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i. V. Kent P. von Maubeuge
Chairman ASTM Committee D35.04 Geosynthetic Clay liners.

Dear Kent

Thank you for your recent invitation to provide my comments on the need for test procedures for GCLs with polymer modified bentonites. Your request is very timely. As you know, we have published a number of papers with regard to the issue of down-slope erosion that have examined different types of GCLs including a polymer modified GCL. What you will not know is that we have also been conducing (yet to be published) research with respect to geomembrane-GCL interface transmissivity for typical GCLs, polymer modified GCLs, and coated GCLs with different permeants and as part of this study have been also examining the effect of these fluids on GCL hydraulic conductivity in tests that have now been running for about 2-3 years. I am also aware of published research by others that raise the issue of long-term performance with respect to polymer enhanced GCLs with respect to both hydraulic properties and interface shear strength.

I have been working on the issue of long-term performance of geosynthetics for over 25 years both in the laboratory and the field. What this has taught me is that while laboratory tests can be very useful, they need to be run long enough (and often that is years) to capture some mechanism related to ageing (even if accelerated testing is being used) and that field verification is also critical. For example, the laboratory method we developed for examining down-slope erosion (Ashe et al. 2014, 2015; Rowe et al. 2014, 2016) was very effective for (a) replicating the sensitivity of the four GCLs tested at QUELTS1 to downslope erosion, and (b) identifying a polymer coated GCL and a number of others as potential candidates for field testing at QUELTS2. However, over two years of field testing revealed a number of factors not evident from the laboratory testing. Let me give two examples:

i. While the laboratory tests showed fairly similar down-slope erosion response for all four conventional (untreated) sodium bentonite GCLs tested, 28 months of field testing demonstrated that the laboratory test only examined one aspect of the issue since it provided the same amount of water to cause erosion for all GCLs tested but, as we now know, this is not what happens in the field. In the field, some GCLs lost much less moisture than others due to evaporation (the mechanism providing the water which causes of down-slope erosion) under identical conditions and thus some conventional sodium bentonite GCLs performed much better than others in the field and did not experience any notable erosion in 28 months (Rowe et al. 2016a,b) contrary to the laboratory predictions of similar problems for all. As you know from my presentation at the *6th European Geosynthetics Conference, Ljubljana,* we have now reproduced in the laboratory the effect of the form of sodium bentonite on the uptake and loss of moisture due to thermal exposure and we can explain why there was a difference between what our initial laboratory tests suggested and the observed field performance. Thus an index test can be too simple; to address this shortcoming of our initial procedure one would need to simulate the subgrade conditions and thermal exposure that allows evaporation and condensation and hence allow simulation of all aspects of the down-slope erosion process.

ii. Our laboratory tests identified the polymer enhanced GCLs as having better performance with respect to down-slope erosion than the conventional sodium bentonite GCLs and while widening of desiccation cracks had been observed (a hint of a future problem) the tests were not run long enough to identify any down-slope erosion. After 15 months in the field the polymer enhanced bentonite was performing similar to when the laboratory simulation was terminated at 60 cycles; however after 28 months we observed irrecoverable (EE as defined by Brachman et al. 2015) and extreme irrecoverable (EEE) erosion for the polymer enhanced bentonite. This suggest that the polymer was washed out sometime between 15 and 28 months and no longer provided the protection needed for longer exposure. I note this to highlight that it is not easy to assess how many cycles are needed in the laboratory test to capture the mechanism (at the time we did the tests we thought 60 cycles was an impressive number – but with hindsight and the field data we now know it was not enough). What was also surprising was that the polymer modified GCL experienced the greatest shrinkage of all the GCLs tested at QUELTS2 (paper in preparation). Thus, even if the polymer enhanced GCL had solved the down-slope erosion problem, it may not be adequate for an exposed composite liner if shrinkage then caused panel overlap loss with prolonged exposure. Message: consider all potential failure modes and test for them.

A limited amount of work has been conducted dealing with geomembrane-GCL interface transmissivity. As I have indicated in a number of papers (e.g., Rowe 2012), this property can be as important, if not more important, as GCL hydraulic conductivity when dealing with composite liners. Most of the published work to-date has been with respect to typical Na-bentonite GCLs where the permeant was distilled or tap water and the tests typically were only run for a few weeks. Rowe and Abdelatty (2012a, b) ran a test with a simulated landfill leachate for several years and they observed a very different effect of the permeant on hydraulic conductivity to that on transmissivity. Suggesting that one cannot extrapolate performance with respect to one property (e.g., interface transmissivity) from another (e.g., hydraulic conductivity). Based on this we have been studying transmissivity with respect to different permeants and found that to get reasonable results one needs to run many of the tests with aggressive permeants for years; and even then it is not clear that it is long enough for polymer enhanced GCLs if there is potential for washout of the polymer.

