SAND2015-6732C

Wellbore Seal Repair Using Nanocomposite Materials

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U.S. Department of Energy

National Energy Technology Laboratory

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Presentation Outline

- Introduction and overview
- Materials synthesis
- Materials testing and characterization
- Seal system testing
- Numerical simulation
- Summary

Benefit to the Program

- **BENEFITS STATEMENT: The project involves the development and testing of polymer-cement nanocomposites for repairing flaws in annular wellbore seals. These materials will have superior characteristics compared to conventional materials, ensuring hydraulic isolation of the wellbore after closure. The technology contributes to the Program's effort of ensuring 99% CO_2 storage permanence.**

Project Overview: Goals and Objectives

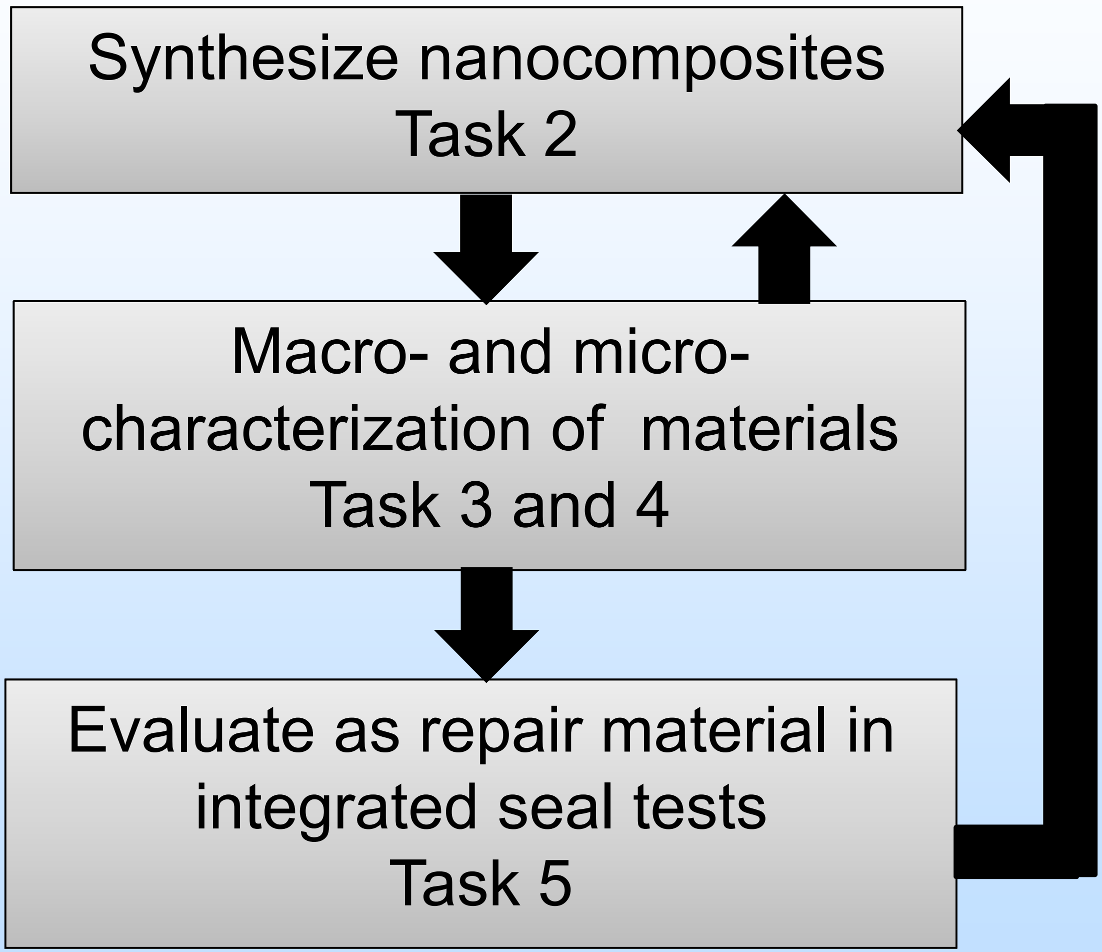
- (1) Develop and test ***nanocomposite seal repair materials*** suitable for expected wellbore environments that have ***high bond strength*** to casing and cement, ***high fracture toughness,*** and ***low permeability***.
  - These materials will have superior properties compared to conventional materials to permit improved wellbore seal repair, contributing to the program's goal of 99% storage permanence.
  - Success criteria: Materials shall have superior properties and characteristics compared to conventional materials.

Project Overview:
Goals and Objectives (CONTINUED)

(2) Evaluate the effectiveness of developed materials to repair flaws in ***large lab-scale annular seal systems*** under conditions expected in wellbores.

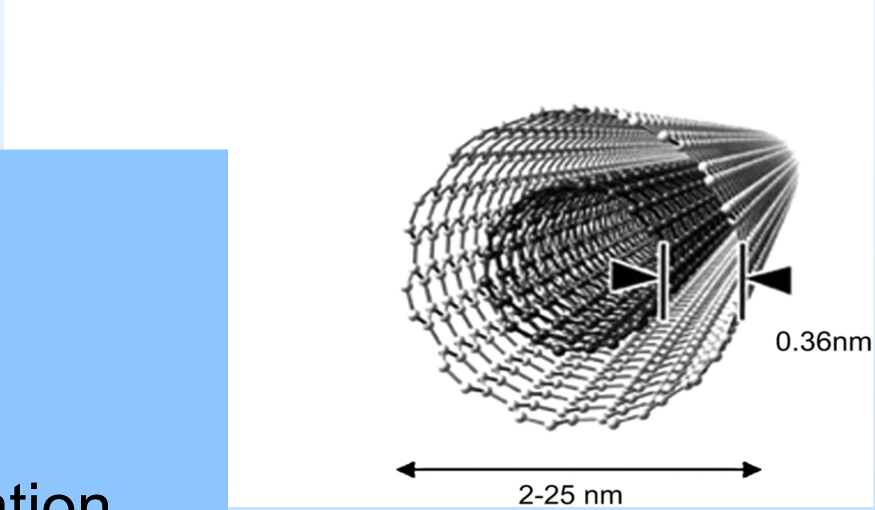
- Evaluation and understanding of the expected performance of these materials to repair flaws within sealed wellbores will lead to more confidence in the ability to ensure 99% CO_2 storage permanence.
- Success criteria: The degree to which system permeability to CO_2 is reduced after repair, cost, material availability and ease of use compared to conventional materials.

Project Task Flow



Nanocomposites - addition of small amounts of nano-scale materials can dramatically alter properties of materials such as polymers, composites, and cements.

- Strength
- Ductility
- Reduce shrinkage
- Thermal stability
- Resistance to degradation



