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Innovative Composite Solutions

TESTING AND HISTORY OF COMPOSITE REPAIR SYSTEMS FOR SUBSEA PIPELINE REPAIR

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AOG

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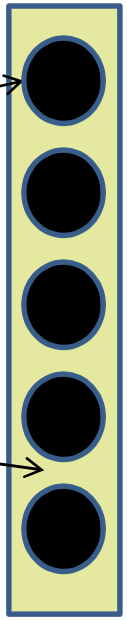
What is a Composite

A composite is a combination of two or more materials, differing in form or composition, which retain their individual identities while acting in concert.

Two Components:

- Reinforcing fibers (carbon, glass or synthetic)
  The high tensile strength of the fiber is used to handle the loads in the hoop, axial, flexural, compression, & shear
- Polymeric matrix (epoxy, vinyl ester, urethane)
  Matrix material binds the fibers into shapes and provides bond strength to substrates for load transfer



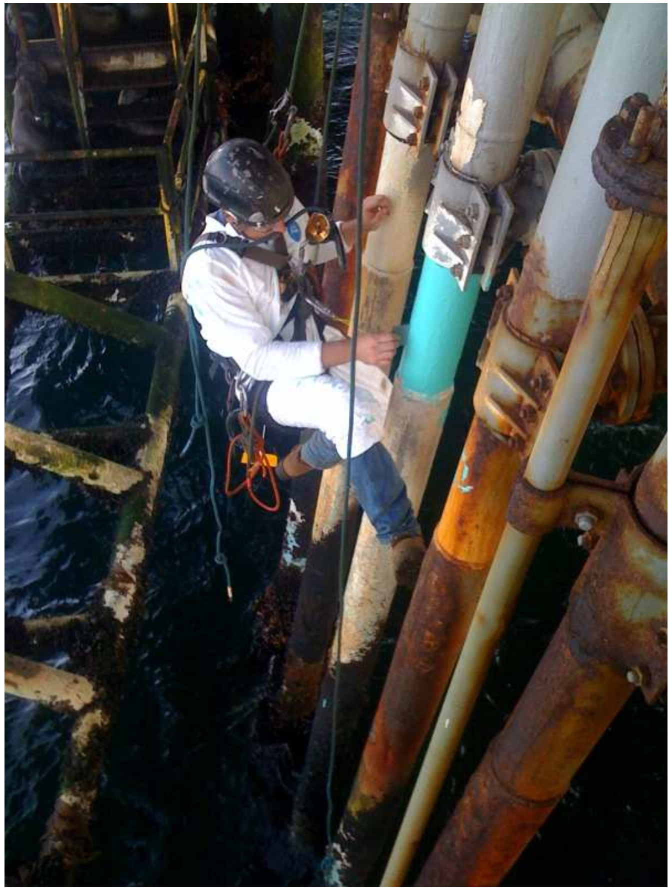
Composites can be designed to share the loads & stresses with the host pipe, tank or concrete structure. Composites can also be designed to neglect the host strength of the host pipe, tank or structure for internal corrosion or erosion reinforcements needs.

Composites as Pipe Repair
Brief History

- Beginnings in the 1980s
- Aging pipe infrastructure led to the industry seeking new technologies
- By wrapping the pipe with composite material, higher pressure ratings can be maintained
- This means higher profit for owners

Composites as Pipe Repair
Brief History

- New technologies require new testing, validation, and qualification
- New uses facilitate the need for governing regulations
- Independent organizations were developed to provide best practice guidelines for composite usage as pipe repair

