Polymer with self-healing properties for use as a composite in wellbore cement

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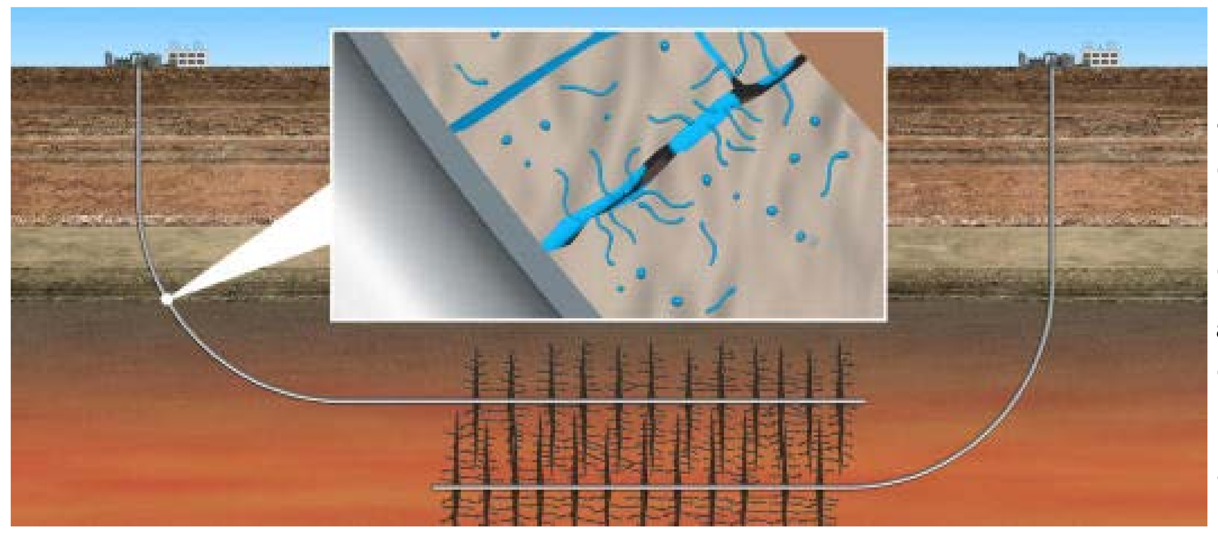


Figure 1. Self healing cement polymer composite in geothermal operation (Childers et al. 2017)

INTRODUCTION

Failure of wellbore cement from physical and chemical stresses is common and can result in significant environmental consequences and significant remediation financial costs. This research investigates novel polymer-cement composites which could function at most geothermal temperatures. By plugging fractures that occur in wellbore cement, reducing permeability of fractures, both environmental safety and economics of subsurface operations will be improved.

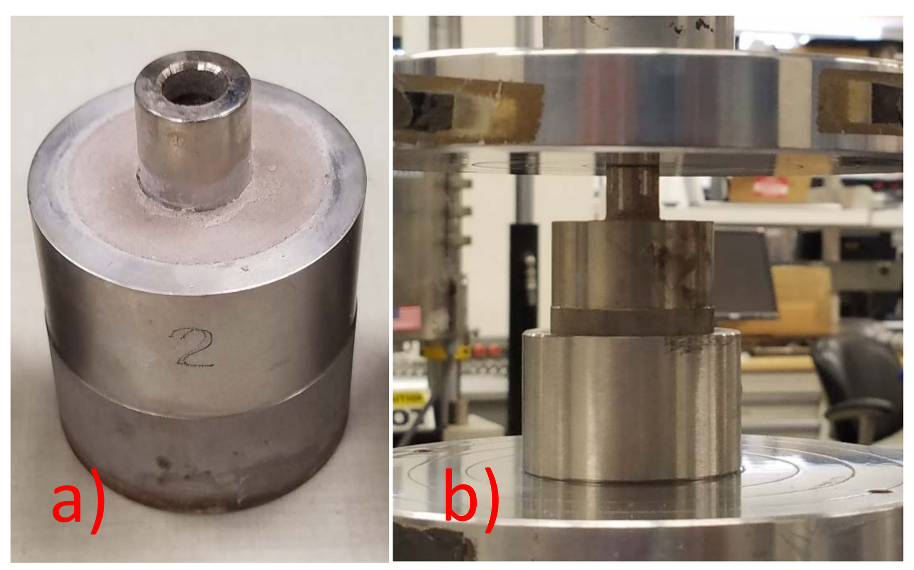


Figure 2. Set up of adhesion test: a) cement in annulus between pipes, outer diameter inner pipe = 0.5" and length = 2"; b) inner pipe being pushed down with hydraulic press