Materials

Base materials

- Siloxane
- Novolac

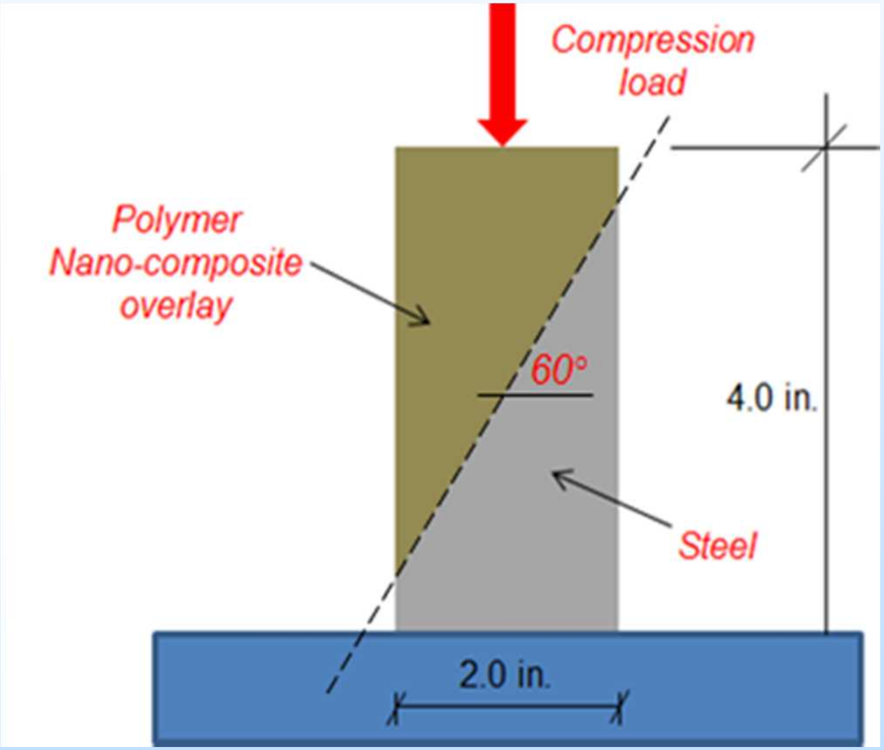
Nanoparticles

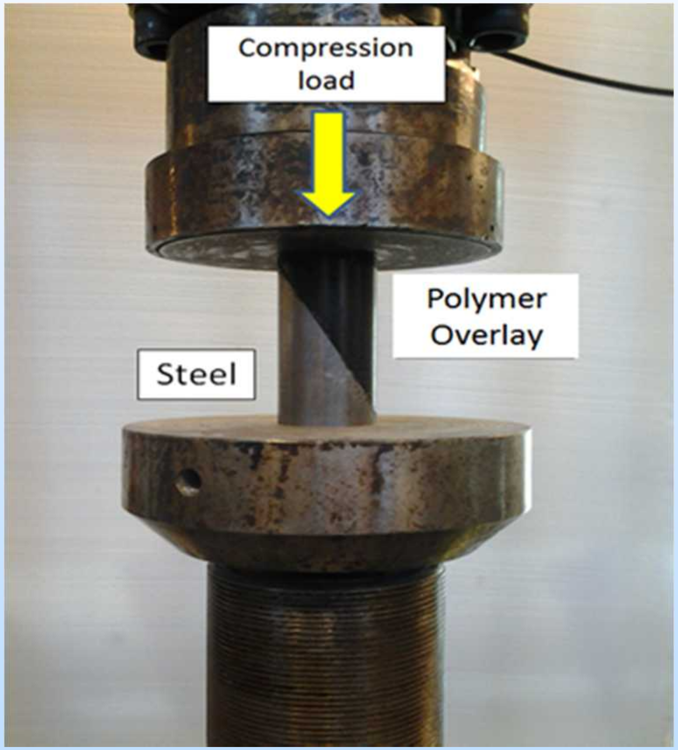
- MWCNTs
- Nanoclay
- Nanoalumina
- Nanosilica

Nanocomposites

Bond strength characterization

