Wellbore Seal Repair Using Nanocomposite Materials

Project Number DE-FE0009562

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Developing the Technologies and
Infrastructure for CCS

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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

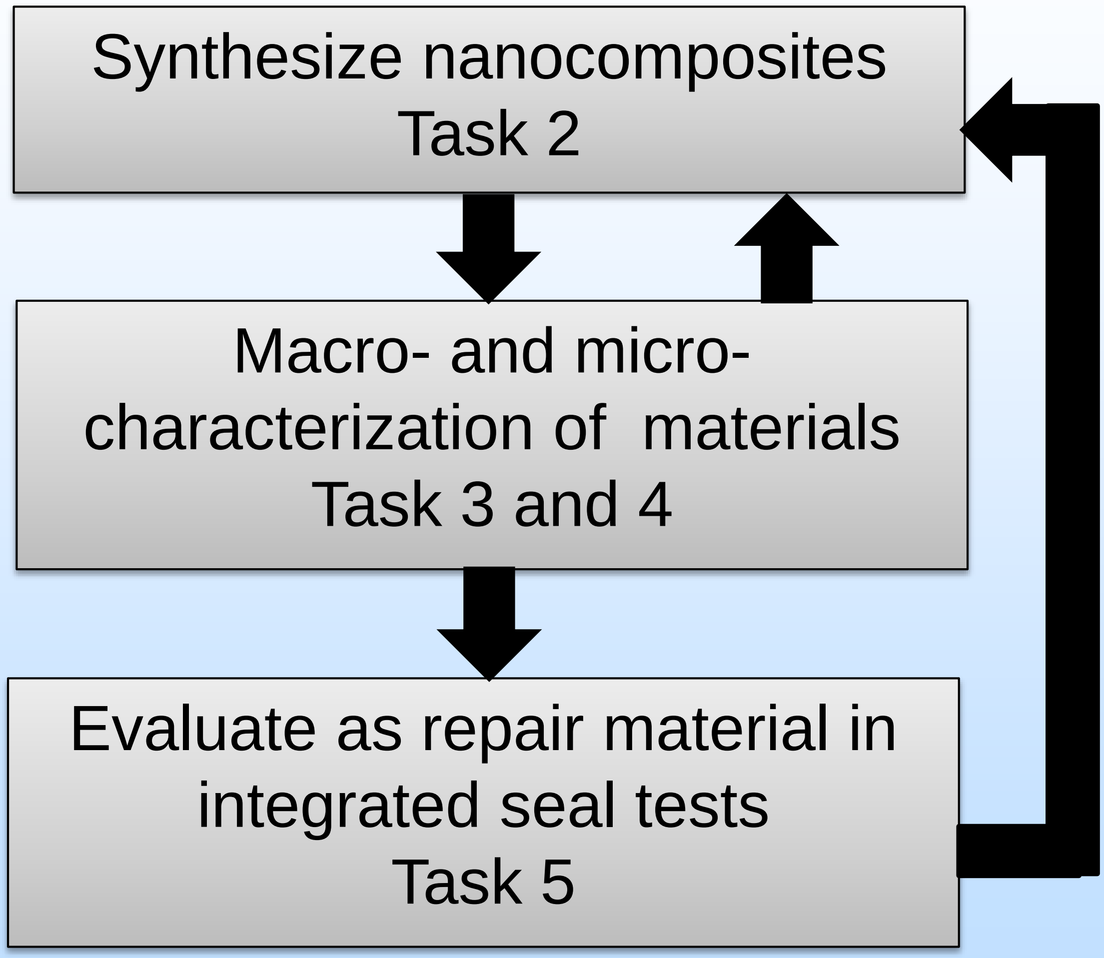
- (1) Develop and test ***nanocomposite seal repair materials*** suitable for expected wellbore environments that have ***high bond strength*** to casing and cement, ***high fracture toughness,*** and ***low permeability***.
  - These materials will have superior properties compared to conventional materials 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)

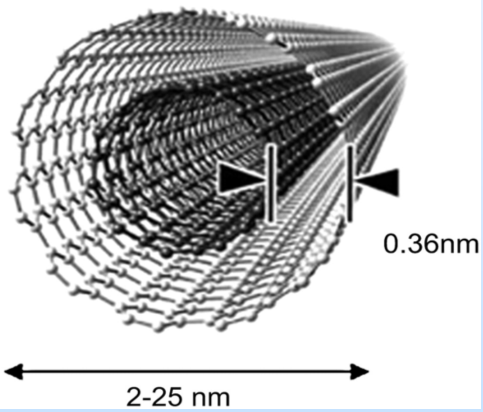
(2) Evaluate the effectiveness of developed materials to repair flaws in ***large lab-scale annular seal systems*** under conditions expected in wellbores.