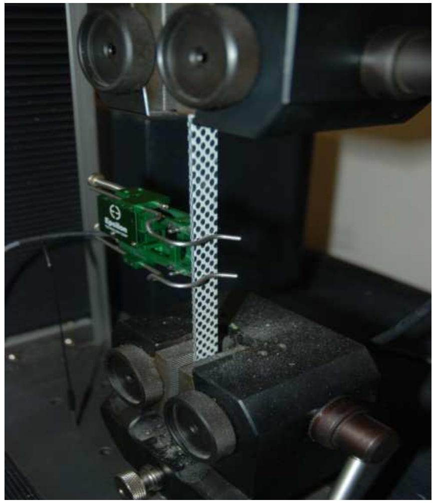


Code Requirements

- Two of the main organizations to create specific qualification codes are ASME and ISO
- ASME PCC-2 Article 4.1 – Nonmetallic Composite Repair for High Risk Pipeline and Pipe work
  - Originally published in 2006 – Newest revision 2015
- ISO/TS-24817 – Composite repairs for pipe work — Qualification and design, installation, testing and inspection
  - Originally published in 2006 (next revision expected 2015)

Code Requirements

- These codes and standards define the scope related to using composite materials for the repair of pipe in detail
  – Mechanical properties of the material
  – Design criteria and formulas



- In order to safely design and use a composite system for pipe repair, the material properties are of utmost importance

Testing for Subsea

- The codes provide for a good foundation and material understanding
- Additional testing should be done to simulate subsea environment and insure adequate performance
- Various testing programs have been conducted specific to subsea applications with composite materials

Testing for Subsea

- Testing evaluated material performance when applied in subsea environment
- Tests have also been performed by industry in general with great results for composite repairs
- This presentation will focus one testing program performed in joint collaboration with an offshore operating company (ADMA), testing review/certification company (DNV), and material manufacturer (NRI)

Testing for Subsea

Testing Development

- The test program was developed to determine suitability for a specific need for the client
- Of importance to them was to understand if the composite could restore the corroded pipe to sufficient design pressures
- The primary issue for the pipeline in question was internal corrosion, so this was to be modeled in the testing specimen
- It is important to note, this testing was after much initial testing on materials was already completed

Specimen Creation

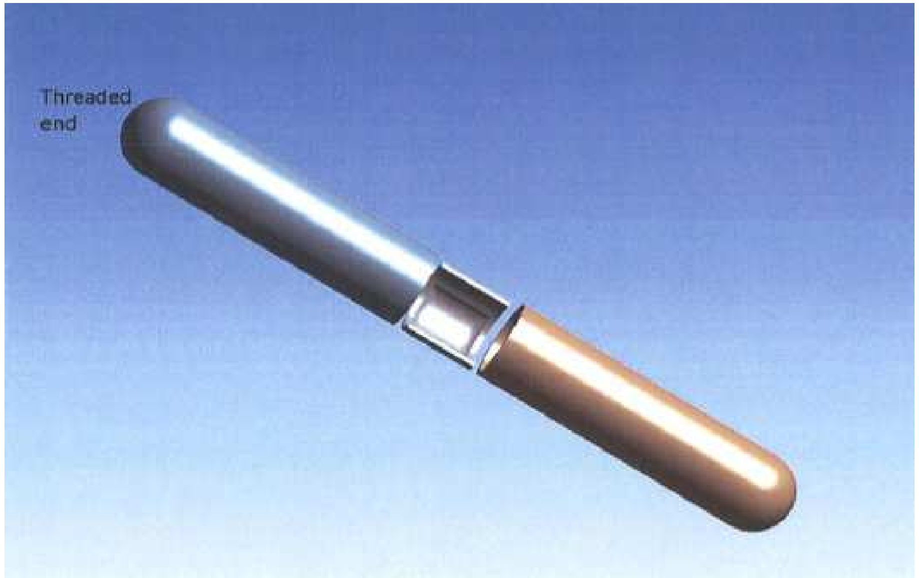
- An internal wall loss defect was to be manufactured into a pipe section and repaired using composite materials
- The pipe specifications:
  - 8″ diameter
  - API 5L X65
  - Pipe length approx. 6 feet
  - Domed end caps
  - Weldolets for pressurization