- Slant shear test – a direct measure of nanocomposite – steel bond strength





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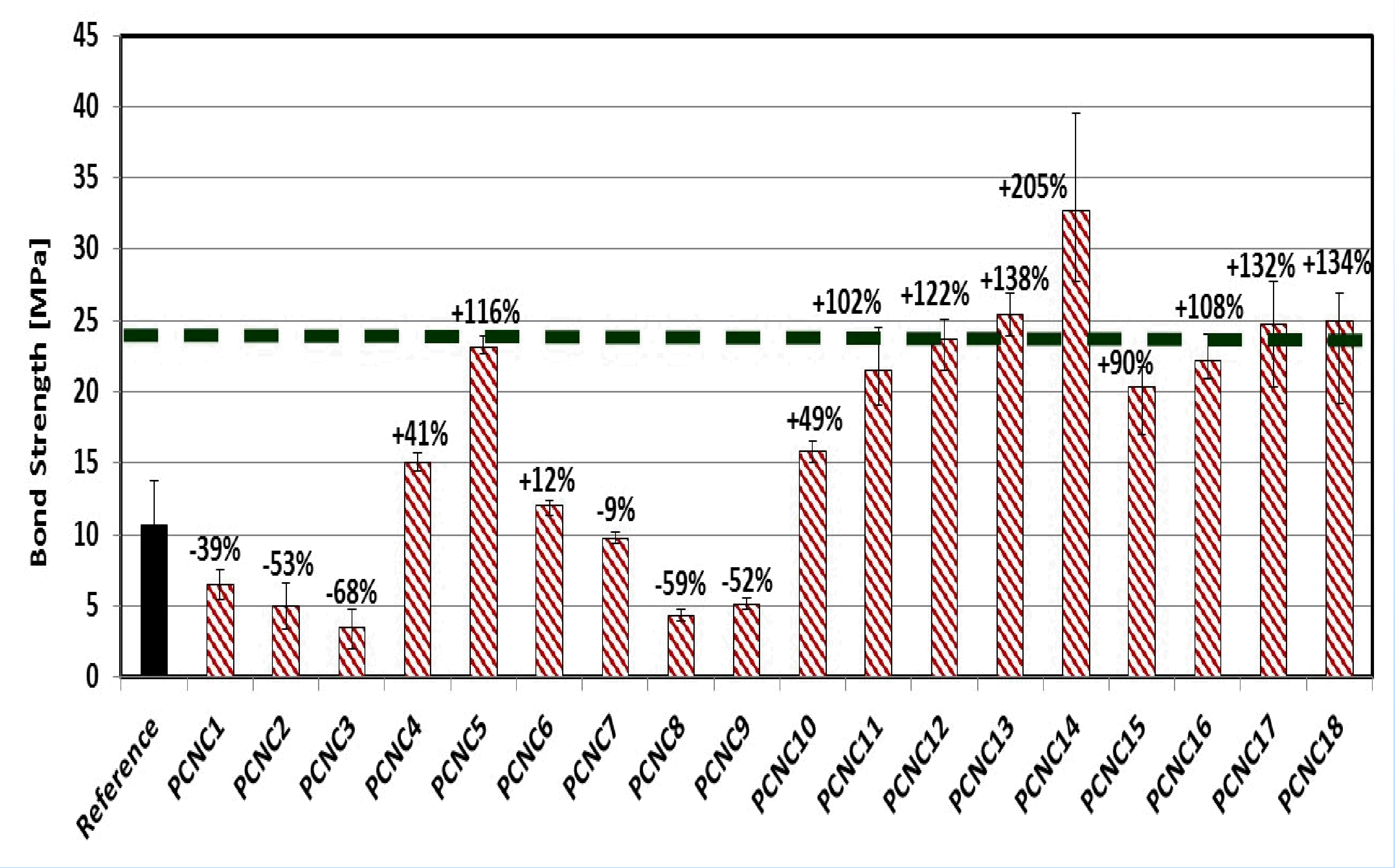
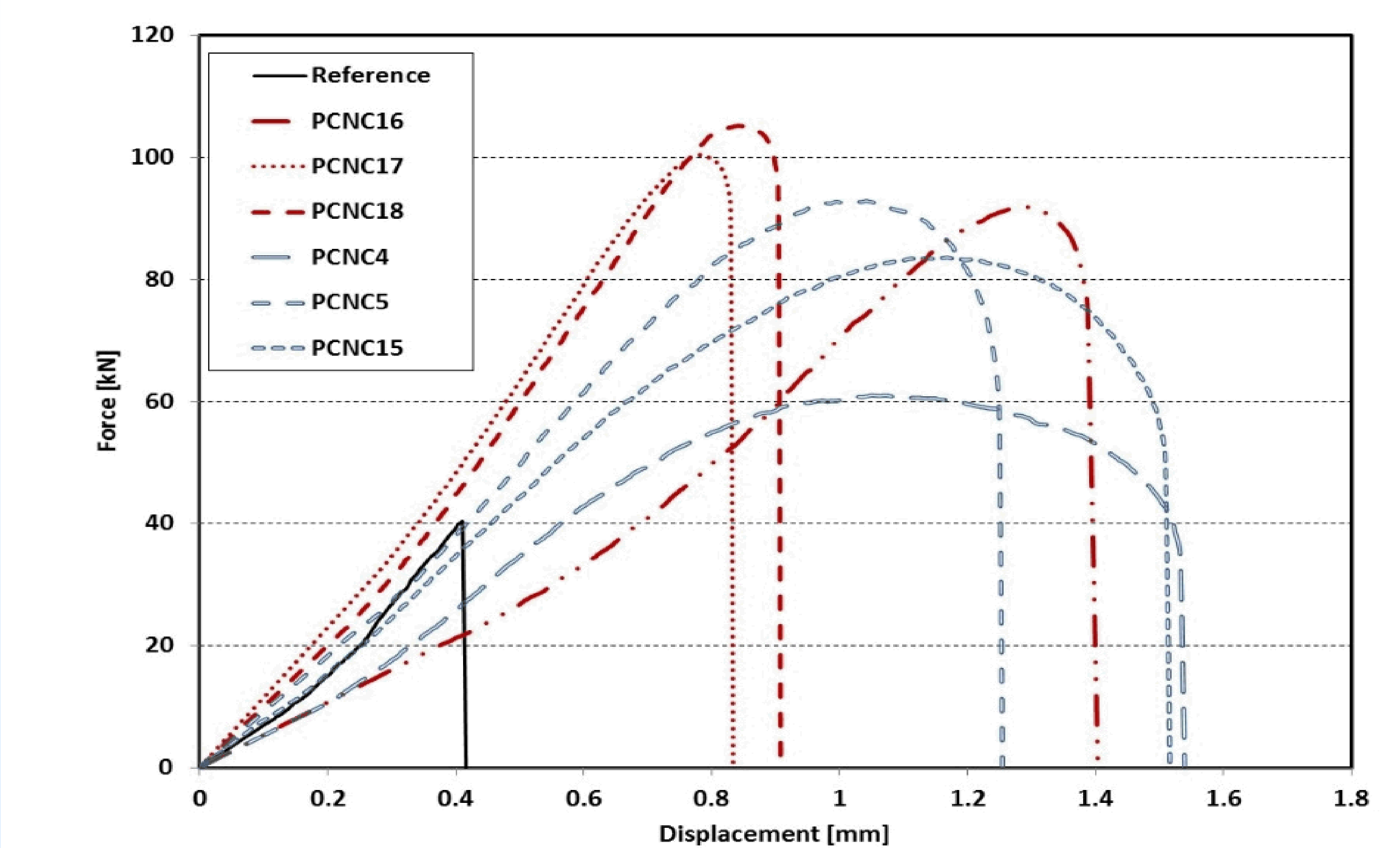
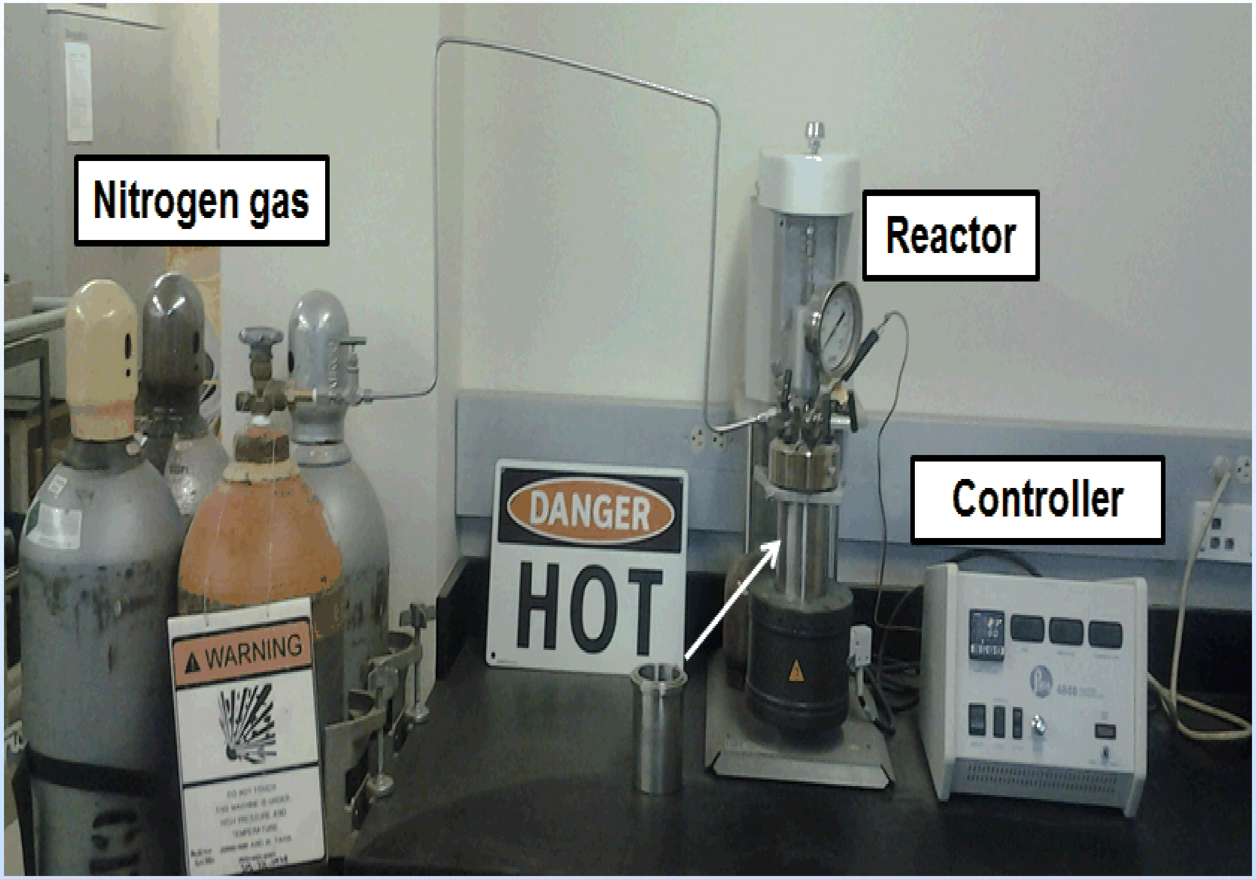
Bond Strength of PCNC and Steel

