

How Should Clay Stabilizers Be Evaluated for Fracture Conductivity?

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Abstract. A clay stabilizer should be evaluated against a hydraulic endpoint as well as a material-screening endpoint. Suppressing clay dispersion does not necessarily preserve fracture-wall strength or prevent nonclay particle damage. This technical note proposes a staged screening and validation workflow using matched stress, fluid exposure, and sample history. It defines an incremental conductivity-benefit metric and explains why a large relative improvement can still leave poor absolute retention. No product ranking or dosage recommendation is inferred.

What should a stabilizer demonstrate?

The term "stabilizer" can refer to control of swelling, dispersion, or related fluid-rock behavior. Those objectives should be specified before selecting an assay. A shale-fluid screening protocol combines several material responses [1], whereas nanoindentation-enhanced screening measures exposure-related mechanical changes [2]. Neither approach makes the hydraulic endpoint unnecessary when conductivity preservation is the intended claim.

The primary comparison proposed here is between base fluid and base fluid plus additive, tested on matched specimens. A gas-only or minimally reactive reference provides additional context, but it is not interchangeable with the base-fluid control. Earlier shale-fluid conductivity experiments establish the relevance of comparing exposure histories [3], and preservation research makes the initial specimen state part of that comparison [4].

Kakkar investigated clay stabilizers under elevated pressure and temperature within a broader study of propped and unpropped conductivity [5]. The 2017 investigation included brines with and without stabilizers [6]. The related 2019 paper reports that amine-based stabilizers reduced clay-based fines damage but were less effective against nonclay fines [7]. This is a mechanism-specific observation about tested formulations, not a guarantee for every amine or shale.

Independent propped-fracture water-damage work identifies several potential contributors to conductivity loss [8]. A meaningful stabilizer evaluation should therefore ask whether the intended mechanism was suppressed and whether total hydraulic performance improved. Counting the related 2017 and 2019 summaries as independent trials would overstate the breadth of the evidence.

A staged additive-evaluation sequence

Proposed evaluation of a conductivity-preserving additive.

1. **Compatibility screen.** Use swelling, dispersion, and fluid compatibility as endpoints to reject clearly unsuitable candidates.
2. **Mechanical screen.** Measure retained hardness or modulus to identify wall-weakening risk.
3. **Loaded flow test.** Measure absolute C and matched-stress retention to verify hydraulic benefit.
4. **Repeatability check.** Use independent specimens and report uncertainty to assess the robustness of the ranking.

A product described as a clay stabilizer may be intended to address a particular material response. A conductivity study should translate that label into a testable claim before selecting the assay. Possible questions include whether the formulation reduces particle release, preserves a measured mechanical property, or improves loaded flow capacity relative to the same base fluid. Success on one endpoint should be reported in those terms rather than automatically extended to every possible meaning of stabilization.

A proposed evaluation begins with a claim-to-measurement statement. If the claim concerns fines, specify whether the measurement addresses generated particles, transported particles, or retained deposits. If it concerns wall support, specify the loading condition and mechanical observable. If it concerns conductivity, state the comparison stress, phase, exposure duration, and baseline. This statement links the experiment to the intended benefit and makes it possible to identify a result that would contradict the claim.

The anchor studies provide a useful example of why that distinction matters: the reported stabilizer benefit concerned clay-based fines, with less protection against nonclay fines [5, 6, 7]. The proposed framework treats that as a reason to test mechanism specificity. It does not turn the observation into a universal division between successful and unsuccessful chemical families, because the tested formulation, rock surface, and exposure conditions remain part of the reported result.

Choosing endpoints and controls

Absolute capacity and incremental benefit

An additive comparison should state whether its primary objective is to retain mechanical properties, reduce mobile solids, or preserve loaded conductivity. These outcomes can be related, but none is a guaranteed substitute for another. The staged sequence in this article deliberately places the hydraulic endpoint after compatibility and mechanical screening. Early tests reduce the candidate set; they do not establish final performance.