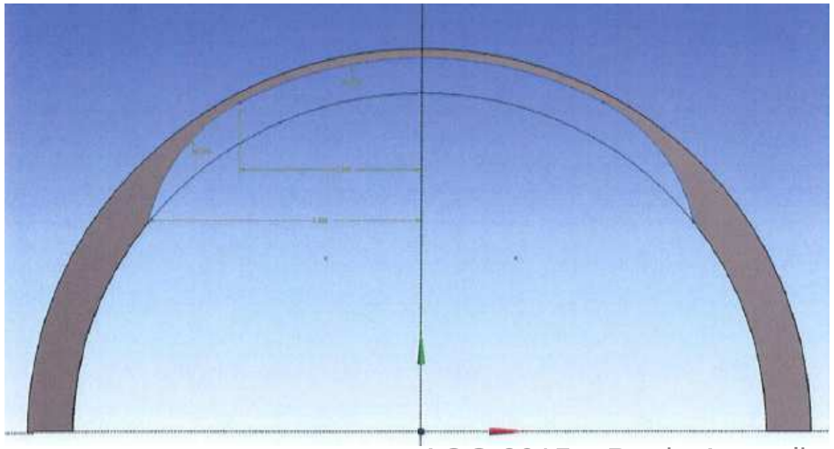
Specimen Creation

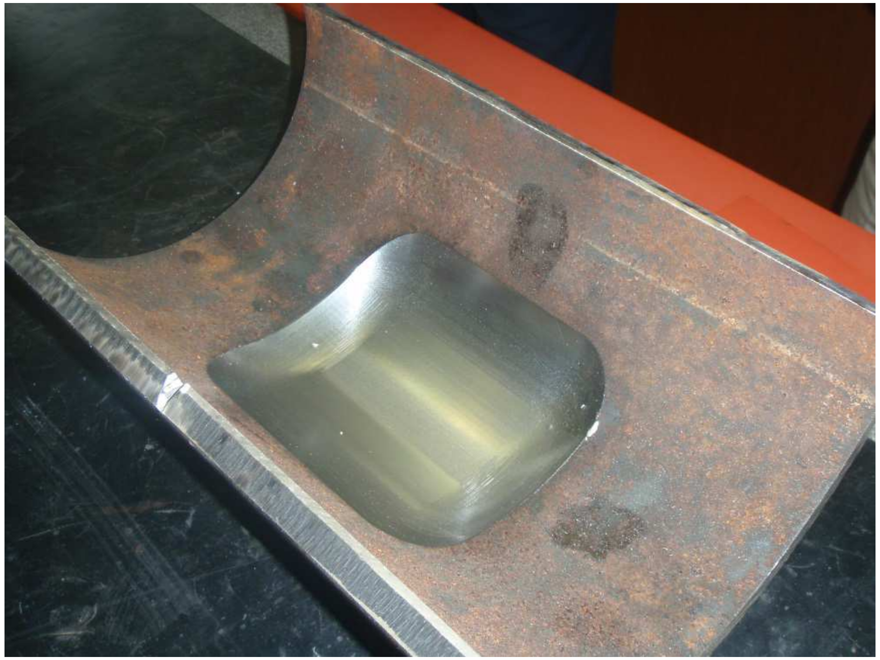
Specimen Creation

- Internal defect was machined in a section of the pipe
- Once machined to specifications of 78-80% wall loss, it was welded back into the pipe section
- In addition, another pipe was created for testing with no composite wrap

Specimen Creation







Specimen Creation

- Once prepared, the pipe was then placed into a tank of simulated sea water
- The specimen was wrapped with composite material after submersion to reflect subsea application
- Material was designed as per industry codes and standards
- Once wrapped, it was left to sit in the solution for 7 days (similar to a chemical soak test)

Specimen Creation

Specimen Creation

Test Procedure

- Upon completion of specimen soak, pipe was removed from solution
- The specimen was filled with water in order to perform the hydrostatic pressure test
- A specific pressurization rate and hold points were observed during the test
- This procedure was completed for both the repaired and un-repaired pipe samples

Test Procedure

- Pressurization rate of approximately 1,000 psi per minute
- Pressure held at 3,500 psi for 30 minutes
- Pressure held at 6,000 psi for 30 minutes
- The repair was observed during the pressure testing phase to note any change or failure