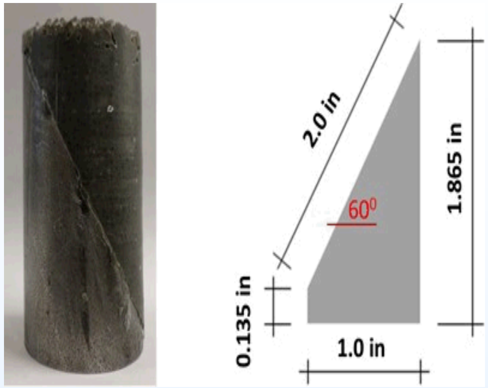


PCNC – Steel slant shear behavior

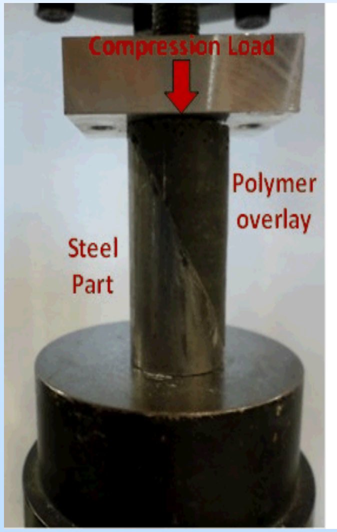


Examining the effect of high temperature and pressure



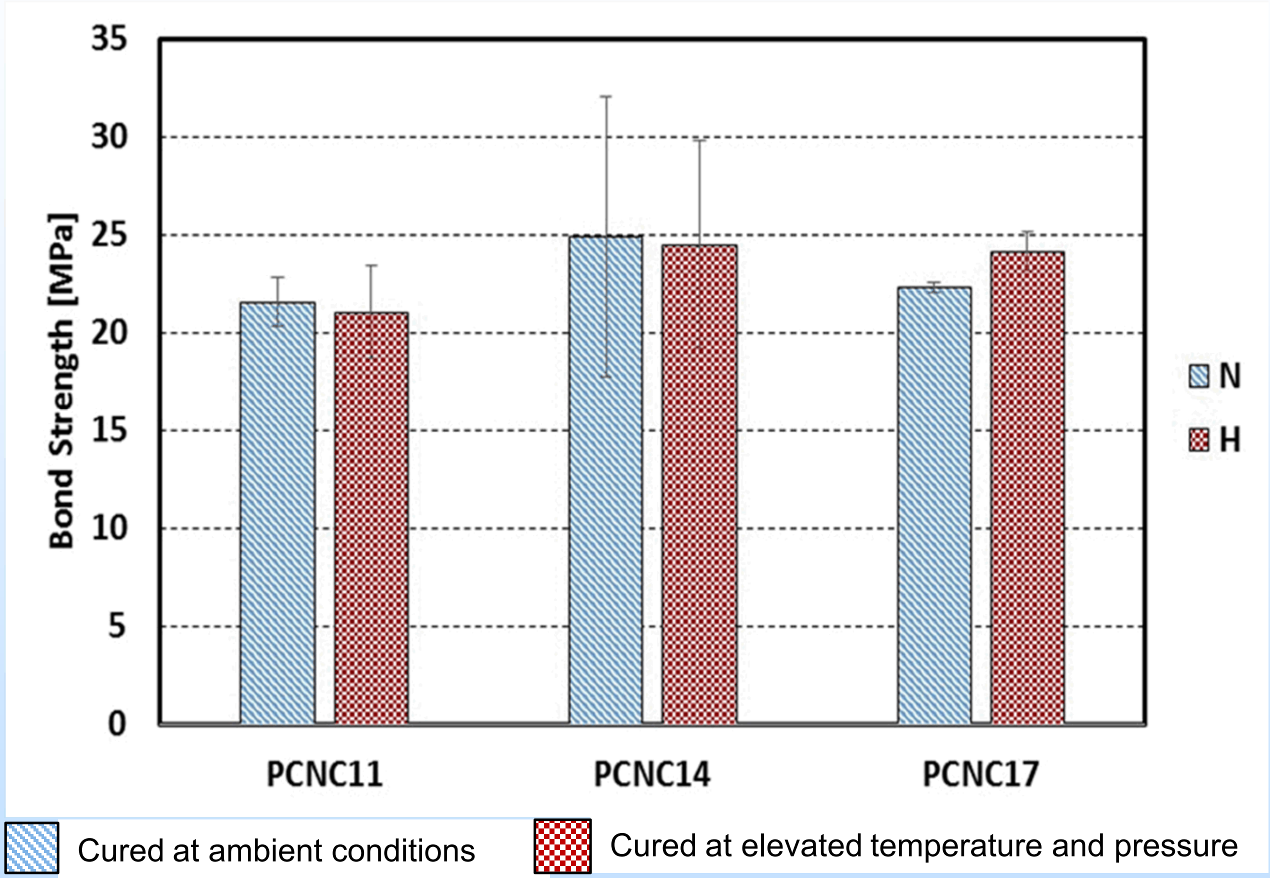


Scaled specimens

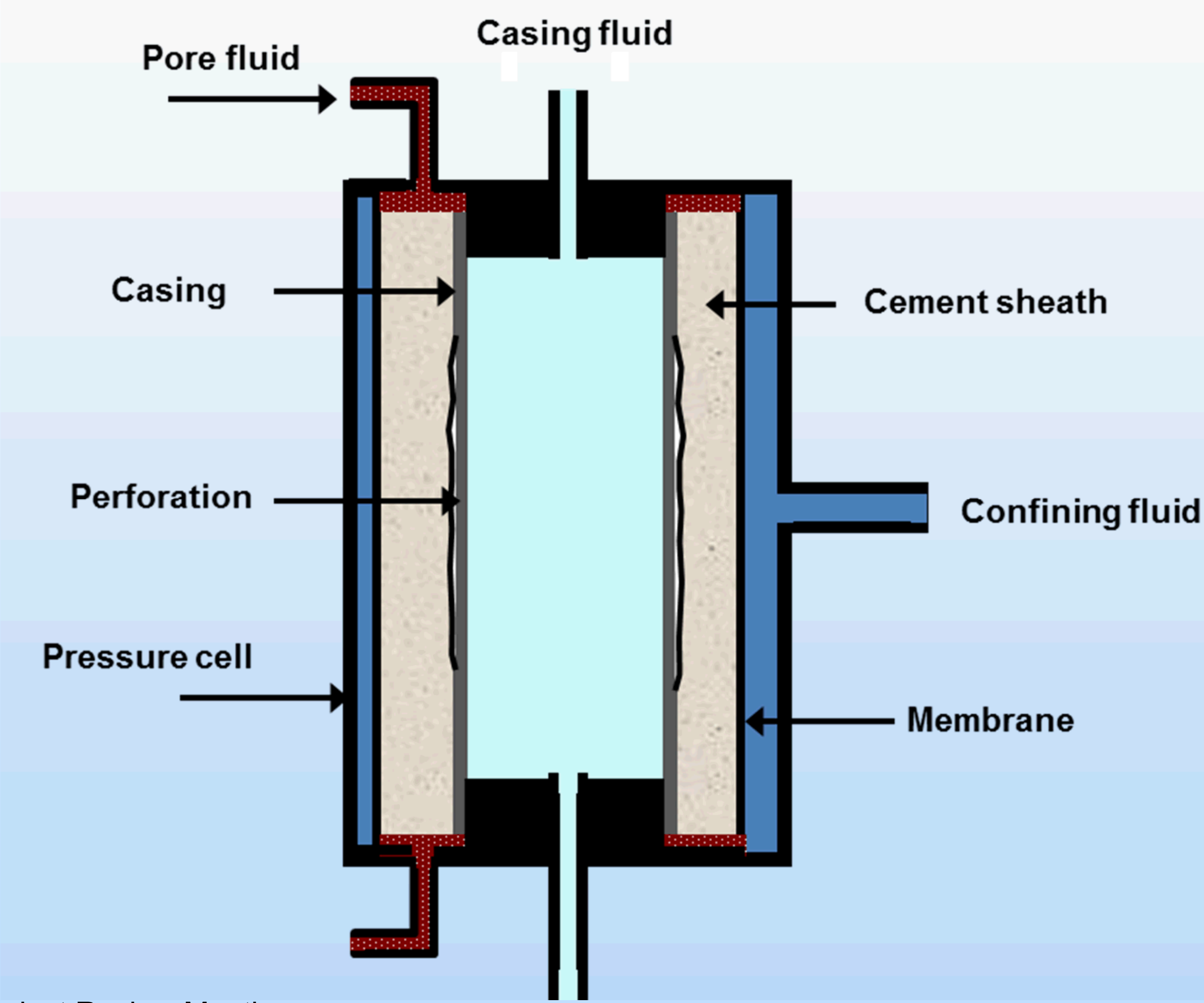


Temp: 80 °C, Pressure 10 MPa

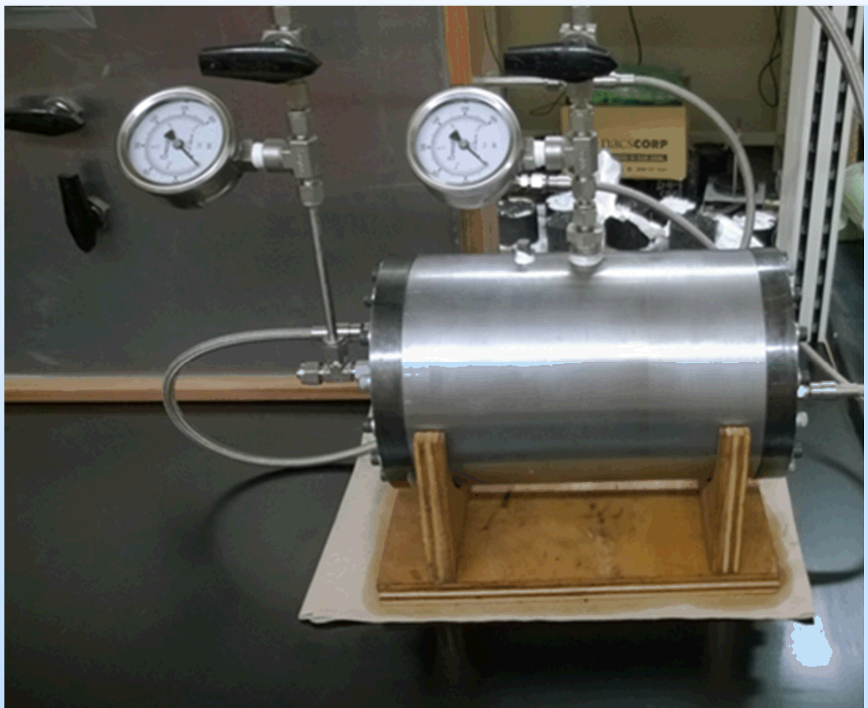
No effect of elevated temperature and pressure



Flow through damaged and repaired wellbore systems



Pressure vessel



Independent control of confining pressure to 30 MPa and casing pressure to 20 MPa.

