

Appendix 5 – Proppant Embedment Standard Testing Procedure

1 Proppant Embedment Standard Testing Procedure

- 1. Client Info** – Complete client parameters are needed before beginning any tests. Test depths, proppant type, proppant loading (1x, 3x, etc), testing temperature, fluid, maximum confining pressure (relative to well pressure), are all needed. This info will be taken from the client and entered in a text matrix. This test matrix will be used in coordinating the prepping of the test samples and tests.
- 2. Core Samples** – Sample plugs are taken from the client’s core at the specified depths. The plugs are pulled using a drill press and a plugging bit. The bit diameters are 1 inch or 1 ½ inches and on average, the plugs are roughly 3½ inches long. The sample is placed in an individual bag and labeled with the job number and sample depth.
- 3. Prepping Plugs** – Each plug is carefully inspected and validated for testing.
- 4. Cutting the Plugs into Pucks** - The prepped plugs are then cut with a diamond wire saw into the proper testing size length (Figure 1.1). Ideal lengths for these testing samples are as follows; 1.5” dia samples should ideally be 1” long and 1” dia plugs should roughly be .75” long. These cut test samples are now referred to as “pucks”.

Propped and Un-propped Test Samples: The samples will be cut again in half, on the same wire, across the diameter perpendicular to the rocks bedding plains. Mark the sample using a ruler and a marker. Line up the cut on the saw and cut. When the cut is finished, place the two halves back together.

Natural Asperity Test Samples: For Natural Asperity samples, the pucks will be marked across the diameter and perpendicular to the rocks bedding plains, on both sides of the puck. The marked puck will then be placed in a vice and scored with a hacksaw. The score marks should not be too deep, only about a 1/16 of an inch deep on both sides. Once scored on both sides, the puck will be placed in a special fracturing vise, with the score marks lined up on the fracturing points. This will fracture the sample between the two score marks. Carefully remove the fractured sample and place the halves back together.



Figure 1.1 Using diamond wire saw to cut samples

- 5. Proppant Loading Pucks** –The puck halves are inspected for fractures. If the pucks have fractures or failures, these must be replaced. The pucks are now ready to be loaded with the requested proppant at the requested loading. When the sample is loaded with proppant, it is ready to be photographed. Natural Asperity test samples are not loaded with proppant.