- 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

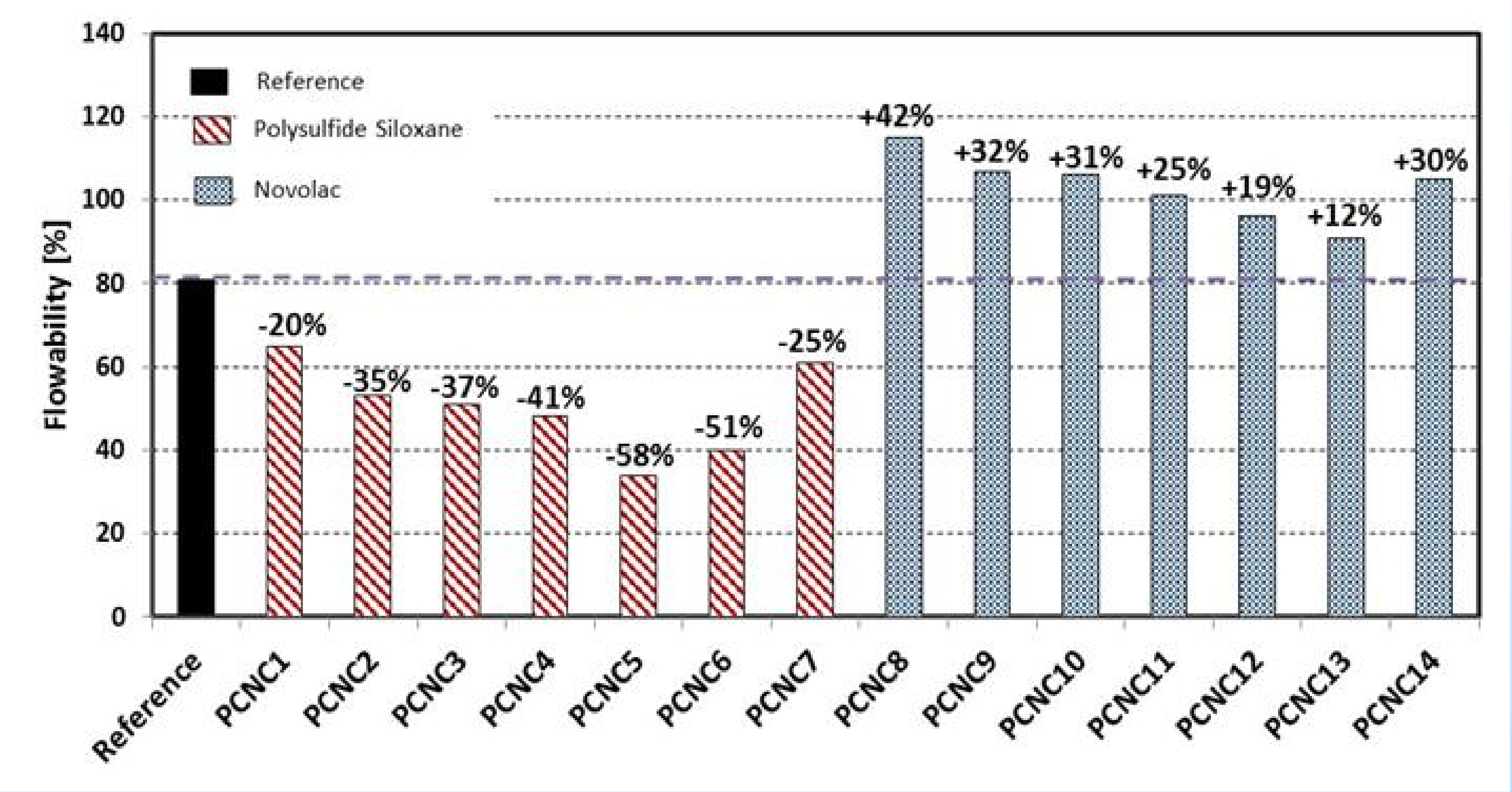
Materials

Mixture Abbreviation	Base Material	Nano-particles	Content %
Reference	Microfine cement	None	----
PCNC1	Polysulfide siloxane epoxy	None	----
PCNC2	Polysulfide siloxane epoxy	MWCNTs	0.5%
PCNC3	Polysulfide siloxane epoxy	MWCNTs	1.0%
PCNC4	Polysulfide siloxane epoxy	MWCNTs	1.5%
PCNC5	Polysulfide siloxane epoxy	Nanoclay	4.0%
PCNC6	Polysulfide siloxane epoxy	Nanosilica	1.0%
PCNC7	Polysulfide siloxane epoxy	Nanoalumina	2.0%
PCNC8	Novolac epoxy	None	----
PCNC9	Novolac epoxy	MWCNTs	0.5%
PCNC10	Novolac epoxy	MWCNTs	1.0%
PCNC11	Novolac epoxy	MWCNTs	1.5%
PCNC12	Novolac epoxy	Nanoclay	4.0%
PCNC13	Novolac epoxy	Nanosilica	1.0%
PCNC14	Novolac epoxy	Nanoalumina	2.0%

Flowability

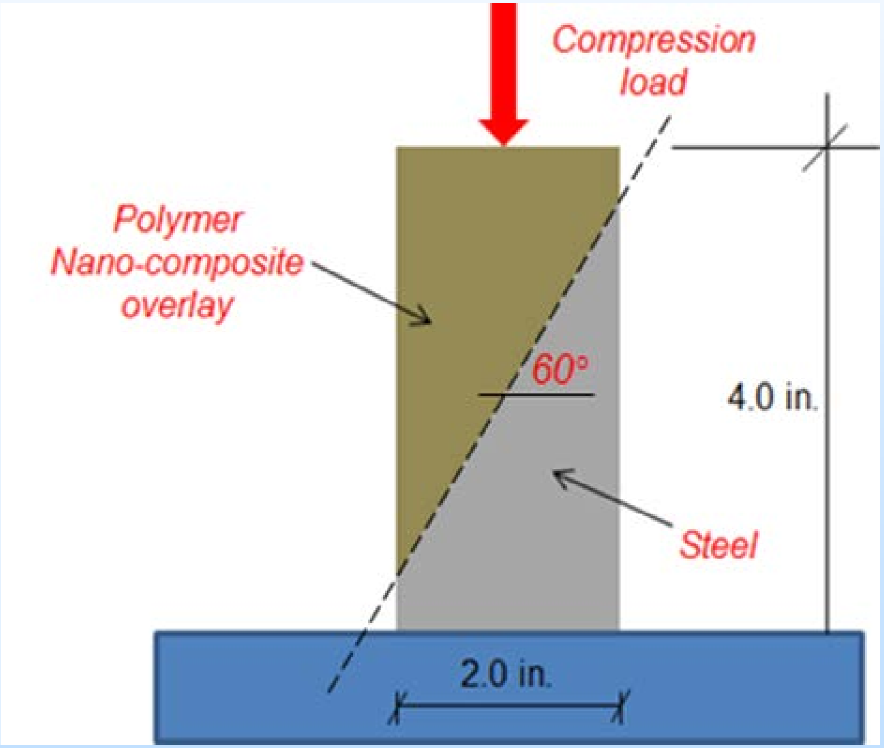
related to ability to inject nanocomposite into flaws.