Test Results – Unrepaired Pipe

Pressure	Time	Observations	Result
2,100	~ 2 min	Pipe ruptured catastrophically in defect area before the first hold point	Failure

Test Results – Repaired Pipe

Pressure	Time	Observations	Result
3,500 psi	30 min.	No failure or change in properties was identified	Pass
6,000 psi	30 min	No failure or change in properties was identified	Pass

Test Results

Discussion

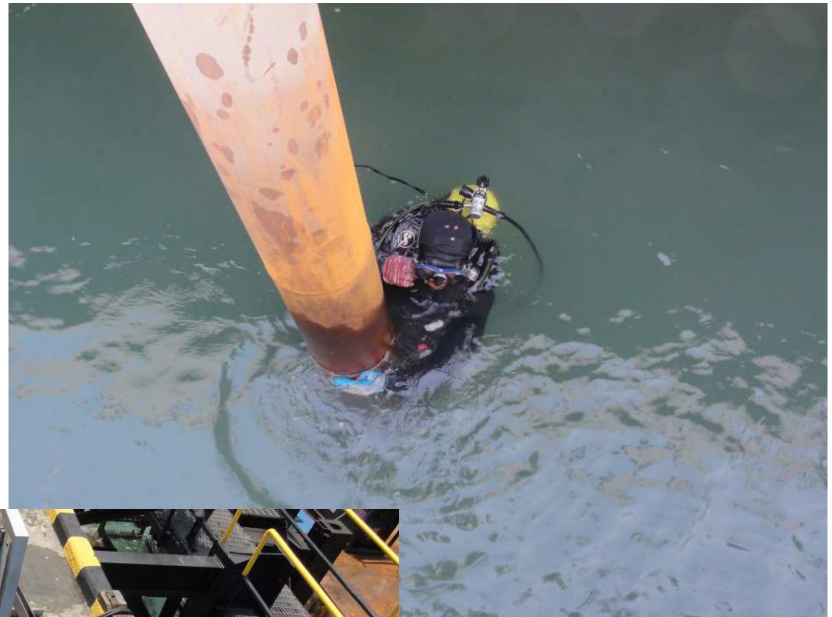
- Successful testing which was previously completed supported the testing discussed here
- This testing further proves that the materials will perform as expected
- Composites have been used in this manner successfully for many years

Field Case Studies

- Offshore gasoline pipeline in Malaysia
- 10” carbon steel
- 28 linear meter total repair
- Multiple defect locations with majority subsea
- Operating pressure of 800 psi
- Fully repaired via Syntho-Glass® XT composite repair system