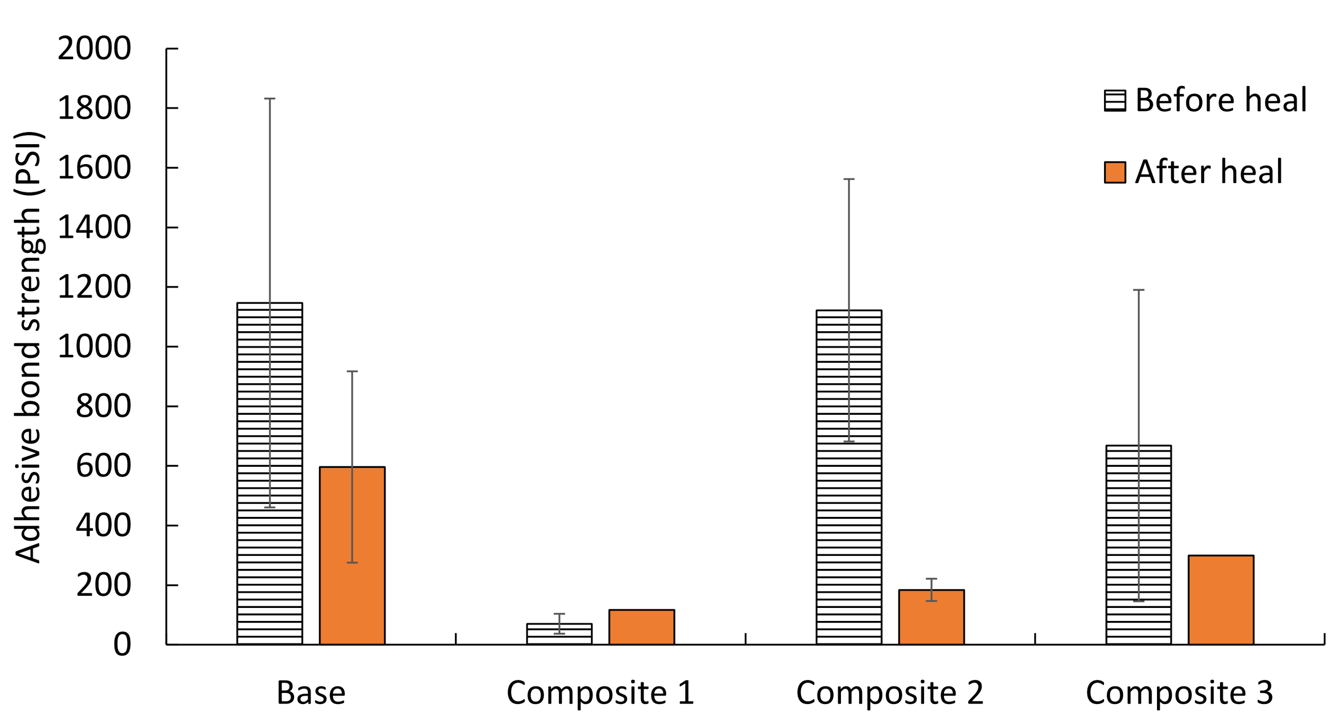


Figure 3. Adhesion bond strength of cement to steel for four conditions

MATERIALS AND METHODS

•Cement

•Class H cement with silica flour. Water content ratio of 0.54 (mass) for base cement and composite 2 and 3. At least 0.63 water content for composite 1.

• Composites included 3 different proprietary polymers added to base cement at 10-15% polymer by mass

•Adhesion experiments (Figure 2 and 3)

•Cement slurry added annulus between pipes. Pipes are held in an end cap which holds the sides parallel. Cure at 200°C and 100% RH for 5 days

•Use hydraulic press to compress inner pipe.

