Unique Hydraulic Conductivity Test Results from a Self-Hardening Slurry

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Abstract: Self-hardening slurries using attapulgite clay and blast furnace slag cement have often been used as a low permeability alternative to cement-bentonite slurries. Recently, there has been a growing use of self-hardening slurries in other barrier forms, such as in deep soil mixing, vibrated beams, slurry trenches and jet grouting, largely due to the recognition of the materials capability of providing a low hydraulic conductivity under adverse environments. Recent testing of one of these self-hardening slurries for use in barrier construction has highlighted some of the unique testing problems associated with these materials, which in turn highlight some of the unique characteristics of the material.

For this study, two specimens were trimmed from a single sample of a self-hardening slurry. After consolidation and saturation, one specimen was permeated with tap water using an initial gradient of approximately ten while a second specimen was permeated using a gradient of about 100. Initial hydraulic conductivity measurements for both specimens were on the order of $1x10^{-9}$ cm/sec. Subsequently, both specimens showed a trend of decreasing hydraulic conductivity to approximately $5x10^{-11}$ cm/sec, as shown in Figure 1. At this point of permeation, the flow rate measured using a gradient of ten dropped rapidly to below the sensitivity of the equipment.

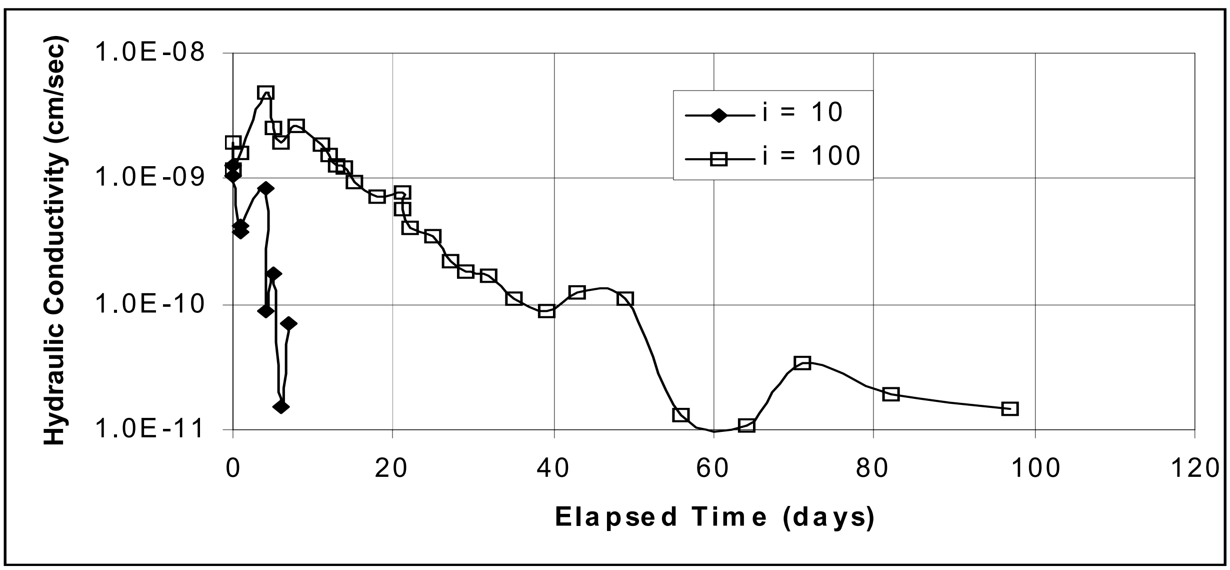

Figure 1 – Hydraulic Conductivity variations as a function of duration of permeation.

The applied gradient for this test was then increased in stages. No measurable flow occurred until a gradient of approximately 40 was applied, at which point a hydraulic conductivity of about $4x10^{-11}$ cm/sec was again determined.

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The test on the second specimen was continued by dropping the gradient in stages, as shown in Figure 2. This resulted in generally increasing values of hydraulic conductivity until a gradient of about 40, at which point measurable flow abruptly ceased. These results indicate that a gradient of about forty may exist as the long-term threshold gradient for this material, below which no measurable flow occurs.