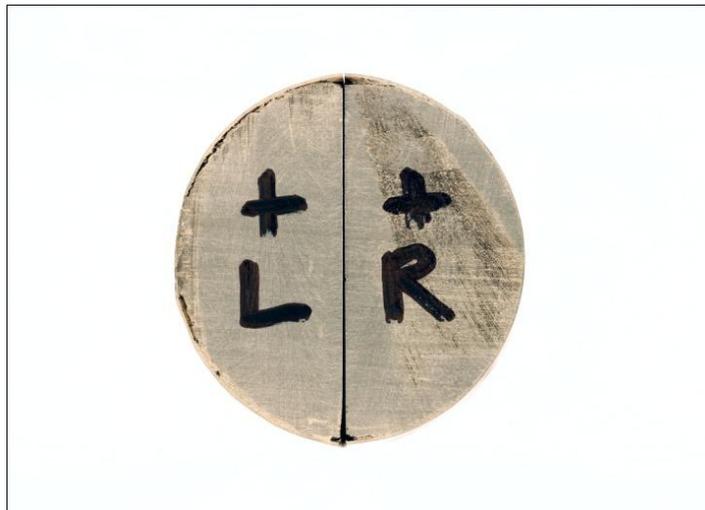


Figure 1.2 Properly labeled test sample

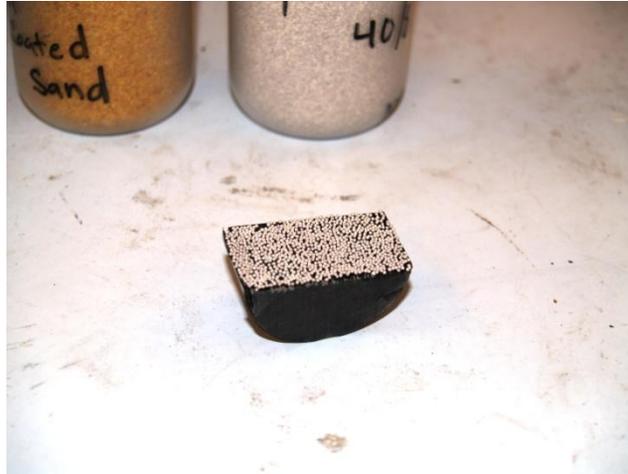


Figure 1.3 Proppant loading of sample half

6. **Pre-test Photograph and Final Preparation** – Carefully place the loaded samples on the copy stand in the designed tray side by side, with the left side on the left and the right on the right side. Set the camera to the proper exposure and aperture settings. Shoot the picture and record photo image number for the pre-test image (Figure 1.4). The same procedure will be used to take a photograph of the Natural Asperity samples (Figure 1.5). Carefully put both halves together and wrap sample with Teflon tape, keeping the fracture horizontal and the proppant from falling out. Next label the sample on the outside of the Teflon tape, with the job number and the sample number.

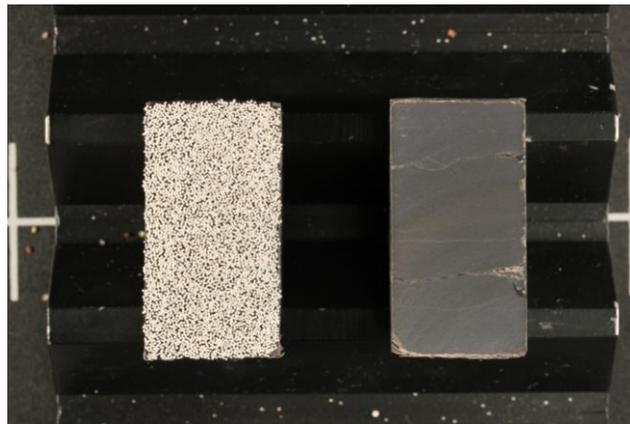


Figure 1.4 Pre-test photograph of prepped test sample

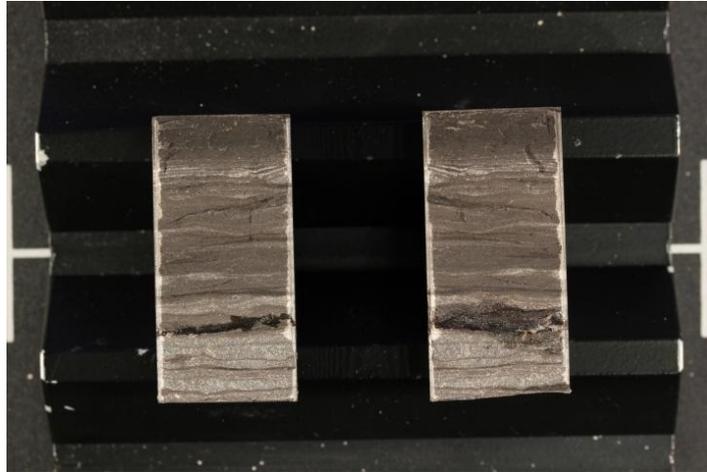


Figure 1.5 Pre-test photograph of Natural Asperity sample

- 7. Fluid Preparation** – Fluids for testing are usually supplied by the clients, but occasionally are mixed in the lab. Once prepared, these fluids are placed in a vacuum flask and loaded into the Teledyne ISCO syringe pump (Figure 1.6).



Figure 1.6 Teledyne ISCO syringe pumps on right of computer

- 8. Loading the Sample into Testing Vessel** – Load the sample into a Viton tube, referred to as a “boot”. The top and bottom of the sample are noted and placed in the proper orientation. Screens are placed on both sides of the sample in the boot. This boot is then loaded into the pressure vessel (Figure 1.7). Connect the sample in the testing vessel into a pressure confining vessel which will replicate the in-situ pressures and temperature. The pressure testing vessel is filled with silicone fluid that will apply the needed confining pressure and heat to the sealed sample.



