  no

If yes, what and where, if no why not? \_\_\_\_\_

**Objective 4: Is the information provided clear, concise and accurate?**

yes  no

If not, why? \_\_\_\_\_

**Objective 5: Broad dissemination of composite repair technology to the Water Industry**

Please indicate how best to disseminate this Technical Guidance Note to the appropriate Water Industry Recipients

Free Website Download  Poster  Pocket Guide  Pamphlet

If poster, what size? A1  A2  A3  Laminated  What selling price? \$

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Any other format? \_\_\_\_\_