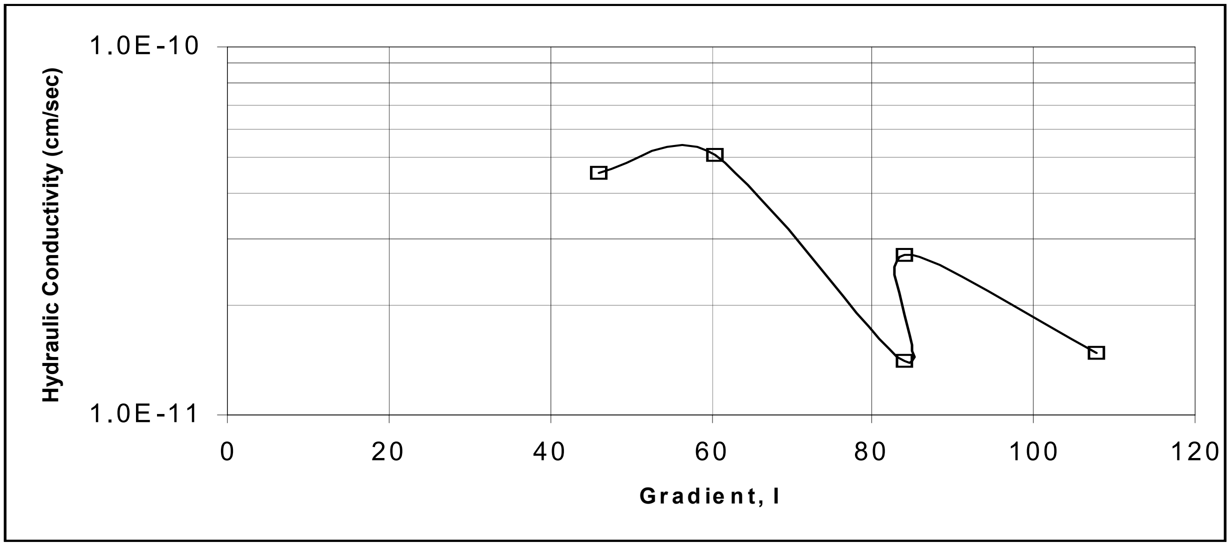

Figure 2 – Example results of hydraulic conductivity vs. gradient

These results are for one specific slurry mix. Results for other self-hardening slurry mixes will depend on the age and amount of solids present in that self-hardening slurry mix, but hydraulic conductivities better than $1x10^{-9}$ cm/sec are typically achievable with these materials. At these low hydraulic conductivities, the use of field level gradients in the laboratory is impractical, and even with an applied gradient of approximately thirty (the recommended maximum hydraulic gradient in ASTM Method D 5084), flow may be minimal to nonexistent.

Under most test programs, the hydraulic conductivities for this material would have been measured using a gradient of approximately thirty and with all readings made within a few days of consolidation of the specimen. Under these conditions, the value would probably have been reported as approximately $1x10^{-9}$ cm/sec. As these tests indicate, the long-term behavior of this material would more likely be on the order of $5x10^{-11}$ cm/sec, if a sufficiently high gradient existed to cause flow at all. However, under most field conditions, gradients would not be above the threshold gradient, and the self-hardening slurry would create a practically impermeable barrier.

Figure 3 shows the results of a series of stages made on a third specimen made from a similar self-hardening slurry as in the previously reported tests. The structural integrity of this specimen was intentionally damaged by hydraulic fracturing by rapid release of the confining stress and by statically shearing the specimen to evaluate the healing characteristic of this material. After each of these stages, measured hydraulic conductivities showed significant increases compared to prior to stressing the specimen, indicating that the specimen was damaged, but in each case the slurry showed that it has some capacity to reheal itself after it is allowed to reconsolidate.