•Bond strength is calculated by dividing max pound force by total surface area of center pipe in contact with cement (shear stress = force/area)

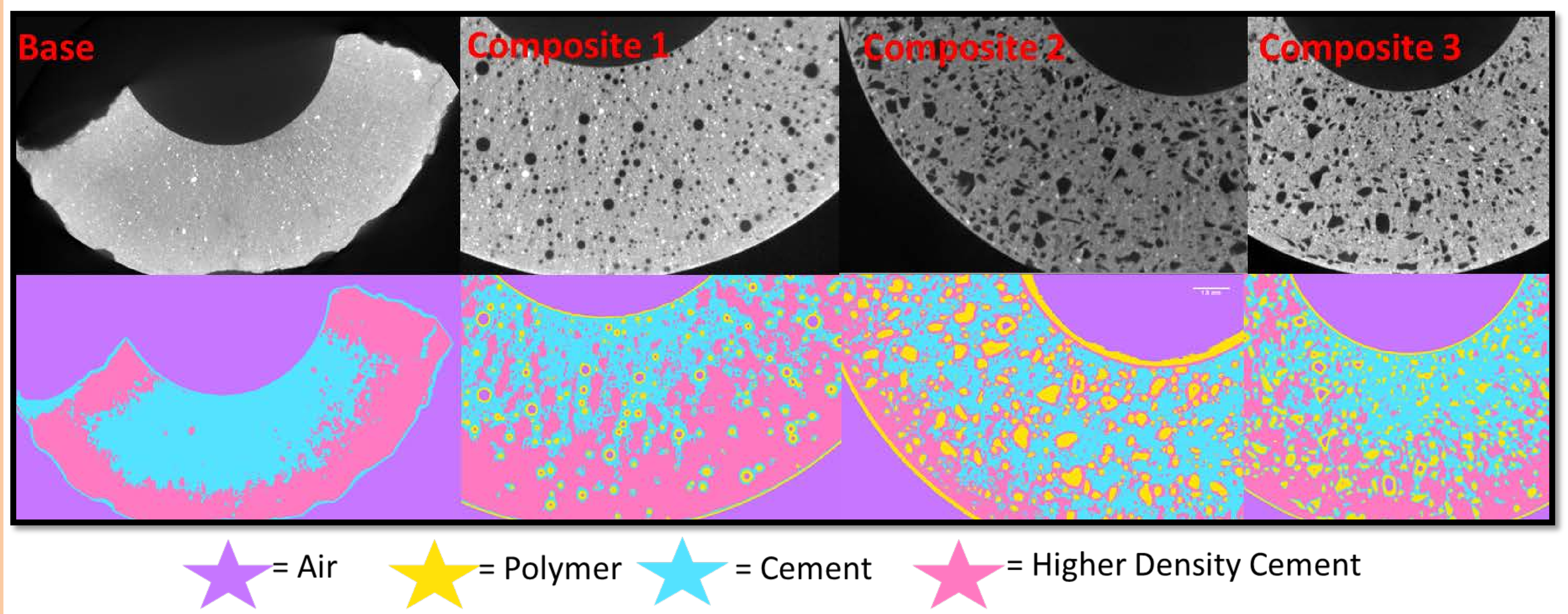


Figure 4. XCT images top row, and paired segmented image below of base cement, and 3 cement polymer composites of samples removed from adhesion experiments. Note polymer along the inner and outer curve where there was adhesive contact with pipes.

•XCT and Fracture Segmentation (Figure 4)

•Scanned samples removed from pipe casing using a high-resolution micro focus x-ray computer tomography (XCT) scanner

•Images are analyzed using a segmentation tool within ImageJ. This allows for cement, polymer, and air to be differentiated and classified with false color

•Permeability (Figure 5)

•Base cement and Composite 1 - 1" diameter core, cured at 200°C and 100% RH for 5 days.