Field Case Studies

Field Case Studies

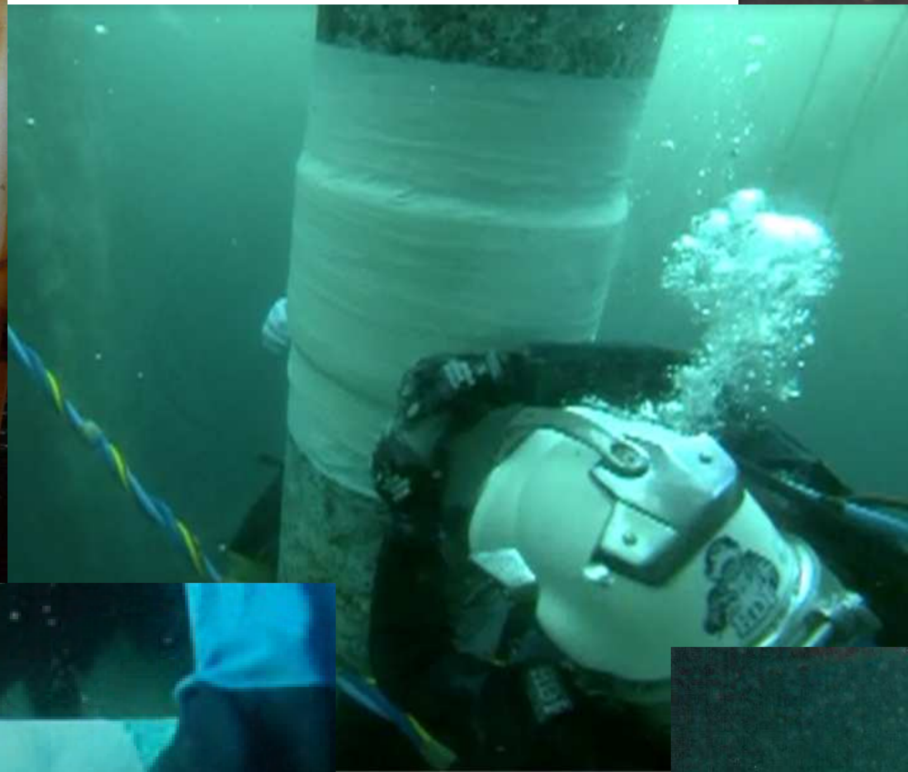


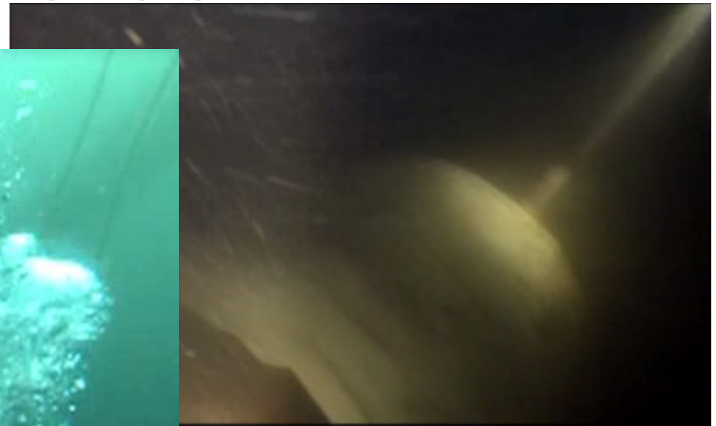
Field Case Studies

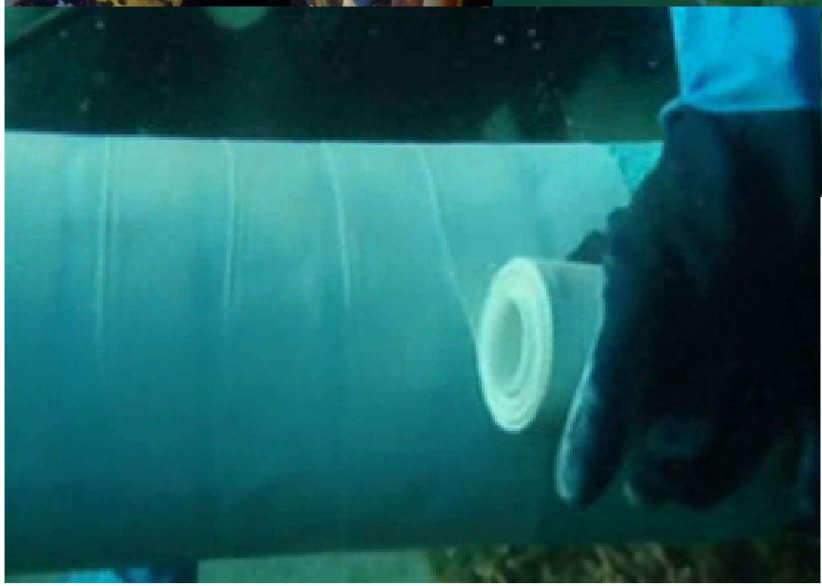
- Offshore pipeline west coast USA
- 6" carbon steel
- 14 linear feet total repair
- Multiple defect locations with external corrosion
- Design pressure of 2,130 psi
- Fully repaired via Viper Skin™ composite repair system

Field Case Studies

Various Field Photos







Conclusion

- Viper Skin composite system successfully passed the subsea application test
- Product was proven to be effective
- Testing confirmed by third-party organizations
- Subsequent ABS Type Approval for the system was issued
- Composites have been used successfully for applications in subsea environments

Thank you for your attention!

Questions?

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