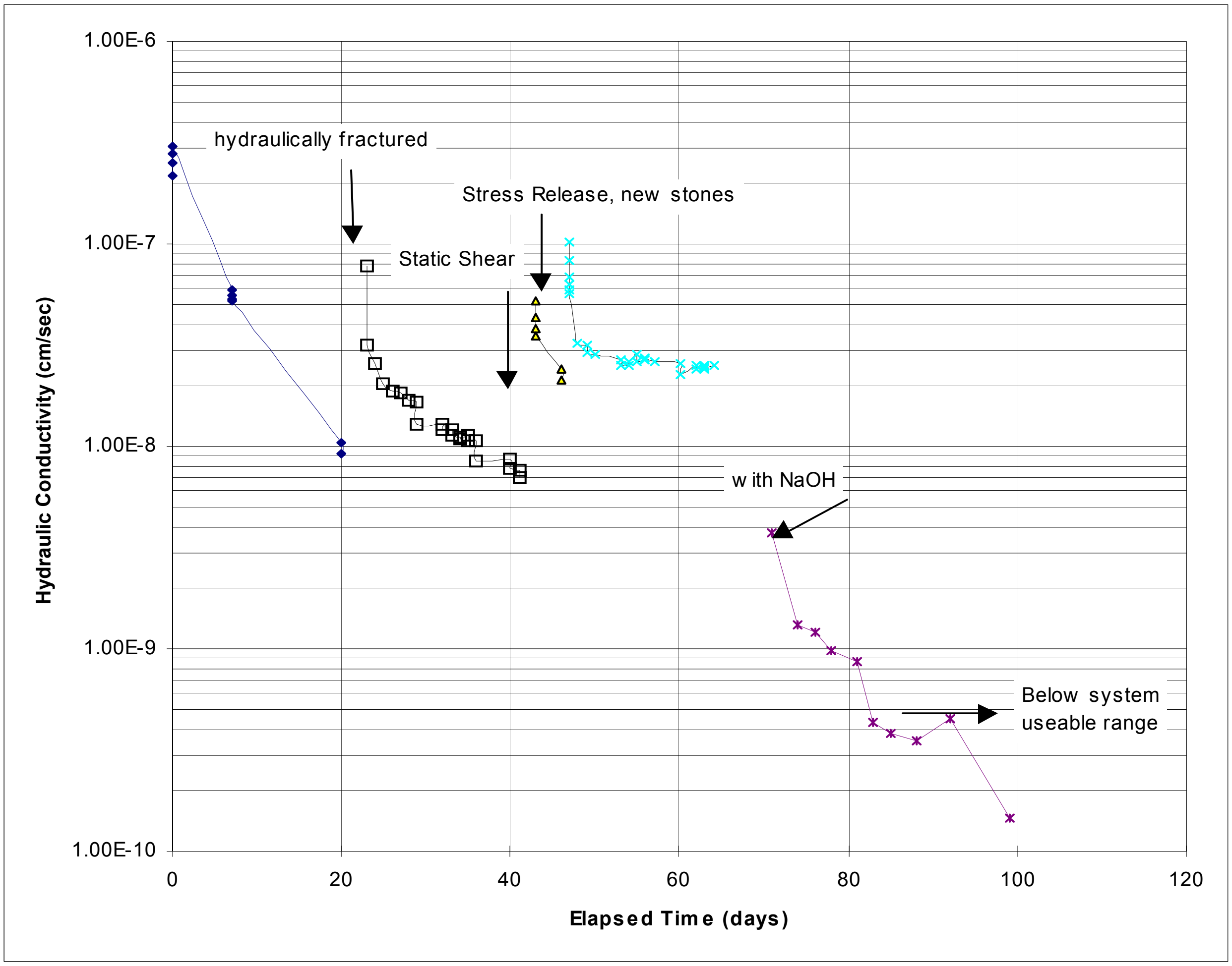

Figure 3 – Example of self-hardening slurry response to stressing and permeant pH

Finally, the permeant was switched from tap water to a caustic NaOH solution with a pH of approximately 13. With this permeant, the hydraulic conductivity dropped rapidly to below the equipment's capacity to measure. Similar trends have also been noted for permeants with low pH values.

Recognition of the unique behavior of this construction material, such as the practical existence of a threshold gradient, its' capacity to decrease hydraulic conductivity with time and to self-heal, and its' response to environments of extreme pH values, may provide benefits if its' particularities are exploited wisely.

References

Annual Book of ASTM Standards, 2001, Volume 04.08. D 5084-90, Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.