Electrophoresis to improve cement-steel bonding in well construction

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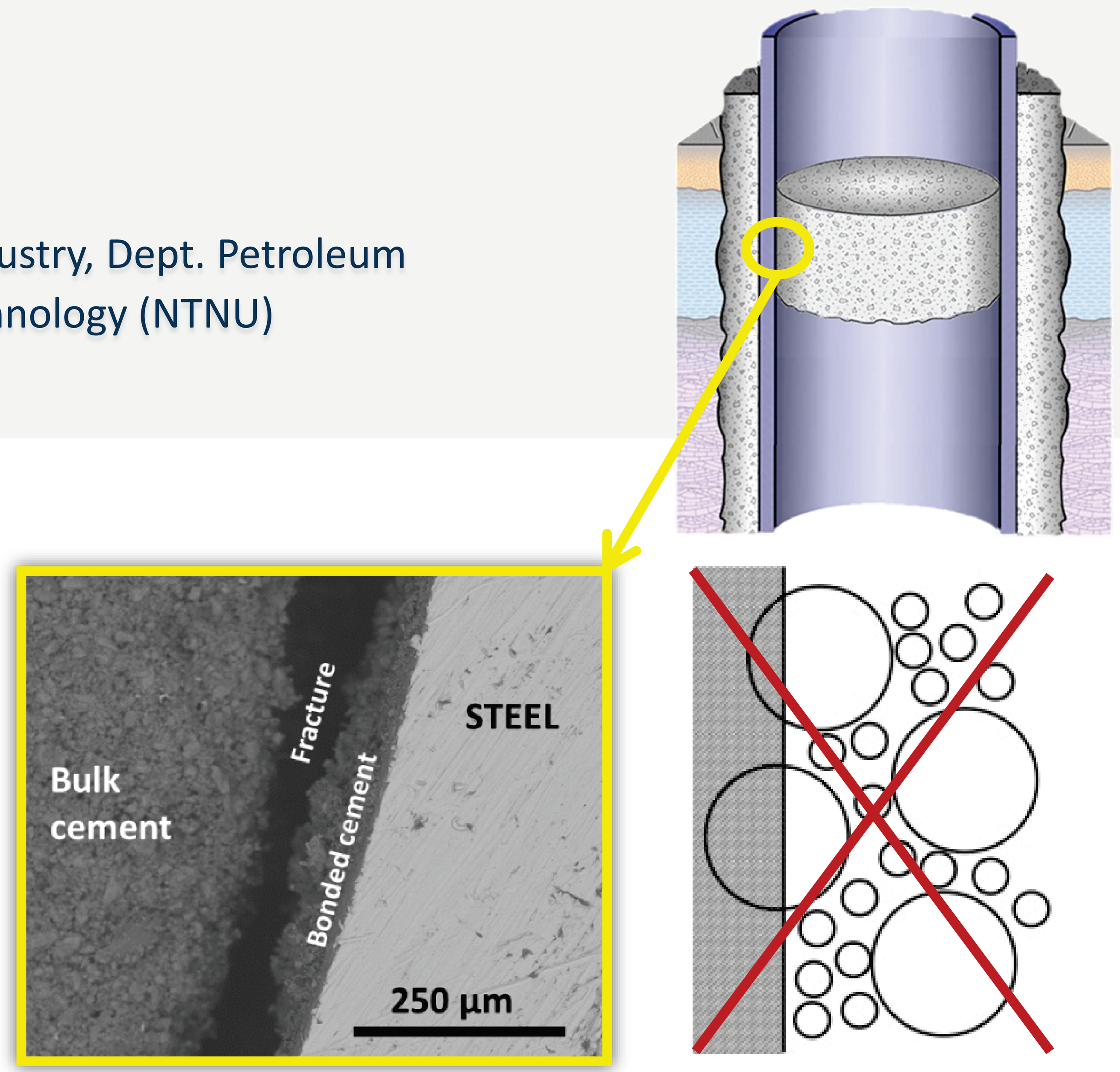
Why focus on cement bonding?

Cement is the most important well barrier material, as it is used both as an annular barrier and a plugging material in wells.

- Cement bonding to casing steel is a "weak link" in today's well construction. It is a porous interface, and defects cannot be avoided here due to imperfect packing of large cement grains adjacent to solid walls [1].
- Field samples show that the interface between cement and casing have given rise to well integrity issues [2].

Hypothesis: An electric field on casing can improve bonding by "forcing" cement particles to pack more optimally at the interface.