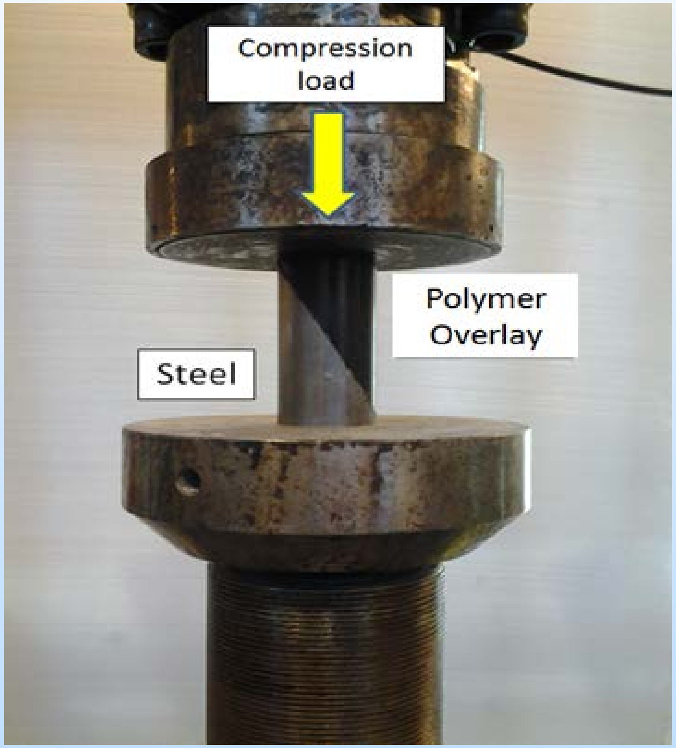
Flowability results



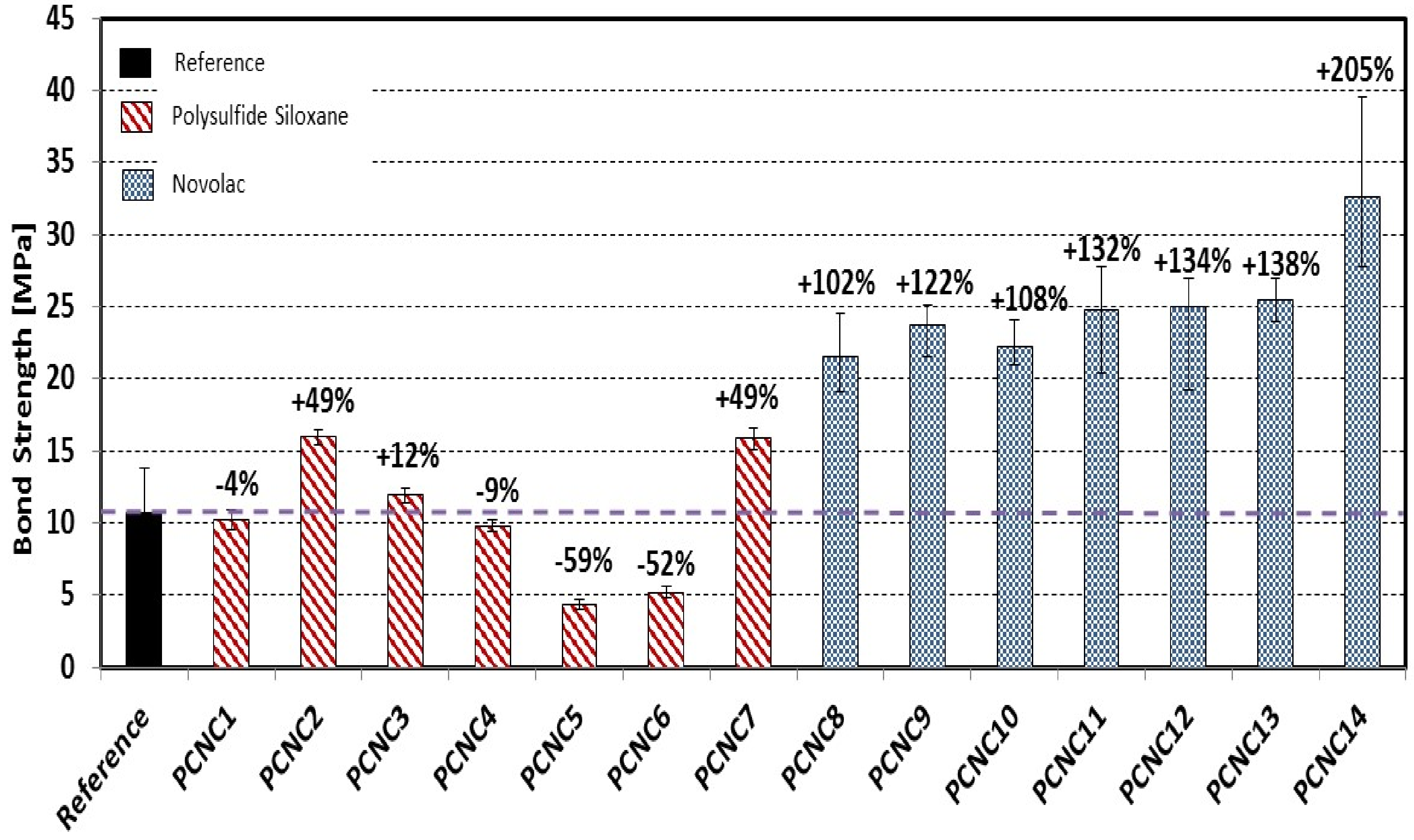
Bond strength characterization

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

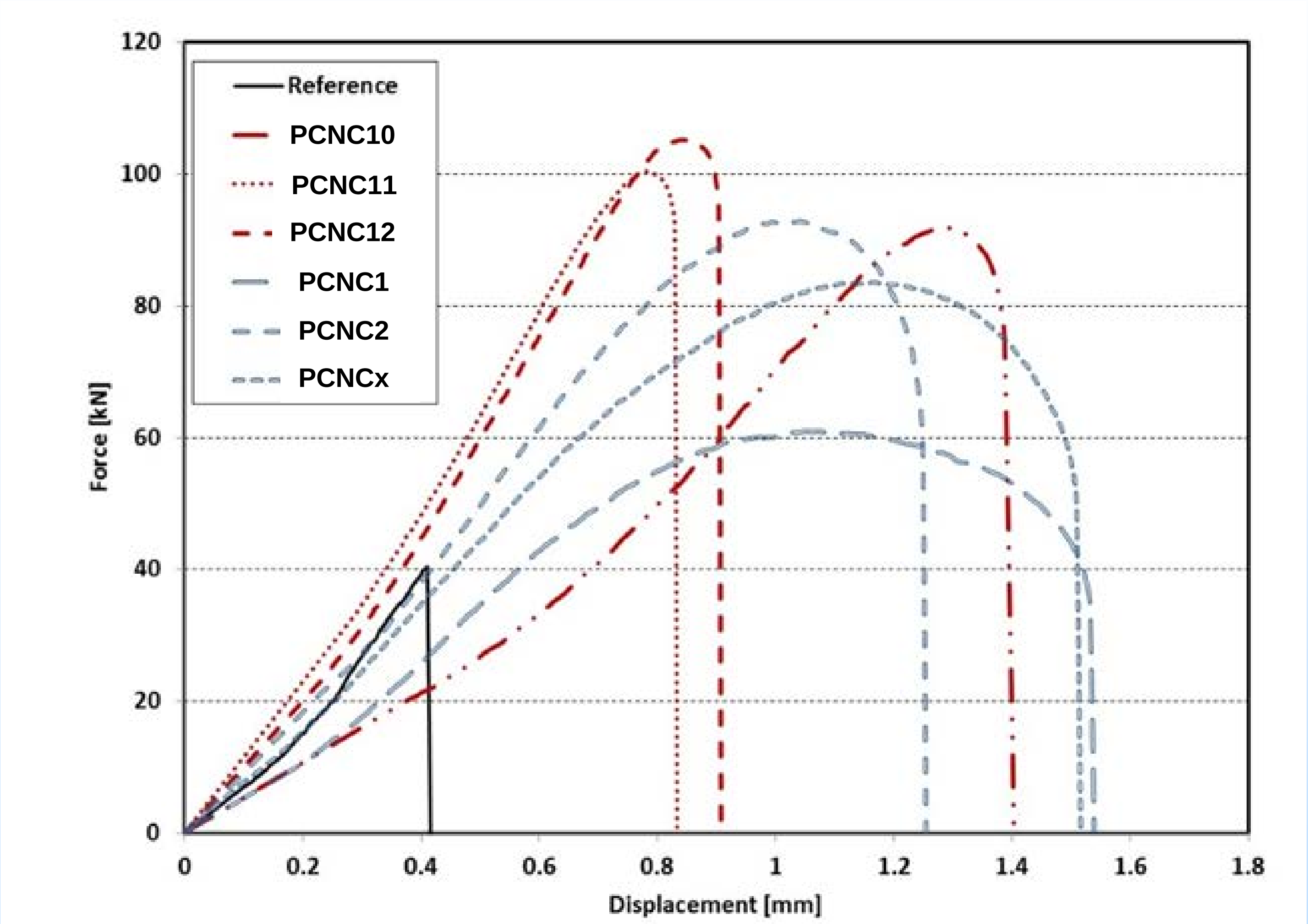




