



Report Partner Document

Understanding and Mitigating Leakage Pathways in Oil and Gas Well
Cements Final Report

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This partner document has been created to provide a non-technical summary of information presented in *Understanding and Mitigating Leakage Pathways in Oil and Gas Well Cements Final Report* (2024) referred to in this document as “The Report”, prepared by Dr. Ergun Kuru and Dr. Ke Hu for and with funding by Petroleum Technology Alliance Canada (PTAC). Additional background information is provided in this partner document to supplement the readers understanding of progress presented in The Report.

Introduction

This study investigates how to improve the integrity of cement sheaths in oil and gas wells to prevent surface casing vent flow (SCVF) and gas migration (GM). These phenomena occur when gases, including methane, escape from wells, posing environmental and safety risks. The primary focus is on evaluating alternative cement blends for repairing wellbore leaks and ensuring long-term well integrity.

Alberta has a legacy of extensive oil and gas drilling, with over 400,000 wells drilled, many of which are now inactive. About 14% of wells completed since 1971 reported serious SCVF, making well integrity a pressing environmental concern. Methane emissions from SCVF are significant and better cement technology is needed to prevent gas leakage and meet evolving regulatory expectations.

The research was funded by PTAC, with in-kind technical and material support from Sanjel Energy Services Inc. (SESI). The research was conducted by Dr. Ergun Kuru and Dr. Ke Hu at the University of Alberta’s School of Petroleum Engineering.

Background Information

Cement is critical in oil and gas well construction, primarily to seal the annular space between casings and between casing and formation, preventing gas and fluid migration between underground zones and the surface.

Failure of this cement system can result in SCVF and GM, where methane leaks into the atmosphere or nearby formations. This occurs through several pathways, including between the cement and casing, through the cement matrix, or via fractures or de-bonded interfaces.

Well integrity depends on the cement’s mechanical robustness and impermeability. Cement de-bonding or structural failure, especially at the interfacial transition zone (ITZ) between cement and casing or formation, can create leakage pathways. The report emphasizes the need for enhanced understanding and testing of different cement blends to improve performance in sealing such pathways.

Project Summary

The objective of this study was to assess and compare the effectiveness of different cement blends in enhancing wellbore integrity during plug and abandonment and remediating leakage pathways in fractured cement systems. Four cement types were studied:

1. A1: Class G Portland cement – standard economic blend
2. A2: Portland Limestone Cement (PLC) – non-100% Class G
3. A3: Microfine cement – premium, particle size < 10 µm
4. A4: Semi-microfine Class C cement – experimental, not yet in commercial use

In this study, porosity, permeability, and shear bond strength were tested under simulated wellbore conditions. CT scans and environmental scanning electron microscope (ESEM) imaging were used to examine microstructures and interface quality. Simulated squeeze cementing experiments were performed on fractured cement samples using shims of various thicknesses (50, 100, and 150 μm).

Key Findings – Water and Nitrogen Breakthrough

Tests were conducted in the wellbore simulator under elevated pressures and temperatures over extended durations of 50 to 100 hours. No breakthrough of water or nitrogen was observed in A1-A3 bulk and pipe cement samples under laboratory conditions, suggesting strong zonal isolation when placed properly. However, A4 cement showed early water and nitrogen breakthrough, likely due to shrinkage and weaker shear bond strength.

Key Findings – Reduced Fracture Conductivity

All cements significantly reduced fracture conductivity, though A1 cement failed to penetrate fractures fully. Particle size matters, as smaller particles (A3) penetrated deeper into microfractures. A1 cement only partially sealed 150 μm fractures near the inlet, whereas A2, A3, and A4 blends fully penetrated and sealed 150 μm fractures. Optimal sealing was achieved when the fracture width was more than 2.2 to 2.4 times the cement's D90 particle size.

Practical Implications

Well placed cement blends A1, A2, and A3 can achieve reliable sealing under standard conditions. A2 and A3 are viable alternatives for use in plug applications, pending regulatory updates. A4 may require further optimization, such as additives to counter shrinkage concerns.

Conclusion

This study highlights that cement choices significantly influence well integrity, especially in remediation scenarios. A1, which is widely used, is limited in remediating microfractures due to larger particle size and poor penetration. A2 and A3 outperform A1 in remediation potential and can meet or exceed current regulatory standards. A4 has potential but needs further development to address shrinkage and improve bond strength.

Regulatory guidelines like AER Directive 20 may need updating to include high-performance, non-Class G cements based on experimental success. Continued testing under more realistic conditions is essential to validate lab results before field implementation.