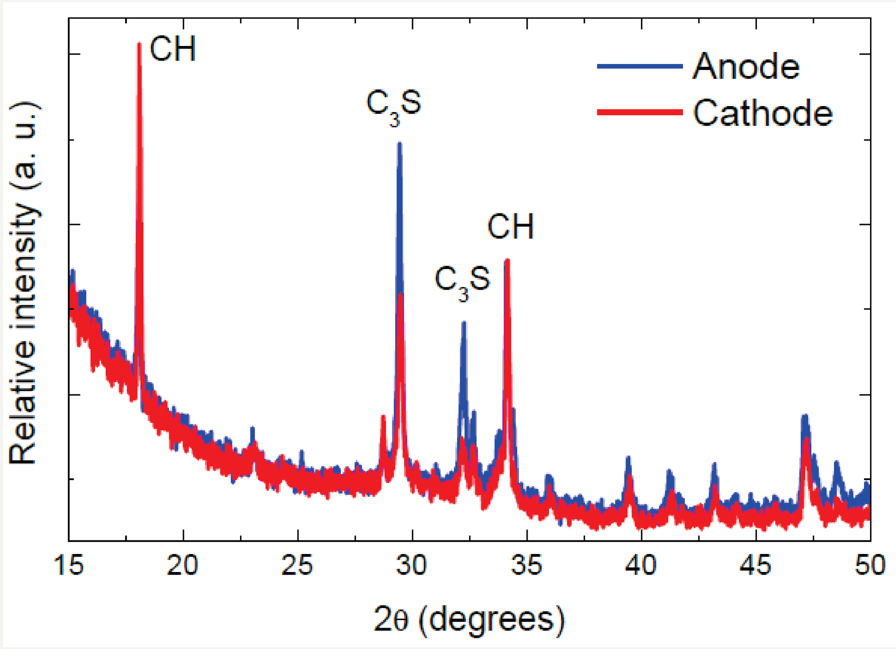


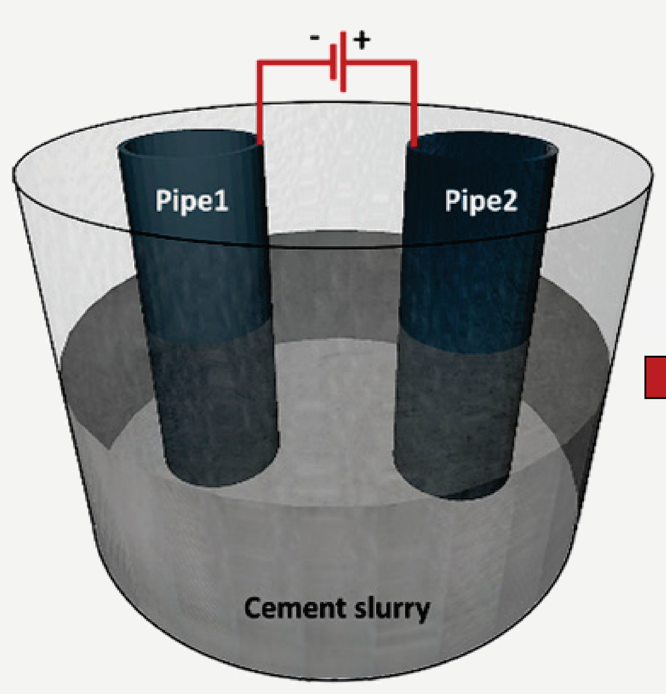
Defects/porosity is unavoidable at the cement-casing interface due to "wall effects" hindering optimal packing of large cement grains

Experiments *(see [3] and [4] for more details)*

- Stainless steel electrodes immersed in Portland G cement slurry (water/cement ratio = 0.44), 18 V applied (const. e-field)
- **For slurry evaluation:** 18 minute immersion with voltage application, thereafter pulling out electrodes.
- **For set cement evaluation:** 5 minute voltage on electrodes, thereafter leaving cement to cure. Structure of samples was studied using the TOMCAT Swiss Light Source, and standard XRD.

XRD: near-wall region at the anode is enriched with Ca_3SiO_5. This suggests more unhydrated cement particles at the anode.