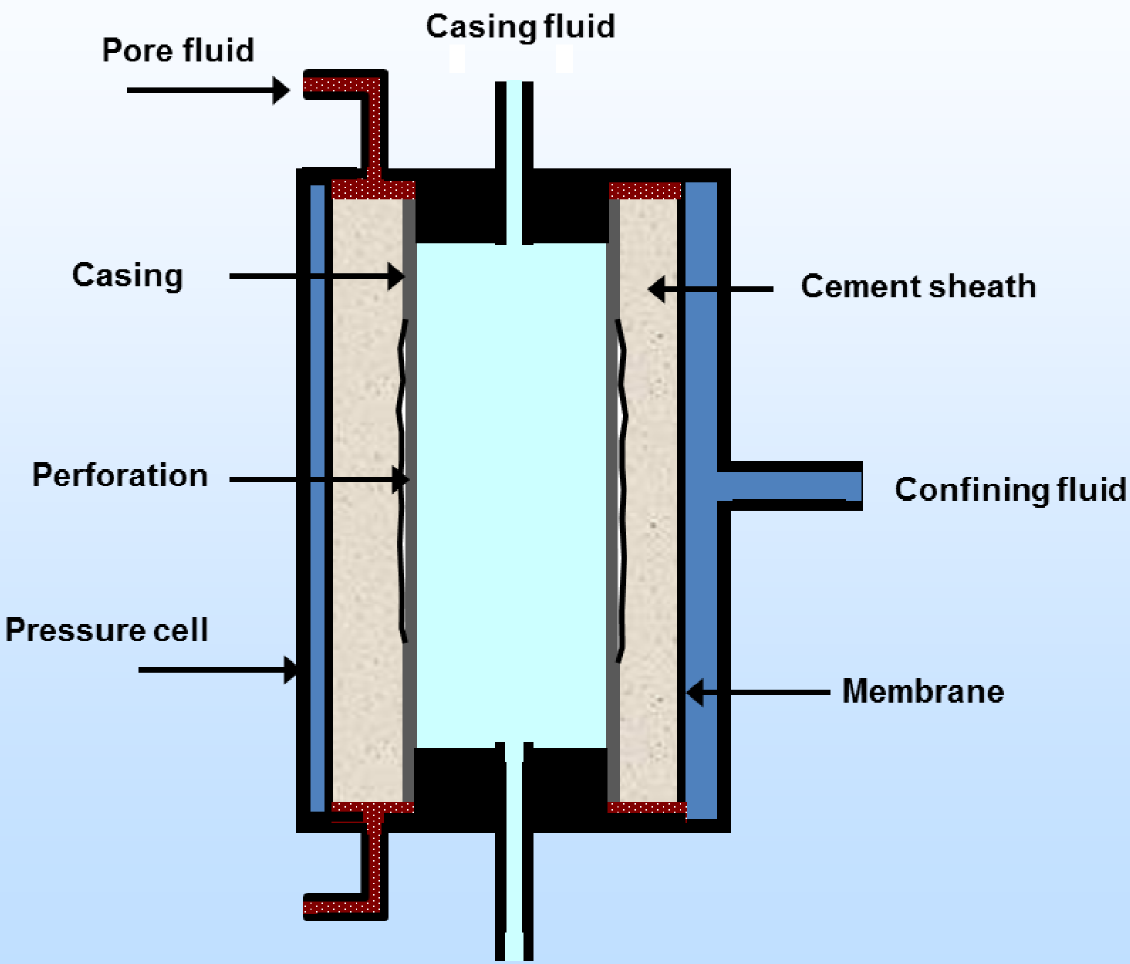
Slant shear test results



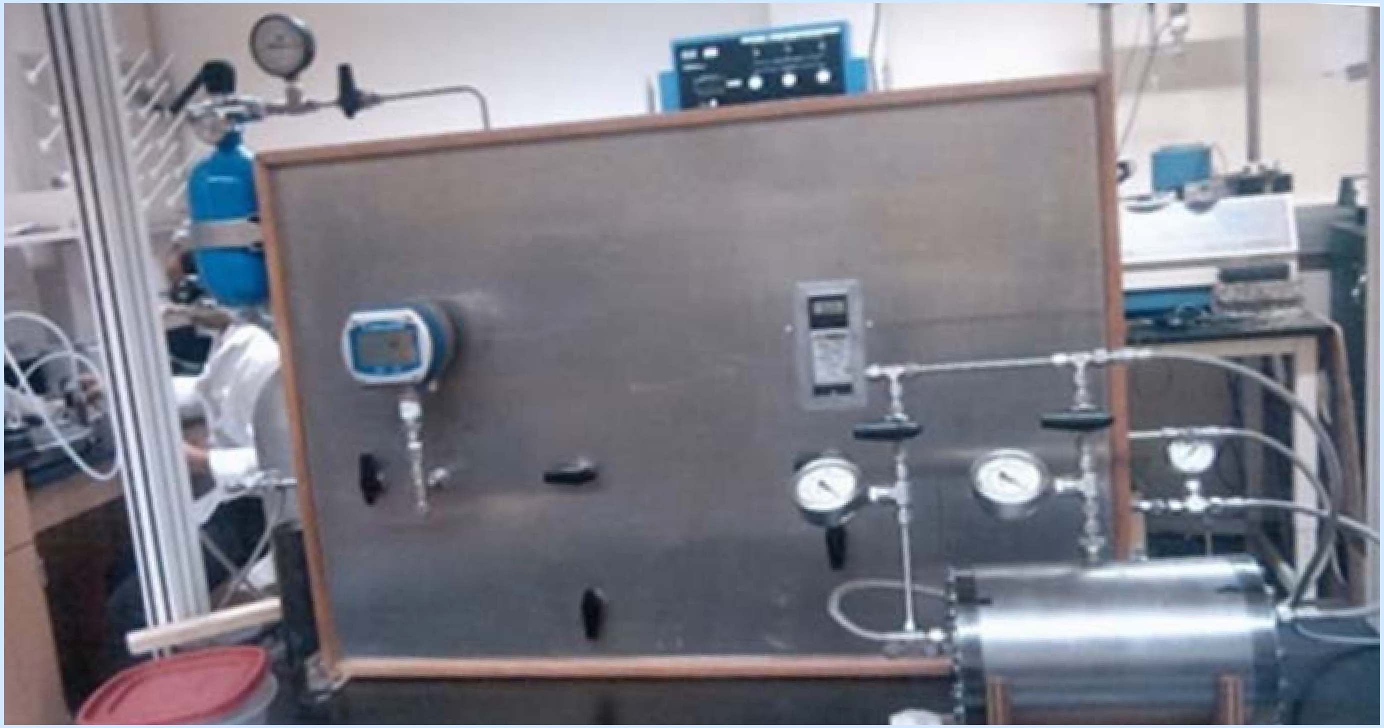
Slant shear test results



Integrated seal system testing



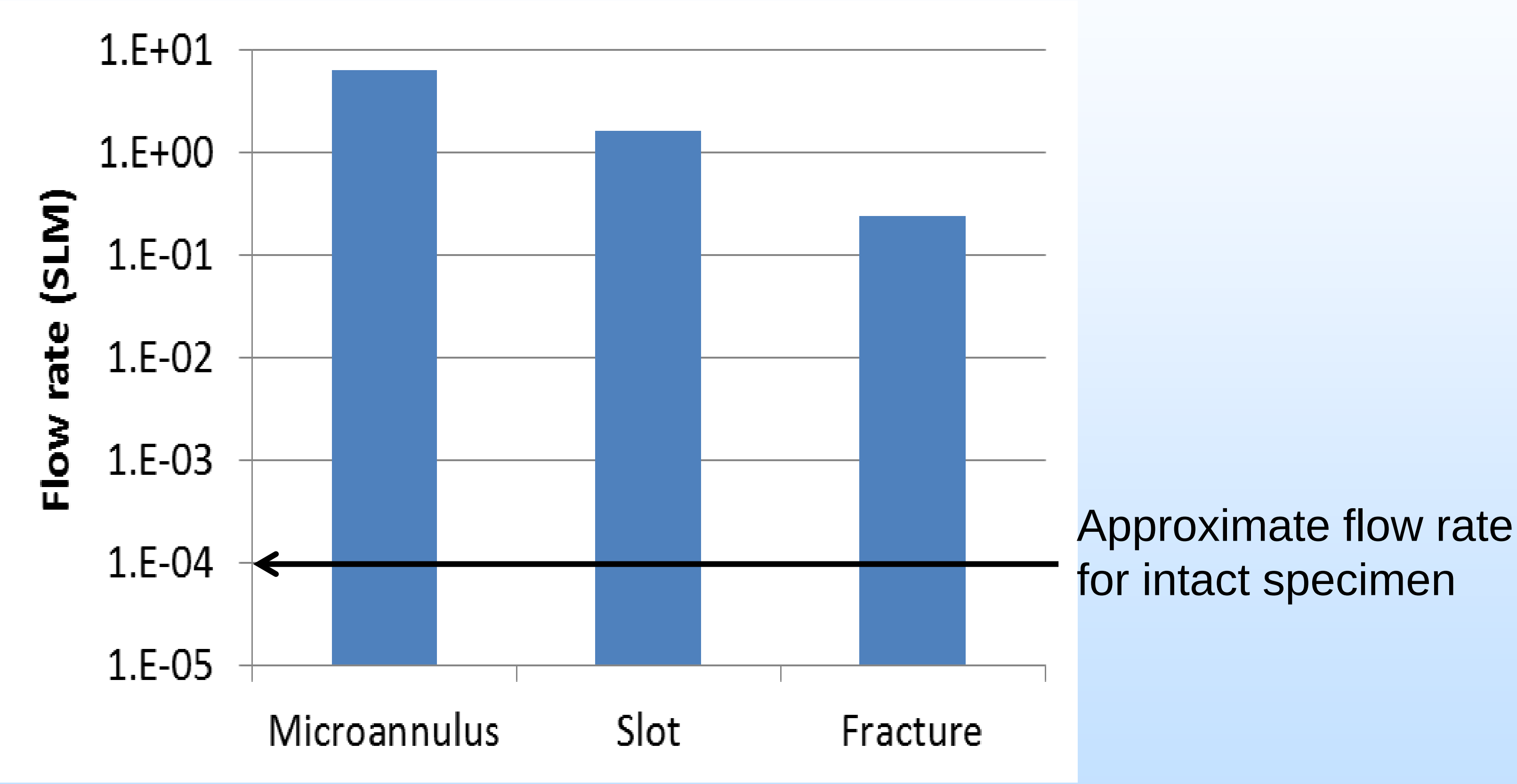
Configuration for wellbore seal system tests