Gas Permeameter

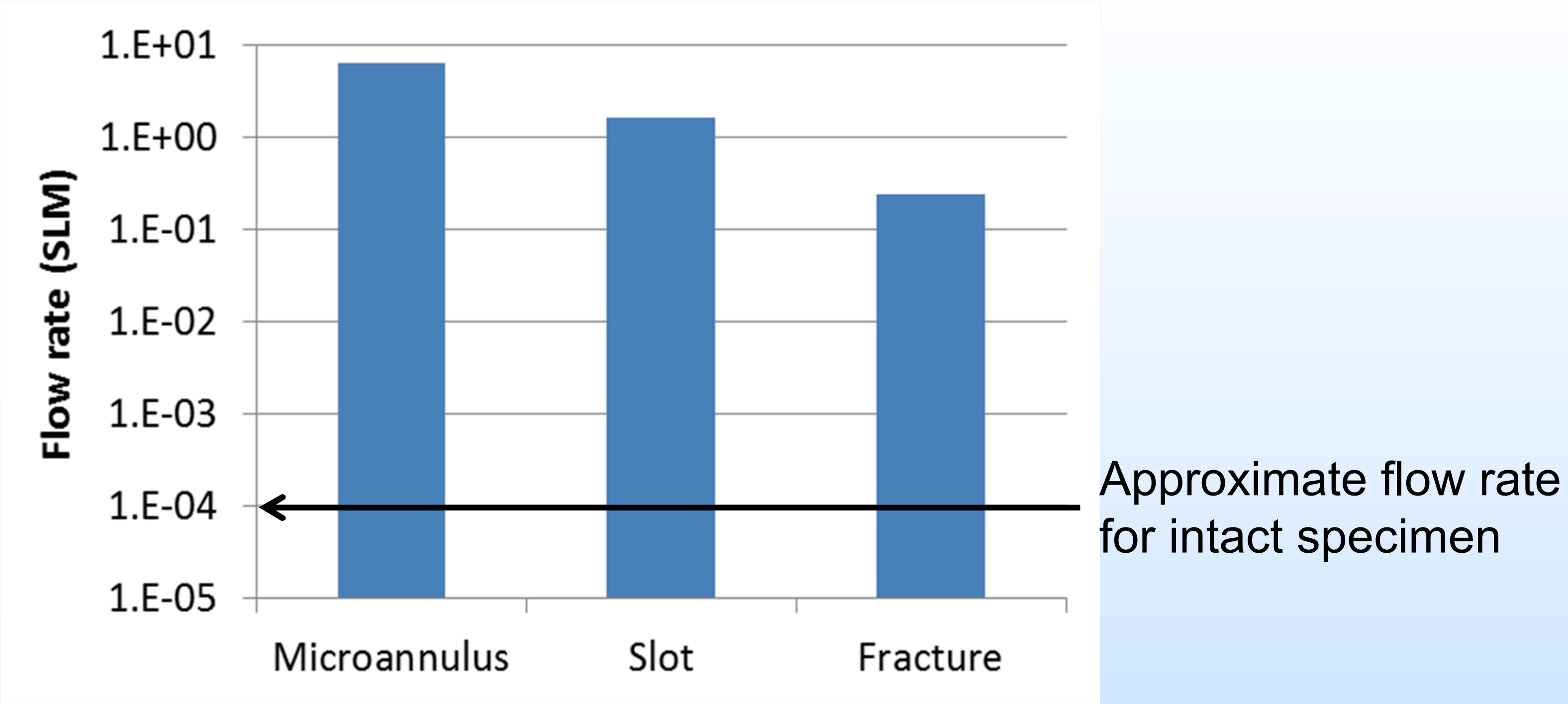
Gas pressures to 14 MPa.

