Polymer nanocomposites for sealing microannuli in wellbores

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Introduction and Objective

- Seal integrity of production and storage wellbores has become a critical challenge.
- The micro-annuli at the cement-steel and cement-rock formation interfaces are the potential leakage pathways.
- Effective repair material would have the ability to flow through the micro-annuli, harden, bond with steel, cement, and rock formations and produce an impermeable media that can stop fluid leakage through the micro-annuli.
- We examine the efficiency of a proposed polymer nanocomposite to seal microannulus cracks at the cement-steel and cement-rock formation interfaces.

Methods

Push-out

Push-out tests were conducted to investigate the bond strength of proposed repair material with cement-shale interface. The results are compared to reference bond between Type G- cement and shale rock.

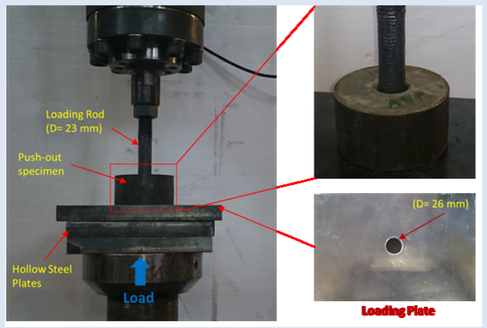


Figure 1: Push-out test setup

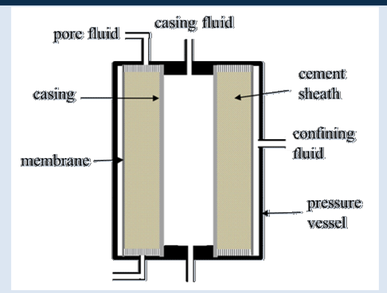
Integrated wellbore testing

- The flow rate of an inert gas (nitrogen) at the cement-steel interface was measured before and after repair.
- The specimens investigated include those repaired with:

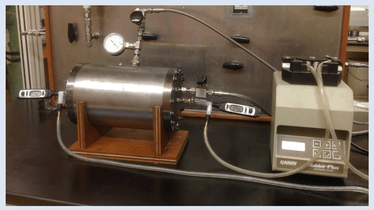
  1- traditional repair material (microfine cement).

  2- polymer nanocomposites

- Flow rates were measured and compared for each specimen before and after repair.
- The repair material efficiency is defined as the ability of the repair material to reduce or eliminate gas permeability through the cement-steel interface.



(a)



(b)

Figure 2: (a) Schematic for integrated wellbore test. (b) integrated wellbore test setup

Results

Push-out

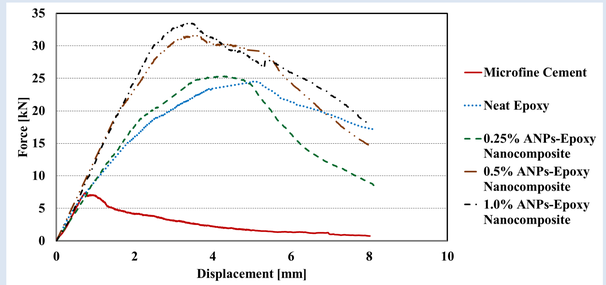


Figure 3: Load-displacement relationships of examined repair materials

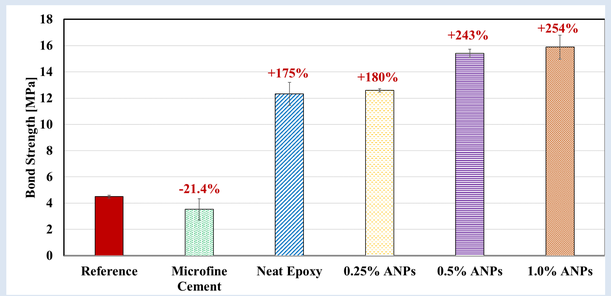


Figure 4: Bond strength of examined repair materials compared to reference.