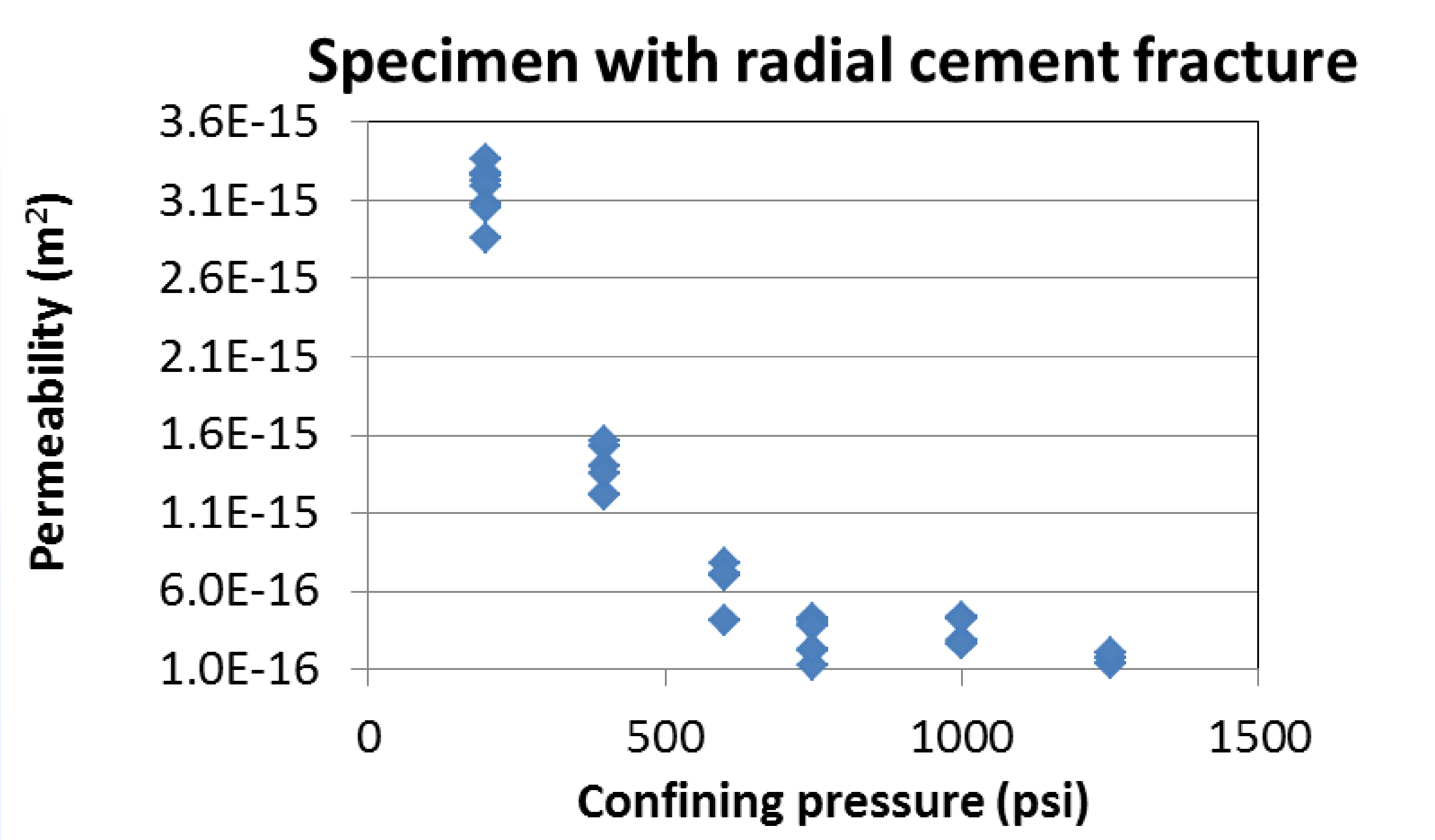
Annular seal system specimen preparation