Figure 1.7 Testing vessel

- 9. Hooking Up The Test** – Pressurize the confinement vessel to 500 psi. At this initial pressure, the boots seals down around the sample and the micro-fractures in the sample will close. The fluid flow is now initiated at a rate of 0.1 ml/min into the boot and across the sample fracture. The flow is continued until the entire boot is filled and fluid is visibly bubbling out the open ports. At this time the pump is stopped and the remaining lines are hooked up to the testing apparatus. Once the lines have been connected the pump is again started and slowly the pressure in the boot is raised until it is equal to the predetermined back pressure. The fluid pressure is monitored by watching the ISCO pump and the back pressure is determined by the regulator on the back pressure tank. The sample is now ready for the test to begin.
- 10. Starting The Computer Recording** – With the sample loaded and ready, the testing computer and equipment is set for testing.
- 11. Running The Test** – With the computer recording, start the ISCO pump at a rate of 0.1ml/min, to start the test. The test will be left running at the set flow rate for the determined time. Once the sample has been running for the allotted time, a reading will be taken. The average pressure steps are as follows: 500 psi, 1000 psi, 2000 psi, 4000 psi, 8000 psi, 10000 psi. Follow these steps until the final pressure step is achieved and the reading has been taken. After the test has ran through all the

pressure steps with the proper time intervals between them, and all the data has been recorded, the testing phase is complete.

12. Post Test Photograph – After the test is completed and the sample is removed from the vessel, carefully cut the Teflon tubing, tape, and place the samples on the copy stand, with the labeled left side on the left and the right on the right side (Figure 1.8) (Figure 1.9). Set the camera to the proper exposure and aperture settings. Shoot the picture. After the photo, carefully place the opened sample in an aluminum tray and take sample and the screens, to the Keyence microscope. Preserve the proppant from the surface, as it will be analyzed for the effects of crushing.

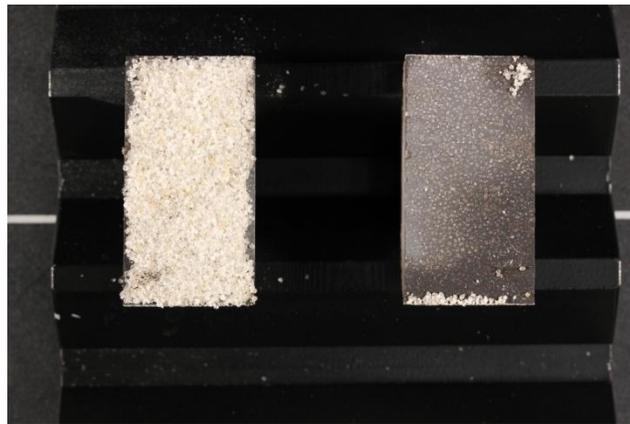


Figure 1.8 Post-test photograph of prepped test sample

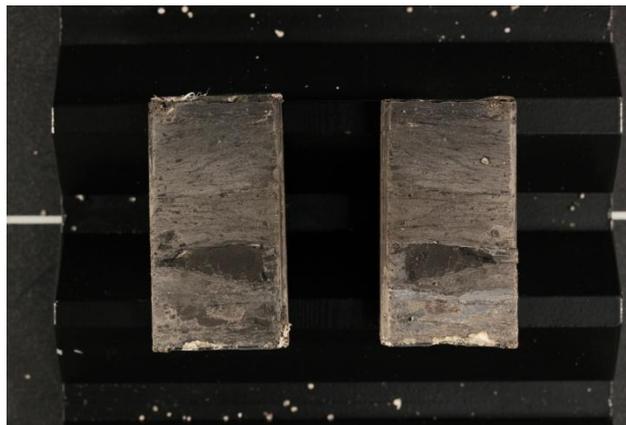


Figure 1.9 Post-test photograph of Natural Asperity sample

13.3D Keyence Microscope: Proppant Crushing Analysis – The Keyence 3D electronic microscope (Figure 1.10) is used to analyze the proppant and the interaction with the sample core. The first step is to analyze the proppant for crushing or failure. Usually six images of the crushing are taken. Next obtain images representative of the multiple craters associated with the embedment process (Figure 1.11). Measure the profile of the depth of the embedment (Figure 1.12).