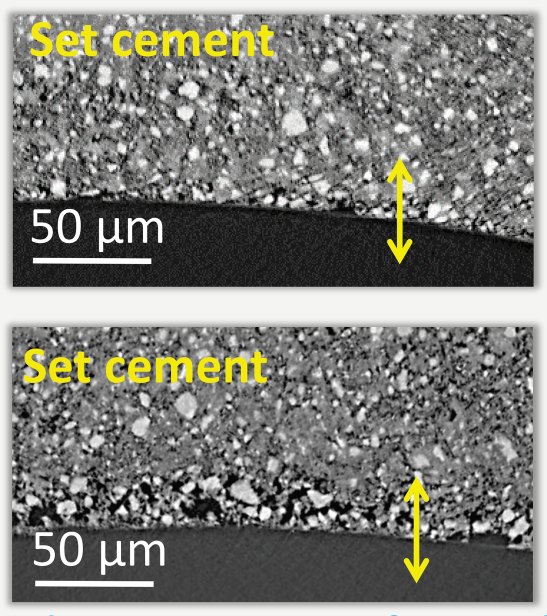




Improved bonding at "+"

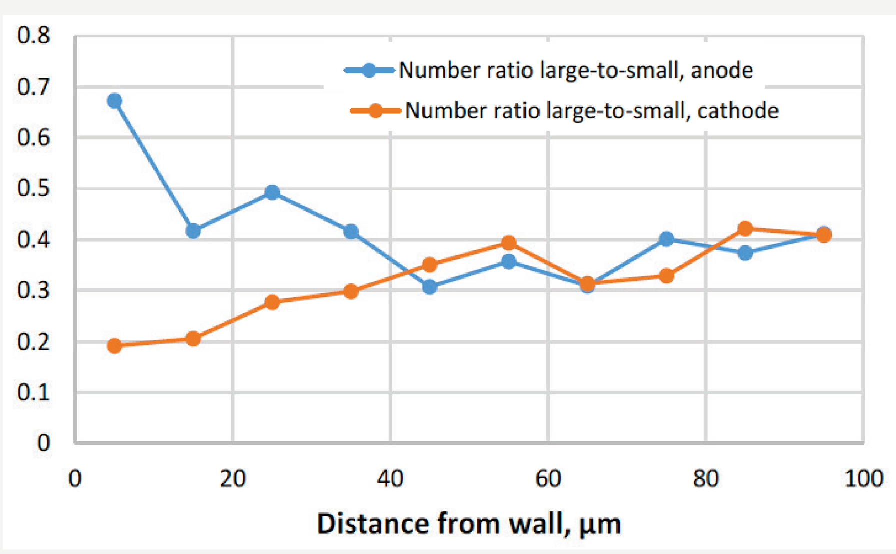
Poor bonding at "-"

Low porosity interface at "+"



High porosity interface at "-"

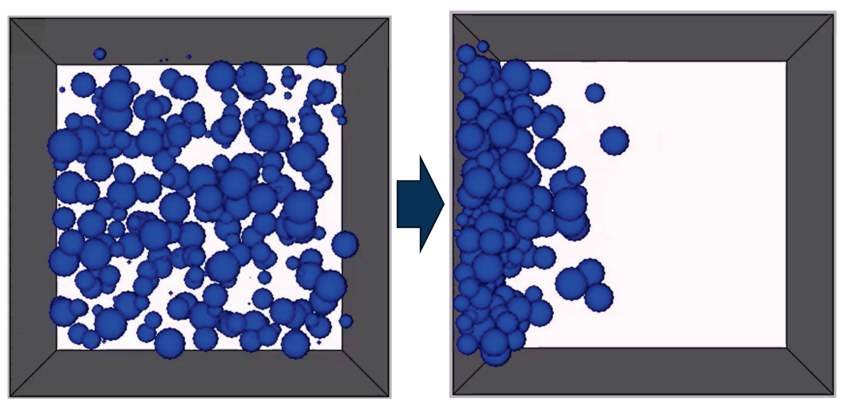
Number ratio large-to-small particles



DEM simulations with PFC^{3D}

Forces at play:

- external electric field
- Stokes drag force
- Interparticle electric repulsion
- Van der Waals attraction
- Inertial and added mass
- Lubrication force
- Brownian motion



Conclusions

- **Macroscopic observation:** Improved cement bond at anode, reduced at cathode.
- **Microscopic observation:** Lower near-wall cement porosity at anode compared to cathode. Higher number of large particles at anode compared to cathode. Distance of influence of the e-field was approximately 40 µm.

References

[1] Torsæter et al., *Constr. & Building Mater.* **96** (2015) 164-171
[2] Carey et al., *Int. J. Greenhouse Gas Contr.* **1** (2007) 75-85
[3] Lavrov et al., *AIMS Mater Sci.* **3** (2016) 1199-1207
[4] Lavrov et al., *AIMS Mater Sci.* **5(3)** (2018) 414-421

Acknowledgements

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