I would ask that your committee consider these observations when considering the nature of tests that they will recommend and that they acknowledge the limitations of laboratory tests (especially ones that do not run for many years) have for assessing long-term GCL performance.

Below I highlight questions/issues that could benefit from consideration by your committee.

1. We have encountered problems with some GCLs that have been polymer amended to increase the swell index (the bentonite alone was obviously not of sufficiently quality to get 24 mL/2g). This has me to the issue of variability in the distribution of the small percentage of polymer added to the bentonite even within a single roll and raises the questions as to what effect a variable distribution polymer in the GCL will have on the GCLs long-term performance. While performing many swell index test may reveal this (with caveats as noted in Item #7 below), they are rarely conducted and, in any event, they only capture one of the many aspects of polymer enhanced GCL performance.

2. There is generally a paucity of data to support the long-term performance of polymer modified bentonite in GCLs and this may, at least in part, be due to the absence of established test methods for assessing long-term performance in a reasonable time. Thus, as yet, the long-term performance of polymers has not been demonstrated and even if it was for a particular product there is the issue of CQC and CQA discussed below.

3. There are many different types of polymers being used to improve the bentonite through different mechanisms. They may be added just to enhanced the swell capability of the clay (as noted in item #1) or to address some specific permeant (e.g., high pH, high salinity, or down-slope erosion where the "permeant" is distilled water etc.). Manufacturers are to be applauded for their innovation in developing these new products, especially when supported by test data (e.g., demonstrating improved hydraulic conductivity with respect to that permeant). However, they keep the additives secret and the end-user has no way of knowing if/when (either intentionally or by accident/error) a polymer used has changed, the percentage of polymer added has changed, the uniformity of polymer distribution has changed, or that the mechanism that was responsible for the improvement has been changed. The usual index tests are inadequate for detecting whether these changes are likely to change its performance in field applications and the detection of the polymers in the GCL is extremely difficult. Thus, even if there was good data to support long-term performance on samples of a particular product, at present standard CQC and CQA cannot ensure that the rolls delivered to site are the same, and hence will perform in the same way, as the product used to get the test data that prompted the specification of that product. It would be desirable for ASTM to develop a means of addressing this for polymer enhanced GCLs.

4. As noted in my introductory comments and examples, while laboratory test can provided insight, the long-term performance under real site conditions may be quite different to that in the laboratory (including cation exchange, dry/wet or frost/thaw cycles) and as yet this has not been adequately investigated.

5. Polymer modified GCLs are usually promoted based on an improvement in some aspect of performance (usually hydraulic conductivity). However, as indicated in my introductory comments and examples, it is not known if there are unintended consequence to the use of the (unknown) polymer with respect to other engineering characteristics such interface transmissivity, shrinkage, desiccation, and interface shear strength when used in a composite liner or roots when used with just a cover soil. While some work is presently in progress to address some of these questions, much more needs to be done.

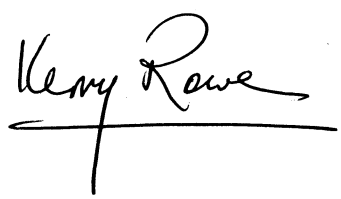
6. Given that the polymer is never indicated and the existing CQC/CQA problems (Item #3), there is a need for a test method for assessing the potential of unintended environmental impact of an unknown polymer additive being washed out.

7. Given that polymer enhanced GCLs may have coarse or fine granular bentonite or powdered bentonite and that bentonite particle size in the shipped GCL is known to impact performance even for normal (unmodified) Na-bentonite, the effect of the granularity on the long-term effectiveness of different polymer enhance bentonite needs to be established. This is especially so when, as is usual in most applications, the GCL is not fully hydrated when it comes into contact with an aggressive permanent and so the performance of exactly same polymer may be different depending on hydration that is achieved with different sized bentonite particles. Current ASTM tests generally do not address this. For example if the performance of the bentonite is assessed only after the bentonite is ground to powder (e.g., in the free swell and fluid loss tests) the effect of the particle size that may be critical in the

field applications is lost. Also, if the GCL is fully hydrated before a hydraulic conductivity test the effect will be lost.

The forgoing questions/issues should not be interpreted as being critical of polymer enhanced GCLs. On the contrary, in my opinion, they are potentially a major advance for some difficult applications where traditional Na-bentonite is challenged and there is some very high quality research demonstrating that they have benefits. Rather my point is that more needs to be known so that engineers can responsibly use them; especially in projects where there are significant consequences if there is a failure or long-term performance is required. Thus, I am delighted to see ASTM showing an interest in the topic and I that hope these comments are useful to you in your committee's work.

Yours sincerely,



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