Figure 1.10 Keyence 3D electronic microscope

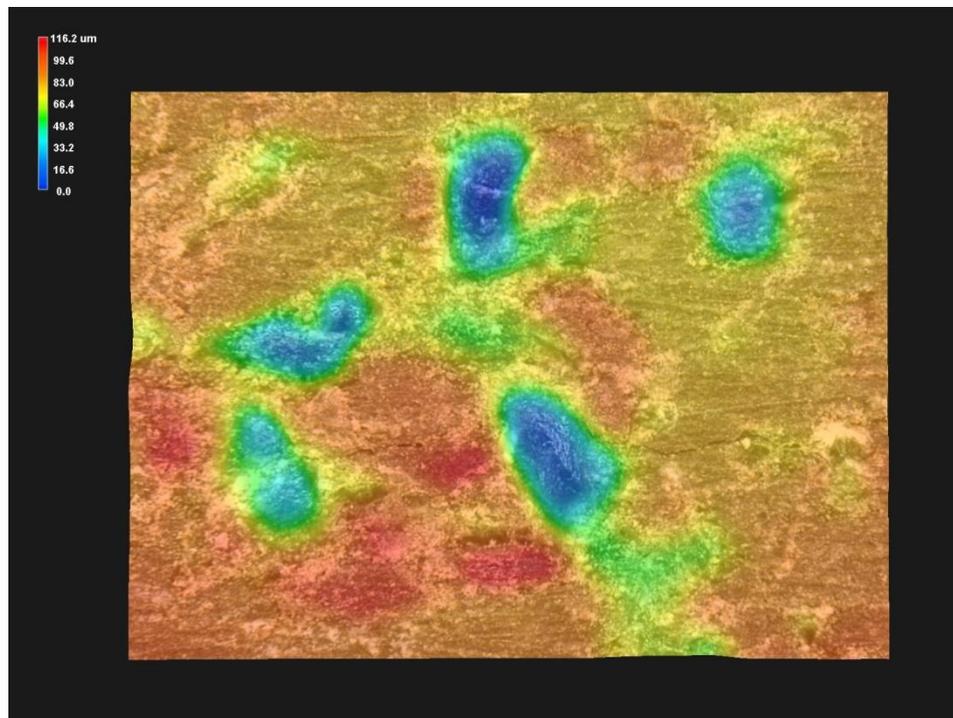


Figure 1.11 Color profile view showing embedment

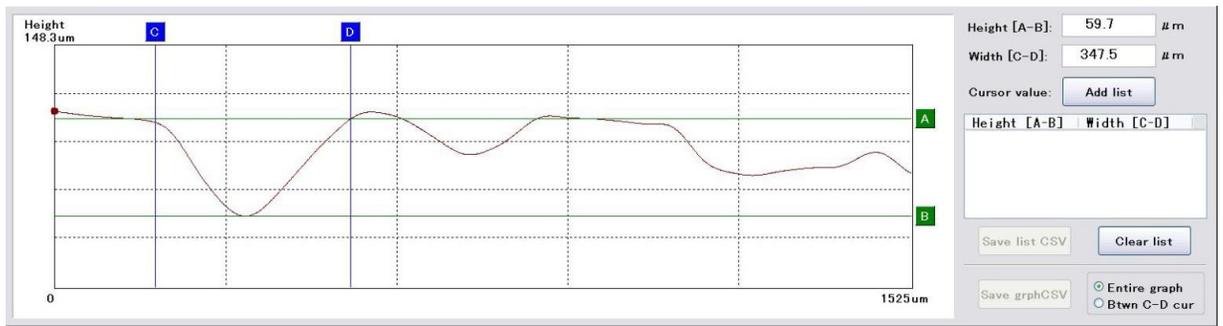


Figure 1.12 Surface cross section graph

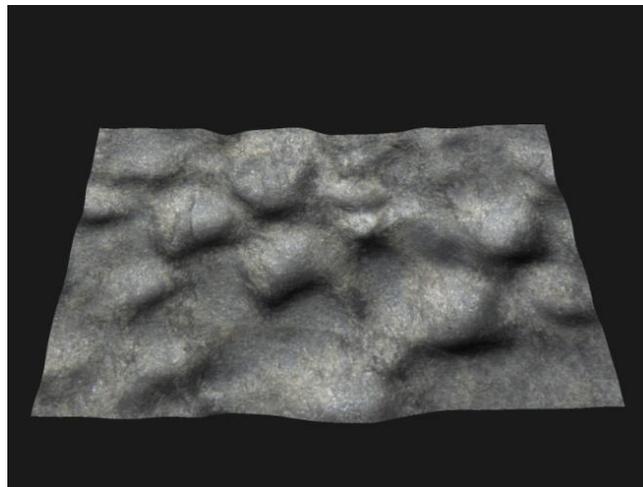


Figure 1.13 Topo image saved for sample

14. Data Reduction – The final step in the proppant embedment testing process is to reduce all the gathered data from the worksheets which contain the data that was recorded during the preparation of the test samples and the testing process.