Permeability range >10^{-12} to <10^{-21} m^2

Specimen preparation

- Microannulus
  - Large
  - Small
- Cement fracture

Flow dominated by flaws



Cubic law for hydraulic aperture

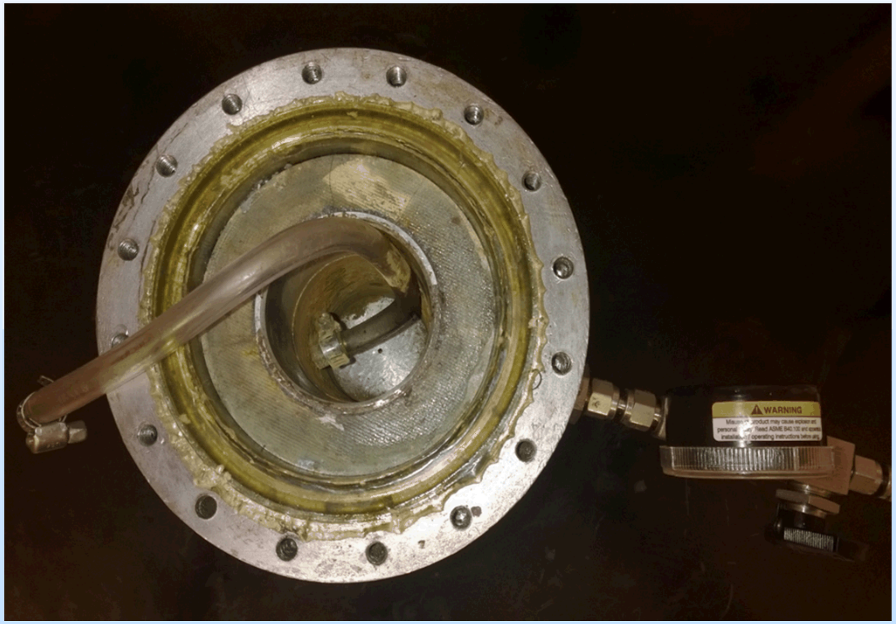
$$h^3 = \frac{12\,k\,A}{w}$$

Repair of damaged wellbores

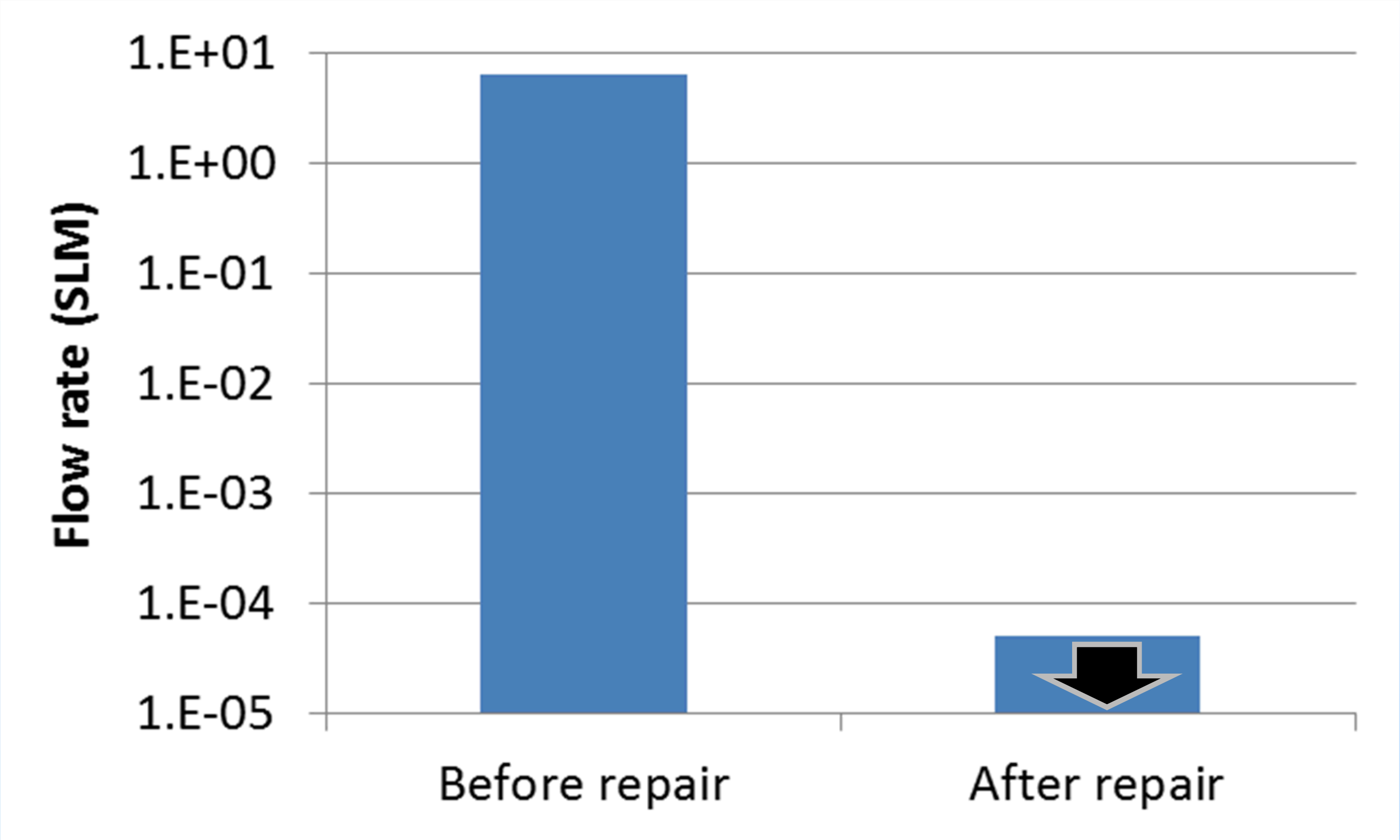
1. No pressure

2. Separate pressurized system

3. In pressure vessel

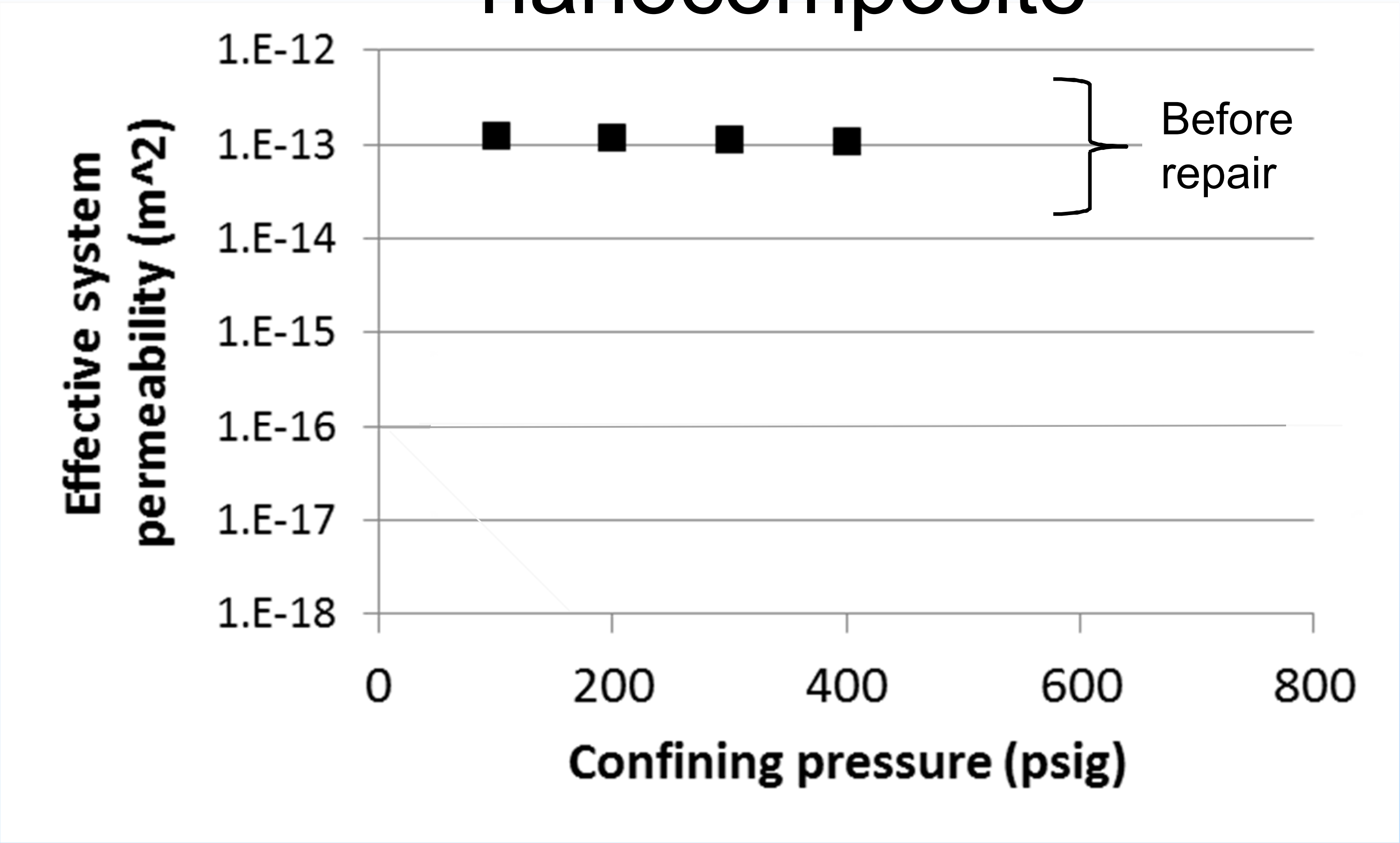


Microannulus repair using nanocomposite



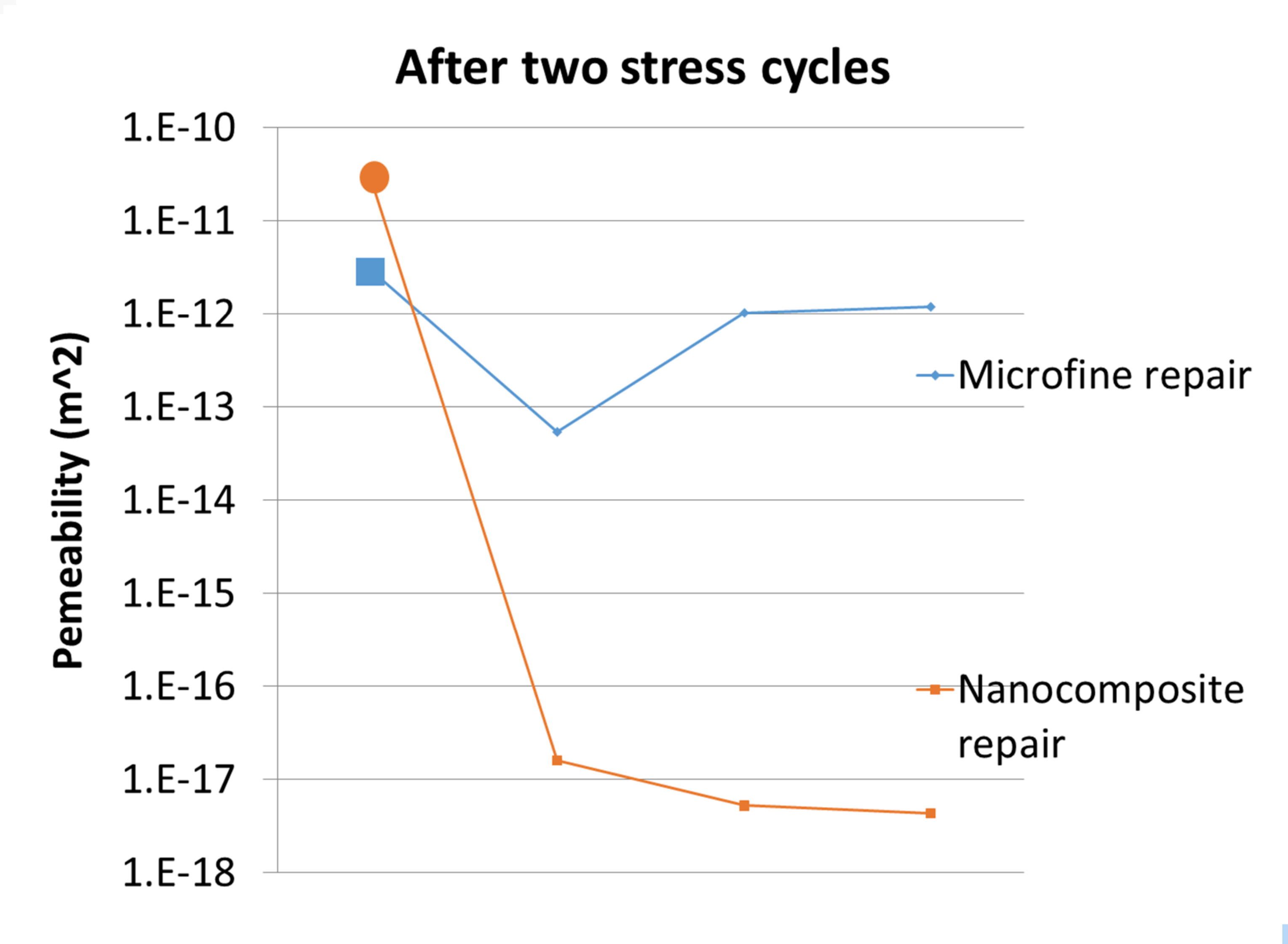
Confining pressure = 200 psig
Internal pressure = 200 psig
Pore pressure = 100 psig