For a proposed ranking, specify the reference fluid, additive concentration, exposure duration, stress, and measurement phase. Compare each candidate with the reference under matched conditions. A result obtained at a different concentration or after a different conditioning period should be treated as another treatment, not pooled under the same additive name. Indentation-based screening motivates efficient early characterization [2], while conductivity procedures motivate a subsequent flow test [9].

The endpoint should also be meaningful relative to measurement uncertainty. A small nominal improvement does not justify a firm ranking if between-specimen scatter is larger. Predefine the comparison metric and retain the absolute conductivity values. This avoids selecting whichever normalization makes a preferred candidate appear strongest and gives an independent reader a clear basis for evaluating the claimed benefit.

Let C_{ref} be the pre-exposure conductivity, C_b the post-exposure value for base fluid, and C_a the post-exposure value for fluid plus additive, all compared at the same stress and measurement conditions. Report $R_b = C_b/C_{\text{ref}}$ and $R_a = C_a/C_{\text{ref}}$. For a matched design with an appropriate common reference, define the incremental retention benefit as $D_R = R_a - R_b$. If each specimen has its own baseline, report those baselines and use a paired analysis.

In a synthetic example, $R_b = 0.10$ and $R_a = 0.20$. The additive doubles the retained fraction, yet the final state has still lost 80% of its initial conductivity. Describing only a 100% relative improvement hides that poor retention. Report both quantities together with the absolute conductivity. These selected numbers demonstrate the reporting issue and do not represent a commercial formulation.

Use an exposure duration and temperature relevant to the comparison. Coupled treatment studies motivate recording temporal changes in material response [10], while acid-shale work illustrates that reactions can involve nonclay minerals [11]. Analyze effluent solids by size and, where feasible, composition. Reduced total solids alone cannot establish whether the remaining particles are more or less likely to obstruct critical openings.

Consider synthetic conductivities of 0.20 mD-ft before exposure, 0.02 mD-ft after the base fluid, and 0.04 mD-ft after an additive-containing fluid on matched specimens. Relative to the damaged base-fluid result, the additive produces a 100% increase. Relative to the original conductivity, the treated result retains only 20%. The recovered fraction of the base-fluid loss is $0.02/0.18$, or approximately 11.1%. Each percentage is mathematically valid, but each uses a different denominator.

This example extends the benefit metrics in the main discussion. Report the three absolute values before reporting any percentage. If the pre-exposure baselines differ between specimens, use a design and analysis that account for those differences rather than borrowing one baseline for the entire group. Shared normalization can conceal variation that is central to the treatment comparison.

The practical interpretation depends on the required absolute capacity as well as the incremental benefit. A treatment can substantially improve a badly damaged specimen while still leaving inadequate transmission for a specified application. Conversely, a modest percentage improvement may be sufficient when the reference already meets the relevant requirement. These conclusions require an explicit requirement; laboratory percentages alone cannot supply it.

Controls with distinct purposes

The base-fluid control estimates the incremental effect of adding the candidate formulation. A gas or minimally reactive reference addresses a different comparison involving the broader fluid exposure. A procedural control can test the effect of mixing, switching, or flushing. These controls should retain distinct names and roles. Combining them into one reference category would conceal which counterfactual each treatment result is being compared against.

Consider selected normalized endpoints of 1.00 for a reference state, 0.20 for base fluid, and 0.35 for base fluid plus additive. The additive improves retention by 0.15 of the reference conductivity and by 75% relative to the base-fluid endpoint. It still leaves a 65% loss relative to the reference. Each statement is arithmetically valid, but they answer different questions. A useful report includes the absolute conductivity values as well as these relative comparisons.

The groups must also be comparable in time and loading. If the additive specimen receives an extra conditioning hold, include an equivalent hold in the relevant control or acknowledge the combined intervention. Preservation studies make initial state part of this comparison [4]. A clear control structure is particularly valuable when an additive improves one material assay but has a weak or inconsistent hydraulic effect, because it shows whether the disagreement arises within a matched experimental contrast.