- Microannulus
- Gap
- Cement fracture

Flows through flaws



Flows through flaws

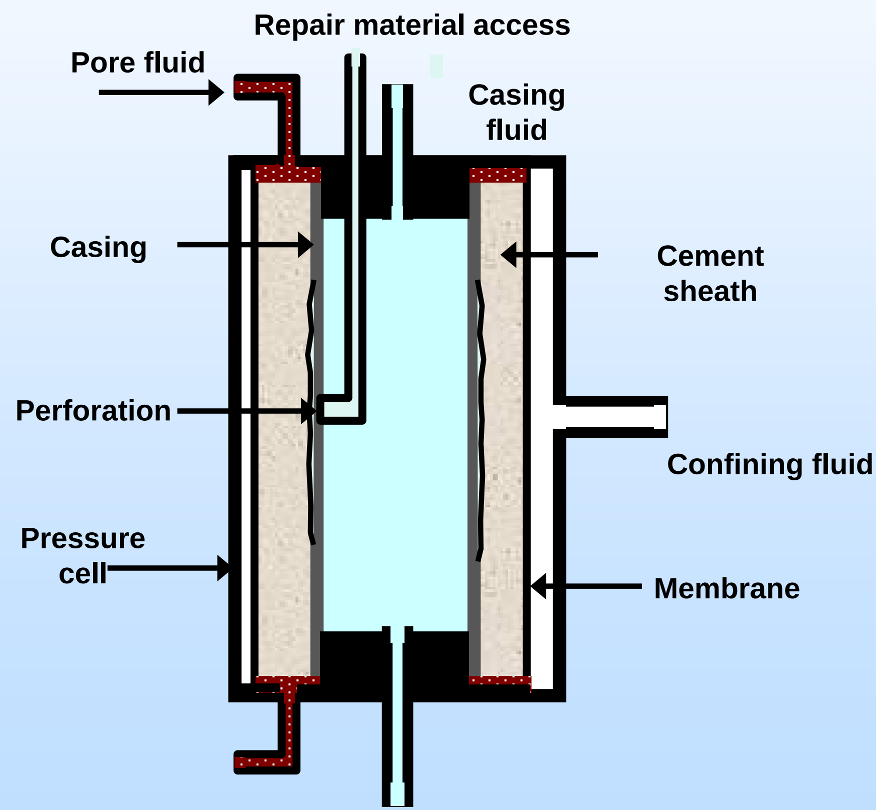


Repair

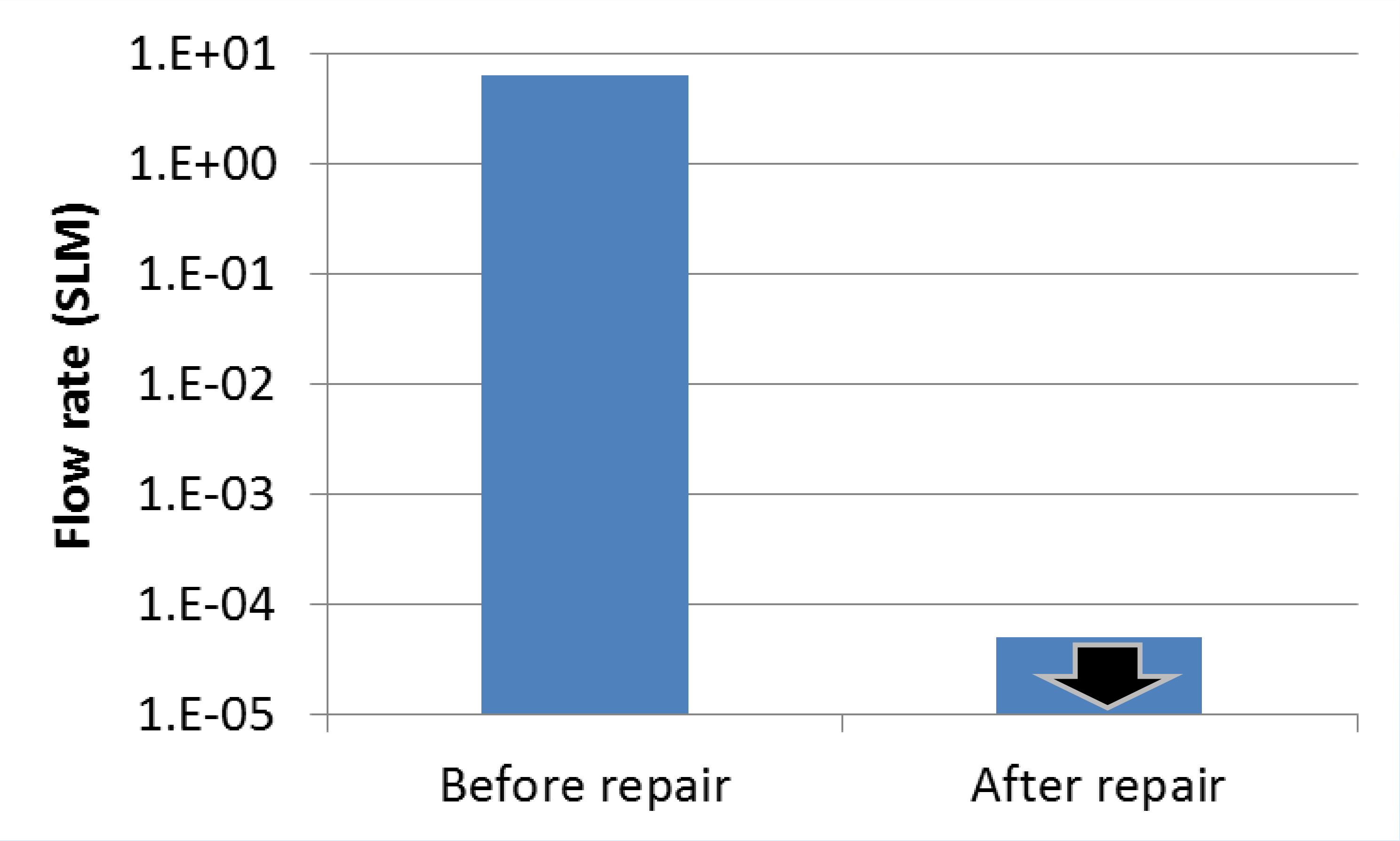
1. No pressure

2. Separate pressurized system

3. In pressure vessel

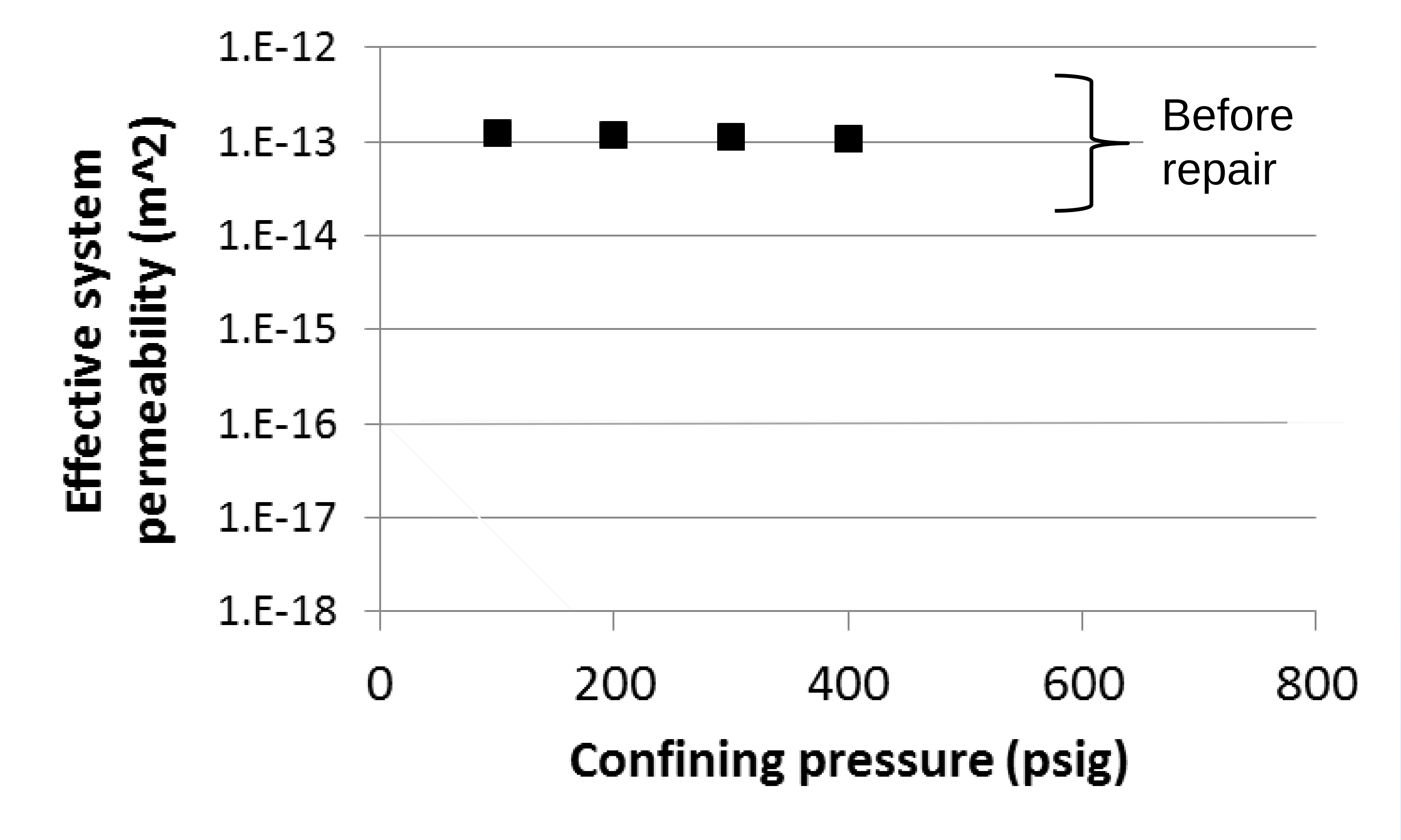


Microannulus repair



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

Cement fracture repair



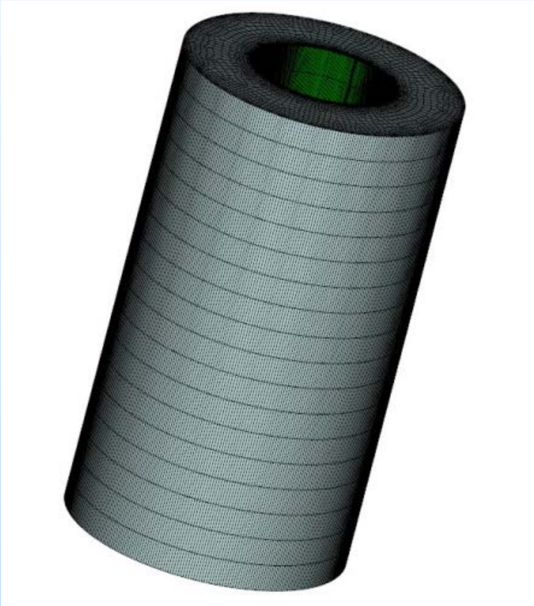
Internal pressure = confining pressure
Gas pressure = 50 psig