Cement fracture repair using nanocomposite

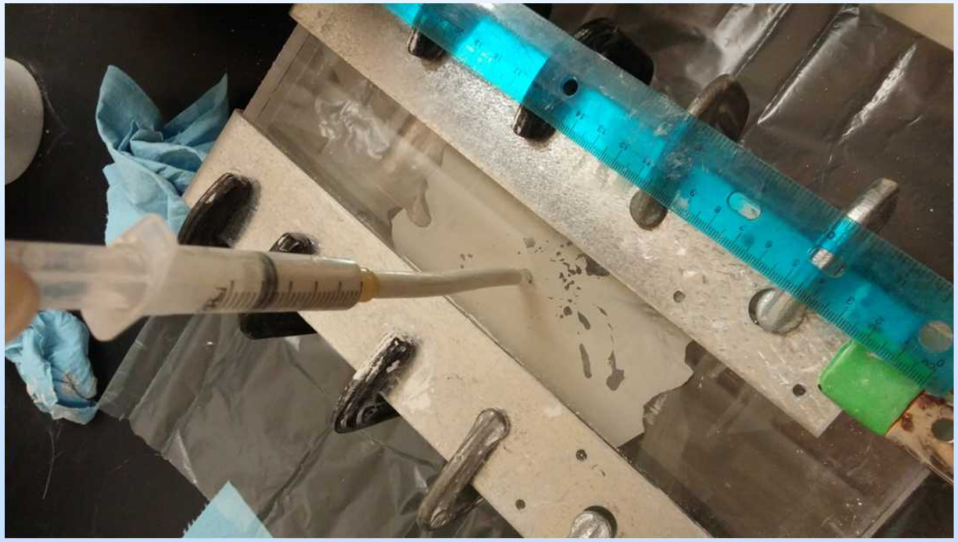


Internal pressure = confining pressure
Gas pressure = 50 psig

Repair response to stress cycles

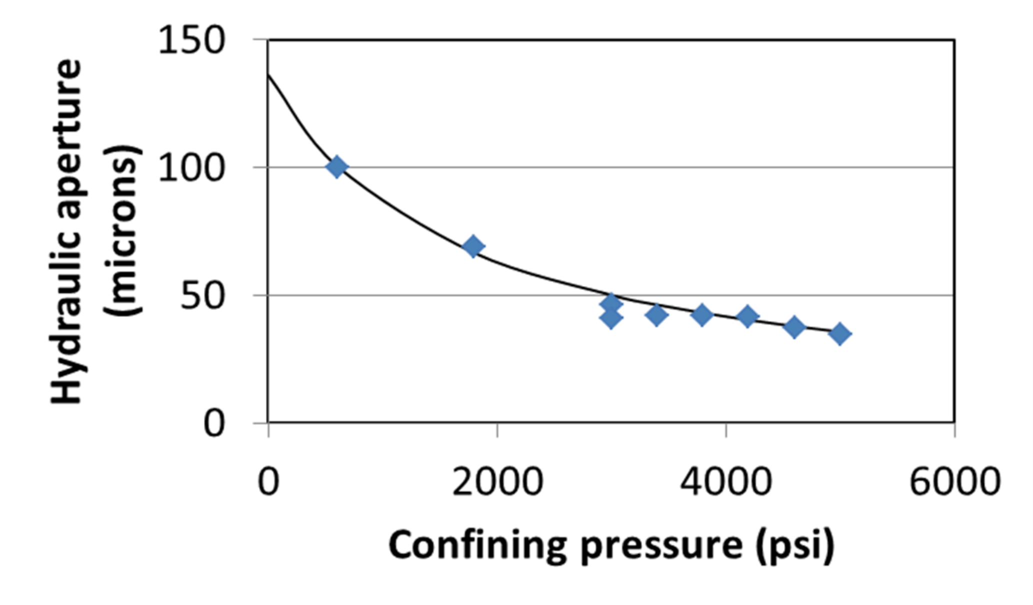


Nanocomposite penetrates smaller annular spaces



Microannulus model

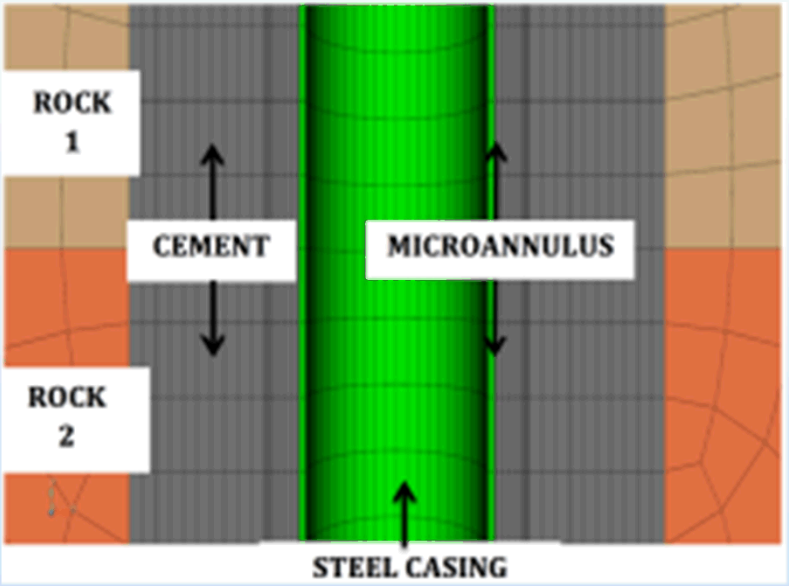
Model microannulus permeability in response to changes in confining and/or casing pressure and temperature.

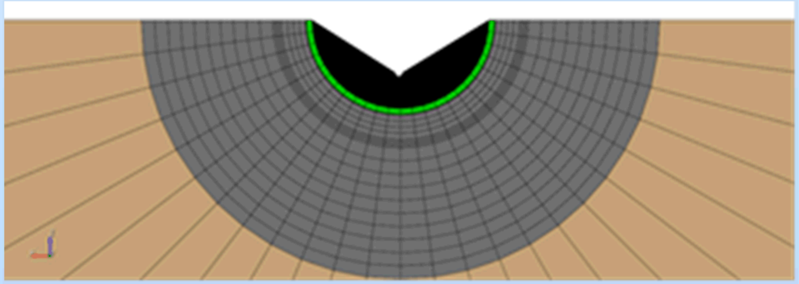


Wellbore model incorporating microannulus

Microannulus space can be modeled as

- Microannulus
- Open
- Cement
- Repair material





Accomplishments to Date

- Synthesized and characterized a number of nanocomposite and reference materials. For some nanocomposites:
  - Acceptable flowability
  - Bond strength and fracture toughness substantially increased
- Testing of wellbore seal systems
  - Developed experimental methods
  - Testing pre- and post-repair condition
- Simulation model developed

Synergy Opportunities

– Develop common performance criteria and testing methods which would allow for direct comparison between different repair materials.