Formulation and loading conditions

Dose response and concentration records

A proposed dose study should include the base fluid without additive and several prespecified concentrations spanning the intended screening range. The purpose is to determine whether the hydraulic response changes systematically with dose, not to assume that more additive is always better. Report how concentration is defined and whether the final fluid recipe differs in other respects across the series.

Test compatibility and mechanical response using the same base fluid used for conductivity evaluation. If an additive is screened in one brine and tested hydraulically in another, the sequence no longer isolates the same treatment. A shale-fluid protocol provides a methodological reason to retain the full recipe [1]. The preserved-shale studies further motivate attention to both fluid chemistry and mineralogy [6, 7].

A useful analysis examines dose and specimen class together. If one dose performs consistently across the tested classes, describe that tested range. If performance differs by class, report the conditional result and the uncertainty. The proposed program does not infer a universal optimum from one sample or one concentration; it seeks a reproducible region of performance that merits confirmation with independent specimens.

A dose comparison needs a defined concentration basis. State whether the reported dose refers to product volume, product mass, or active component, and identify the denominator. If the active fraction is unknown, retain the product-based basis rather than converting it using an assumed value. Record preparation order and final mixture volume or mass. This allows another laboratory to reproduce the formulation even when a direct comparison of active chemistry is not possible.

For a synthetic example, adding 1 g of a product containing an assumed 20% active component to a final 1 kg mixture would correspond to 0.1% product by mass and 0.02% active component by mass. Those are different numerical descriptions of the same selected recipe. The calculation is meaningful only if the active fraction and final mixture basis are known. It is not a dosage recommendation for any stabilizer or reservoir condition.

A proposed dose series should also retain the base-fluid composition after each addition. If increasing dose changes pH, salinity, or viscosity, measure or document the relevant change. A conductivity trend then belongs to the resulting formulations, unless additional controls isolate the additive's intended mechanism. Screening protocols and earlier shale-fluid work motivate evaluating the complete exposure [1, 3], while a carefully defined dose basis prevents avoidable ambiguity in comparing those exposures.

Support condition and durability

For an unpropped fracture, pair conductivity with aperture or displacement observations and a rough-contact interpretation [12]. For a propped fracture, consider wall support and embedment [13, 14]. Mechanical-property studies offer a broader rock-characterization context [15]. The proposed workflow does not assume that a successful unpropped-fracture additive has the same benefit in a dense proppant pack.

Apply consistent flow procedures and control bypass leakage [9]. Include replicate specimens, randomize test order where practical, and state the minimum improvement that would be operationally meaningful before inspecting the results. If confidence intervals overlap substantially, report the ranking as unresolved. A laboratory screen can identify promising candidates, but confirming field benefit requires additional information about placement, exposure, and reservoir conditions.

An initial benefit may not define the performance of interest. A proposed durability sequence measures conductivity after treatment, after a defined reference-fluid displacement, and after a specified stress challenge. Each stage should have an explicit duration and endpoint. Report the full trajectory rather than selecting the stage with the largest improvement. The sequence tests persistence under those laboratory conditions; it does not establish indefinite protection or a reservoir lifetime.

For an illustrative comparison, an additive-treated specimen might retain 0.50 immediately after exposure and 0.25 after a stress challenge, while the base-fluid specimen retains 0.30 and 0.20 at the corresponding stages. The additive's initial advantage is 0.20 of baseline, but its final advantage is 0.05. That narrowing is a useful result even if the treated endpoint remains higher. It identifies the stage at which most of the apparent protection is lost.

Mechanical measurements and particle observations can help interpret the change in advantage. For propped specimens, examine support and embedment alongside the fluid response [13]. For unpropped specimens, retain a contact-based interpretation of the loaded surface [12]. A durability design should also include independent specimens where repeated testing itself changes the state. Otherwise, the reported later performance belongs to the complete sequence and should not be presented as an isolated property of the additive.