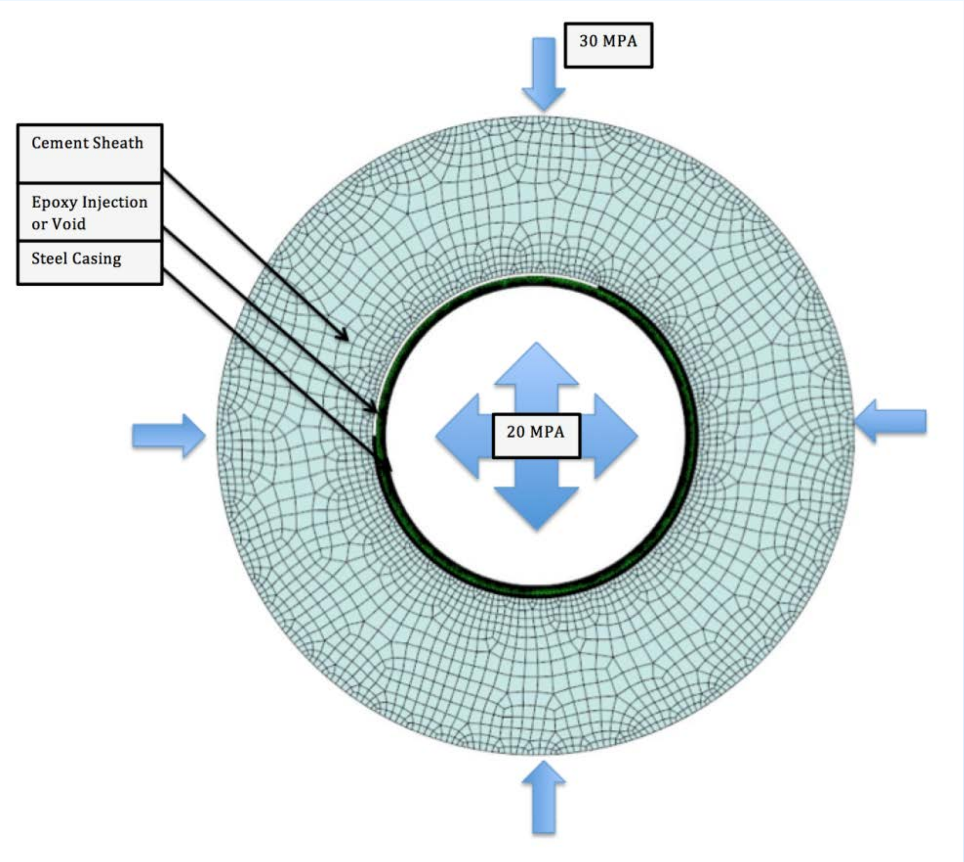
Numerical simulations

Model of pressure vessel system

Estimate stress and strains repair material will be subject to

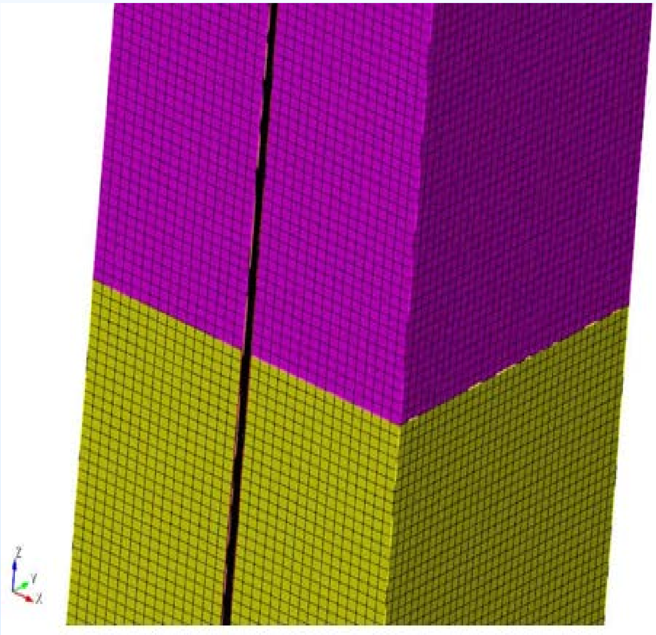
Correlate stress conditions to permeability values



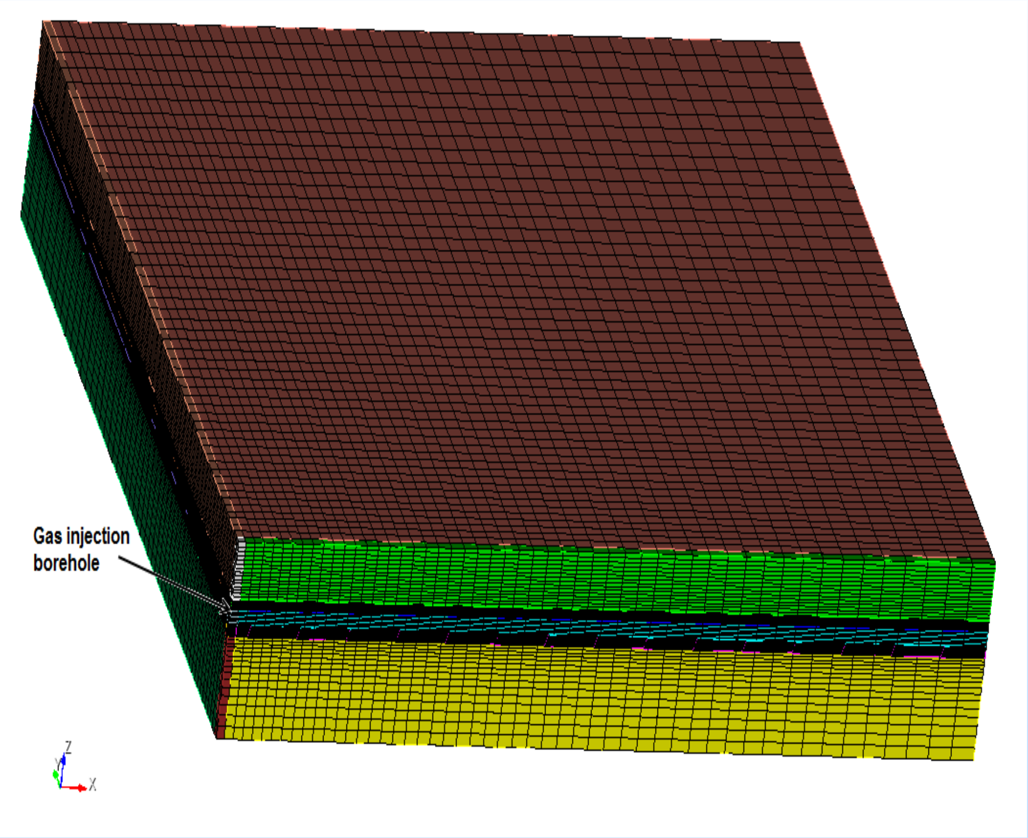


Numerical simulations

Discrete wellbore model



Full-scale Cranfield model



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

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.