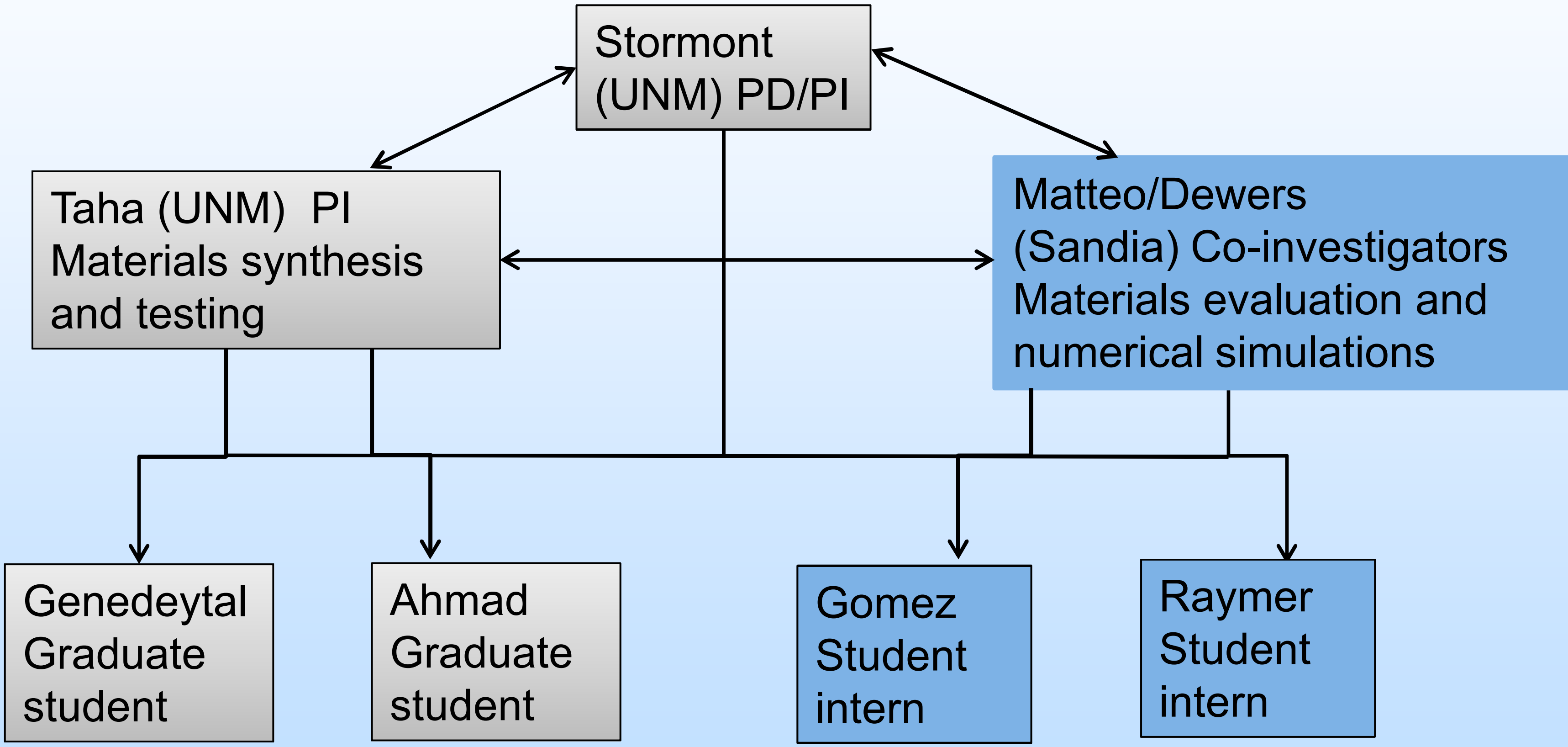
Summary

- Nanocomposites are being developed and tested with favorable properties as seal repair materials.

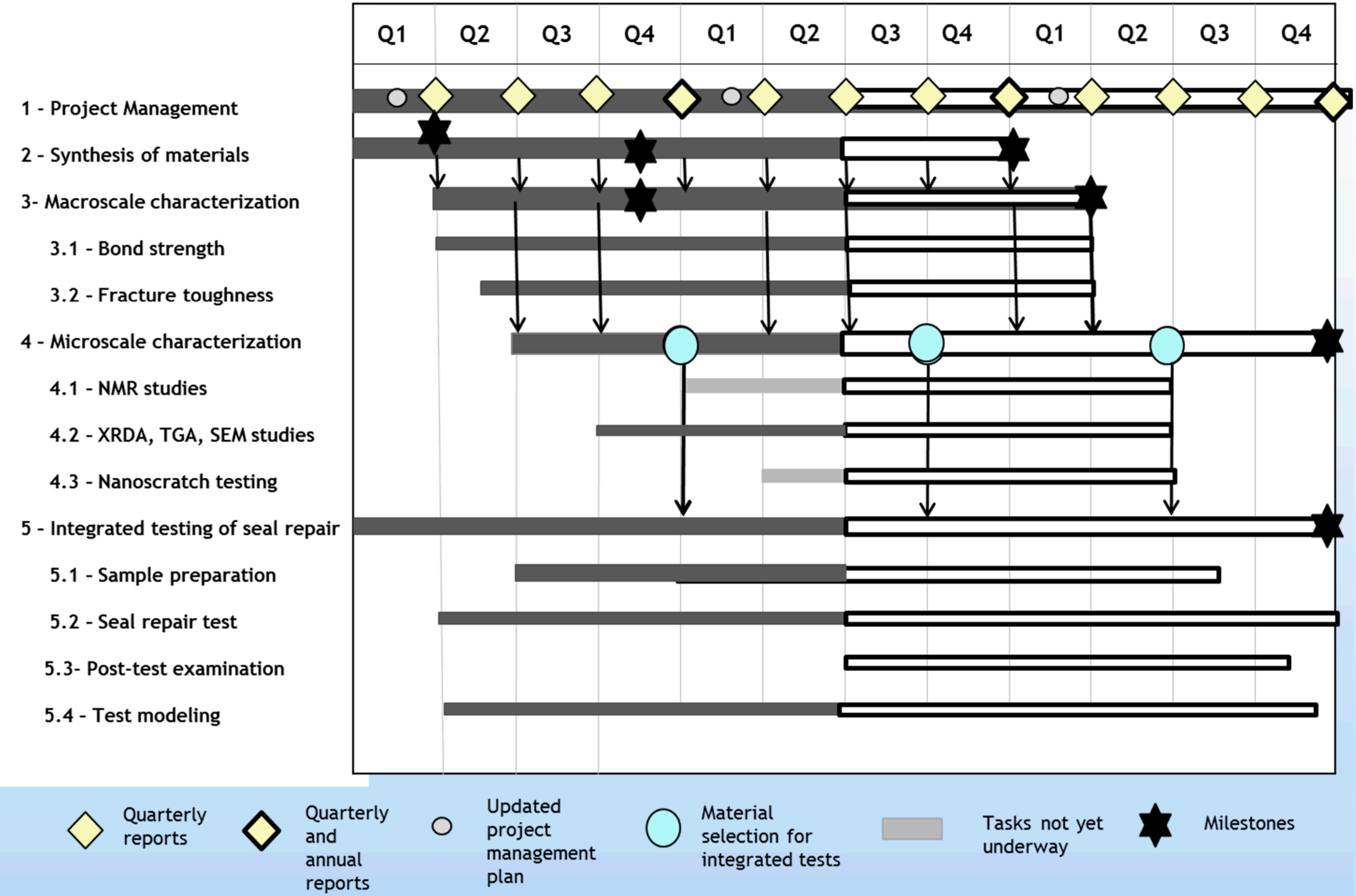
- Future Plan: Continue material synthesis and testing with accompanying testing and evaluation of seal system repair.

Appendix

Organization Chart



Gantt Chart


Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
1 - Project Management
2 - Synthesis of materials
3- Macroscale characterization
3.1 - Bond strength
3.2 - Fracture toughness
4 - Microscale characterization
4.1 - NMR studies
4.2 - XRDA, TGA, SEM studies
4.3 - Nanoscratch testing
5 - Integrated testing of seal repair
5.1 - Sample preparation
5.2 - Seal repair test
5.3- Post-test examination
5.4 - Test modeling
Quarterly reports
Quarterly and annual reports
Updated project management plan
Material selection for integrated tests
Tasks not yet underway
Milestones

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- Gomez, S.P. (2015) Wellbore Microannulus Characterization and Seal Repair: Computational and Lab Scale Modeling. Master's Thesis, University of New Mexico.

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