Experiments to investigate the effectiveness of a new geochemical method to mitigate backward erosion piping

W.R.L. van der Star¹, F.M. Schenkeveld¹, T.M.A. Klessens², G. van Zwieten³ & L.A. van Paassen⁴

¹Deltares, Utrecht - Delft, The Netherlands
²Delft University of Technology, Delft, The Netherlands
³Volker Staal en Funderingen, Rotterdam, The Netherlands
⁴Arizona State University, Tempe, AZ, United States

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In this study, a new method to mitigate backward erosion piping has been evaluated. The method involves separated injection of solutions of sodium carbonate (Na₂CO₃) and calcium chloride (CaCl₂) through a line of wells perpendicular to the flow direction. When these two solutes get in contact, either through overlapping dispersion or through converging flow lines towards or surrounding the pipe, chemical precipitation of calcite (CaCO₃) occurs which may fill up the pipe or increase erosion resistance. The method was named Dynamic Internal Erosion Tackling Zones (DIETZ), considering its expected defensive response towards laterally migrating erosion channels.

Two tests were performed using a setup, which has been extensively used for mechanistic research on backward erosion piping (Van Beek et al. 2015). In both tests, the hydraulic head was increased gradually and the injection rate of solutions was either controlled by hydraulic head (experiment 1) or by flow rate (experiment 2). Solutions were colored to visualize flow-paths. Injection of treatment solutions was started after a visible stable pipe had formed.

Figure 1. Different stages during experiment 2: formation of the pipe (left), initiation/progression of a second pipe (middle) and screens at the location where calcium carbonate has formed (right). Top view of the experiment with a hydraulic gradient from bottom to the top of the image, and flow paths of the injected solutions of calcium chloride (green) and sodium bicarbonate (red).
During treatment in both tests, mixing of the two components took place at the interface between the two solutes forming screens parallel to the flow direction and around the erosion channel. After treatment the hydraulic head was increased further until failure. In the first experiment, the pipe started propagating again towards one of the injection wells and as soon as the well was reached the flow rate in that well strongly increased, but the pipe did not migrate any further.

In the second experiment, the morphology of the pipe significantly changed during injection. After about 2 hours, the hydraulic head was stepwise increased. Initially the first pipe was blocked, but as the hydraulic head increased further, a side branch started to migrate upstream. Lateral pipe migration was constrained by the screens which had formed parallel to the flow lines during the injection phase. The secondary channel passed between two wells and reached the other side of the test set-up. At this stage a third channel had formed and the original pipe started to migrate and erode upstream. During this final stage the effect of chemical precipitation reaction on the erosion resistance was still clearly visible. Post analysis confirmed that the calcite content was elevated at the expected locations, but the values were still very low (0.1-0.5 wt%). When more calcite precipitates (for example through longer injection times) a stronger effect is expected.