From screening to confirmation

When assays and conductivity disagree

A screening assay and a loaded flow test may rank candidates differently because they measure different responses under different conditions. The first step is to identify the exact disagreement. A candidate may reduce dispersed solids but leave lower loaded conductivity, or preserve a local mechanical response while producing little hydraulic benefit. Neither outcome automatically invalidates the assay. It limits the claim that the assay alone predicts the chosen hydraulic endpoint.

A proposed follow-up retains the same specimens or matched companions across the relevant measurements where feasible, with clear timing. Test whether the assay ranking persists under the exposure duration and temperature used in the hydraulic experiment. Then examine geometry, solids retention, and measurement uncertainty as alternative explanations for the hydraulic ranking. Nanoindentation-enhanced screening offers one complementary measurement [2], while water-damage work motivates considering multiple mechanisms [8]. Neither source removes the need to validate the link for the proposed application.

Avoid constructing a composite score after seeing the results solely to make one candidate appear consistently superior. If several endpoints must be combined, define the weighting and decision rule before confirmation testing, then show how the ranking changes under reasonable alternative weights. A candidate that wins only under a narrow choice of weights has a conditional advantage. Reporting that dependence helps a reader choose according to the actual performance objective.

Confirmation and failure cases

Advance a candidate only after its apparent advantage is reproduced on independent specimens under the same endpoint definition. Keep screening data separate from confirmation data so that the final assessment is not based entirely on the observations used to select the candidate. Record any adjustment of dose, exposure time, or test conditions between these stages.

Failure cases are especially informative when they separate mechanisms. An additive that reduces clay-derived effluent solids but does not preserve loaded flow may leave other causes of impairment unresolved. The preserved-shale reports distinguish control of clay-based fines from limitations concerning nonclay fines [7]. That observation should motivate targeted measurements rather than be generalized into a universal statement about all amine formulations.

A final ranking should identify the tested population, absolute performance, uncertainty, and unresolved failure modes. If two candidates cannot be distinguished within uncertainty, retain them as indistinguishable under the test rather than forcing an ordinal list. The outcome of the proposed sequence is a traceable basis for further evaluation, with clear evidence connecting early screening measurements to the final conductivity endpoint.

Confirmation should challenge the boundary most likely to overturn the proposed recommendation. If initial tests used only one mineralogical interval, add a contrasting interval. If the benefit appeared only at low stress, extend the stress challenge. If the ranking depends on a small difference near the measurement limit, improve resolution or replication before expanding the treatment matrix. This approach concentrates effort on the uncertainty that matters for the decision rather than simply repeating the easiest favorable comparison.

A proposed confirmation plan records the primary endpoint, the minimum practically relevant improvement, and the criteria for retaining or rejecting the candidate. The threshold is a study choice and should be justified by the intended use; it is not supplied by the literature merely because conductivity improvements have been reported. Preserve all candidate results, including unsuccessful formulations, so that the final account reflects the actual selection process rather than only the surviving treatment.

The resulting recommendation can remain narrow and useful: a specified formulation improved a defined endpoint over its base fluid in a stated specimen population and test sequence, with a reported spread among specimens. That statement supports the next stage of evaluation. Broader claims about field productivity, chemical compatibility with an entire operation, or long-term protection require additional evidence. A precise laboratory claim is valuable because it states exactly which benefit has been demonstrated and which questions remain to be tested.

Conclusions

A defensible claim of conductivity preservation requires a matched loaded-flow comparison, supported by measurements relevant to the claimed mechanism. Report incremental benefit, absolute retention, and uncertainty together. The preserved-shale findings particularly motivate separating clay-fines control from nonclay reactions and wall softening. This proposed workflow turns "stabilization" into a measurable objective without assuming that one assay or one additive class captures all damage pathways.

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Numbered references correspond to the citations in the text. Links lead to DOI records or the identified source record.

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