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We thank Steve Sobolik and Steven Gomez for their contributions to the modeling work, and Moneeb Genedyetal, Rashid Ahmad and Joshua Ellison for their help with the laboratory work.

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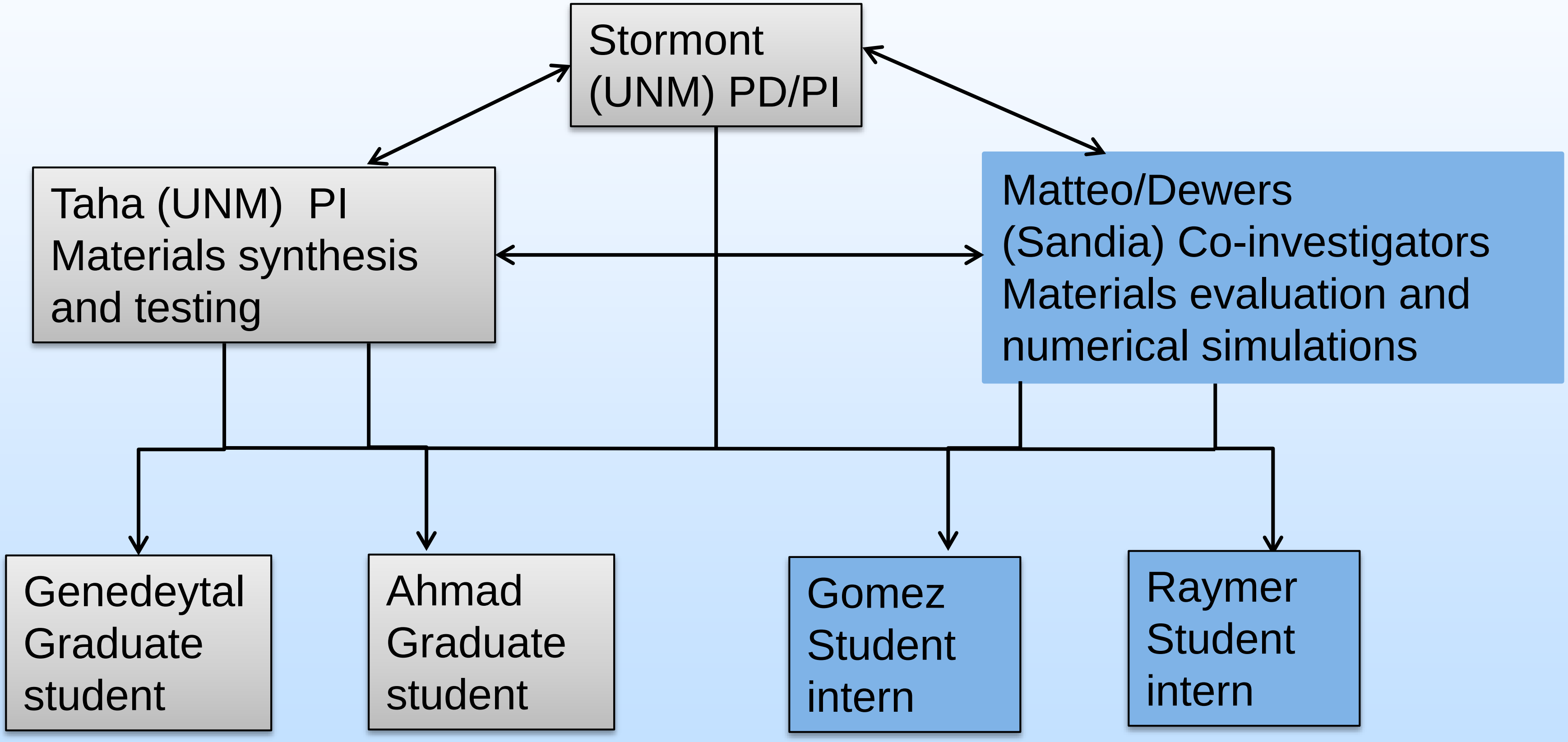
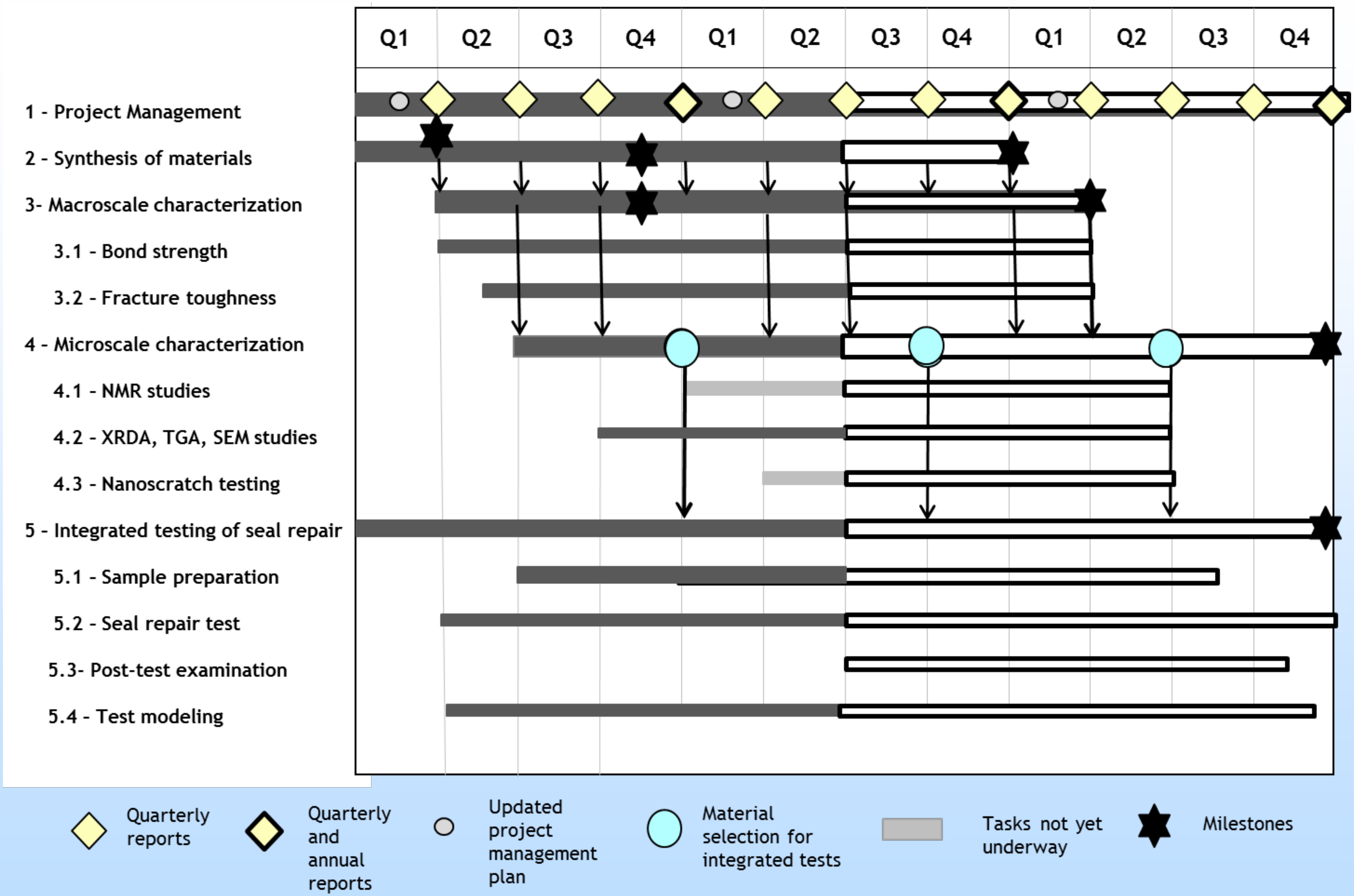
Appendix

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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