•Fractured using shear force and tested for permeability

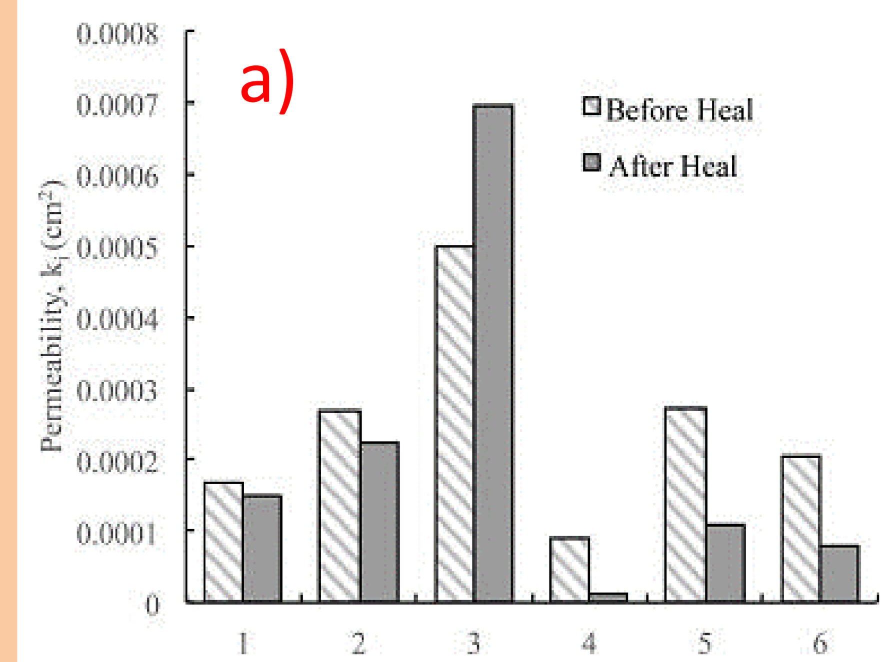
•Heal at 200°C and 100% RH for 5 days. Then tested for permeability

•Calculated permeability using equation 1 and 2 (top right)

$$Q = -\frac{Wb^3}{12\mu}\left(\frac{P_i - P_o}{L}\right) \quad \textit{Eqn 1}$$

$$k_i = \frac{b^2}{12} \quad \textit{Eqn 2}$$

Q = discharge ($cm^3\ s^{-1}$)
W = effective fracture width (cm)
b = effective fracture aperture (cm)
μ = viscosity (Pa·s)
P_i = pressure at inlet (Pa)
P_o = pressure at outlet (Pa)
L = fracture length (cm)
k_i = permeability (cm^2)



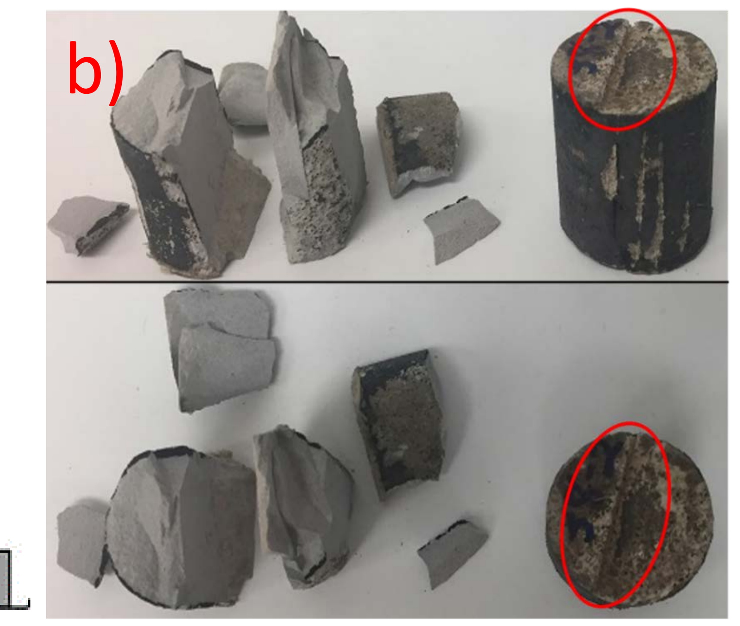


Figure 5. a) Permeability (k_i) of cores with shear fracture, before and after heal. Samples 1–3 = Base, samples 4–6 = 10 wt % composite 1. (Childers et al. 2017). b) Base (left) and composite 1 (right) of 2 k_i tested samples. Top and bottom are two angles of the same samples. Red circle shows healed fracture in composite sample.

CONCLUSIONS

•Addition of polymers to cement weakens its adhesion to steel

•Adhesion strength is improved with initial adhesion (composite 2)

•Adhesion healing ability is improved with new formulations (composite 3)

•Polymers are homogeneously distributed throughout sample

•Polymers fill voids and interfaces including the interface between cement and steel pipe and at air-solid interfaces

•Polymer (composite 1) will reduce permeability of fracture in cement by 60-87% even in large fractures of 0.3-0.5 mm aperture

•Although adhesion is weakened polymer will be able to fill in any void produced and reduce risk of wellbore leaks

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