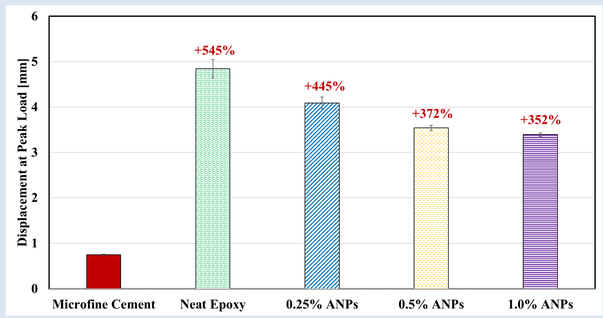


Figure 5: Displacement at Peak Load of proposed repair materials compared to microfine cement.

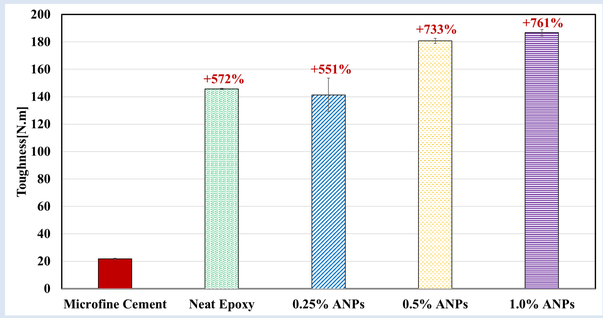


Figure 6: Toughness of proposed repair materials compared to microfine cement.

Microscopic Images

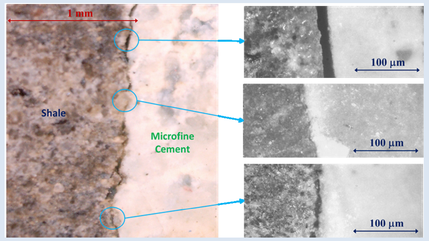


Figure 7: Microscopic images of shale-microfine cement interface with two different levels of magnification.

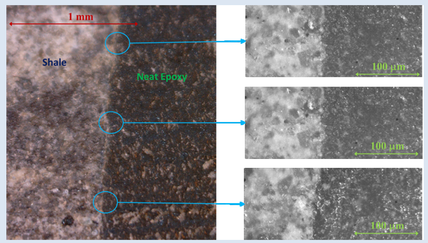


Figure 8: Microscopic images of shale-neat epoxy interface with two different levels of magnification.

Integrated wellbore testing

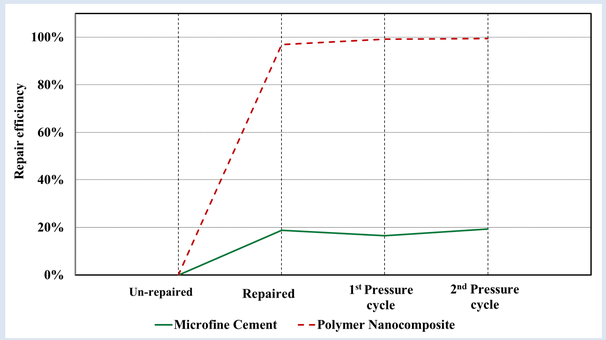


Figure 9: Repair efficiency of repaired wellbore specimens with microfine cement and polymer nanocomposite.

Conclusion

- Novolac epoxy was found to have 175% higher bond strength with shale rock compared with reference Type-G cement.
- Traditional repair wellbore material (microfine cement), was found to have 21% lower bond strength with shale rock than reference Type-G cement.
- Incorporating Alumina Nanoparticles (ANPs) was found to improve the bond strength of Novolac epoxy injected at the cement-shale rock interface by up to 45%.
- PNCs show higher toughness and peak displacement than microfine cement indicating higher ductility and resistance to cracking under repeated loading.
- The wellbore integrated test results show up to 99.4% seal efficiency achieved by using PNCs compared with 20% seal efficiency achieved using microfine cement.
- Microscopic images show that PNCs was able to uniformly fill the micro-annulus cracks compared to very poor filling effect using microfine cement.

Acknowledgments

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