THE BEARING CAPACITY OF HYDRATED GEOSYNTHETIC CLAY LINERS

An experimental program was undertaken to demonstrate the bearing capacity of geosynthetic clay liners and their ability to withstand anticipated loads with varying amounts of cover soils.

Three types of commercially available GCLs were placed in CBR molds under a seating pressure of 0.68kPa and hydrated in water for 24hrs. Following hydration, the CBR mold with the GCL was placed in the compression machine and compressed with a 50mm diameter piston at the rate of 0.25mm/min. Tests were then conducted with a 15mm thick layer of well-graded sand placed on top of the GCL. This was repeated twice more with 25mm and 50mm of sand placed on top of each of the three GCLs. This corresponded to height to breadth ratios of 0.0, 0.30, 0.50 and 1.00 for each of the three different types of GCLs.

Data indicates that a hydrated GCL will loose bentonite via lateral squeezing when a load is placed directly onto the GCL. Reinforced GCLs are less susceptible to bentonite squeezing. However, to protect against this phenomenon, a suitable layer of soil should be placed on the GCL. Laboratory test data indicates that having a cover soil on a GCL with a minimum H/B ratio of 1.00 will cause a potential failure to occur in the overlying soil and bentonite loss in the underlying GCL would not occur. Thus, the GCL can function as it was designed.

TR-216

On The Bearing Capacity of Hydrated Geosynthetic Clay Liners

by

Robert M. Koerner[1], Hon. Member, ASCE and
Dhani Narejo[2], Research Specialist

Abstract: Concern over the bearing capacity of hydrated geosynthetic clay liners (GCLs) has been expressed with respect to the possibility of the various products decreasing in their thickness and thereby sacrificing their low as-manufactured hydraulic conductivity properties. This experimental study shows that with adequate cover soil placement before loads are applied this possibility can be avoided. Traditional design of the cover soil thickness with respect to anticipated loadings, followed by proper installation procedures, should be followed when utilizing GCLs.

Key Words: bearing capacity, geosynthetic clay liners, squeezing, bentonite, geosynthetics, cover soil, protection layer.

1. H. L. Bowman Professor of Civil Engineering and Director, Geosynthetic Research Institute, Drexel University, Phila., PA, USA
2. Research Specialist, Geosynthetic Research Institute, Drexel University, Phila., PA, USA

INTRODUCTION

Geosynthetic clay liners (or GCLs) are relatively thin layers of processed clay (typically bentonite) placed between geotextiles, or bonded onto a geomembrane. They are typically 7 to 10 mm thick in their hydrated state. From the viewpoint of a structural system, GCLs are either adhesively bonded, needle punched throughout the product, or stitch bonded in the machine direction of the roll. There is a rigidly growing body of published information available with respect to GCLs, as well as relevant literature from all of the GCL manufacturers, see Estornell and Daniel (1992) and Daniel and Boardman (1993).

This particular technical note is focused on the bearing capacity of hydrated GCLs. The concern is understandable since hydrated bentonite often exhibit extremely low shear strength, Daniel (1993) and Koerner and Daniel (1994). In order to avoid lateral squeezing of the bentonite from beneath a vertically applied load, one must adequately backfill over the GCL before it hydrates and before concentrated loads are applied and sustained. The thickness of cover soil over the GCL is obviously a critical decision in this regard.

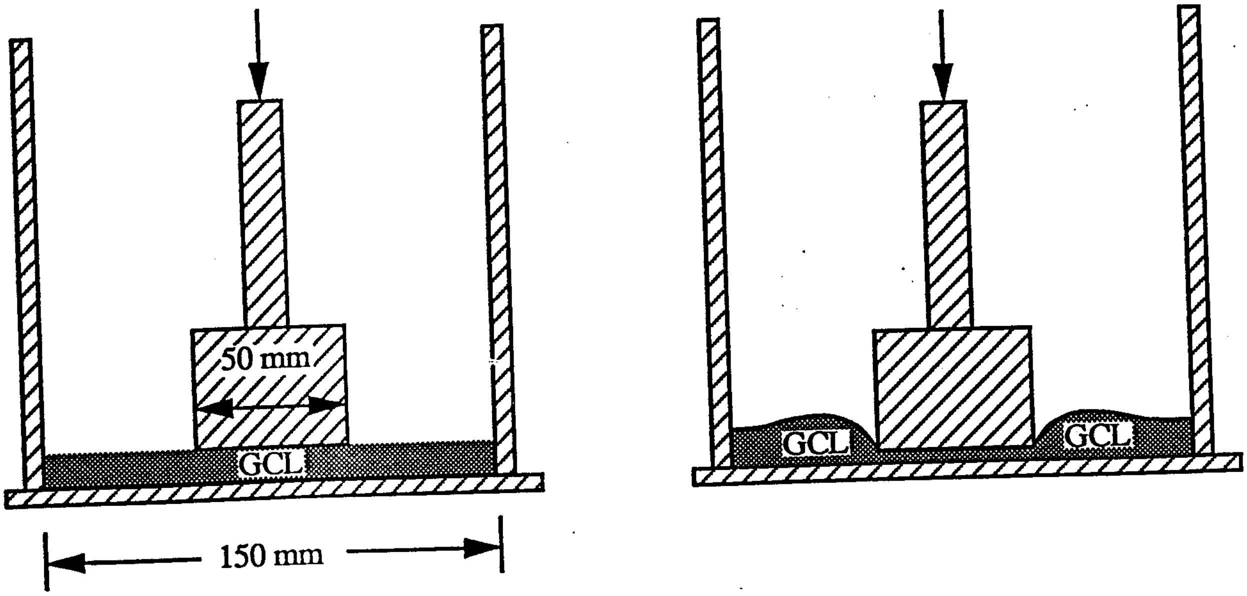
The experimental design of this study uses three different commercially available GCLs in their hydrated states while being contained in a CBR mold. Controlled rate of compression tests were performed on the products by themselves and then were performed on replicate specimens with varying depths of sand cover. The resulting load versus deformation response curves are compared to one another. As will be seen, the visual appearance of the exhumed GCLs is also of interest and compares favorably with the load versus deformation response curves.

EXPERIMENTAL SETUP

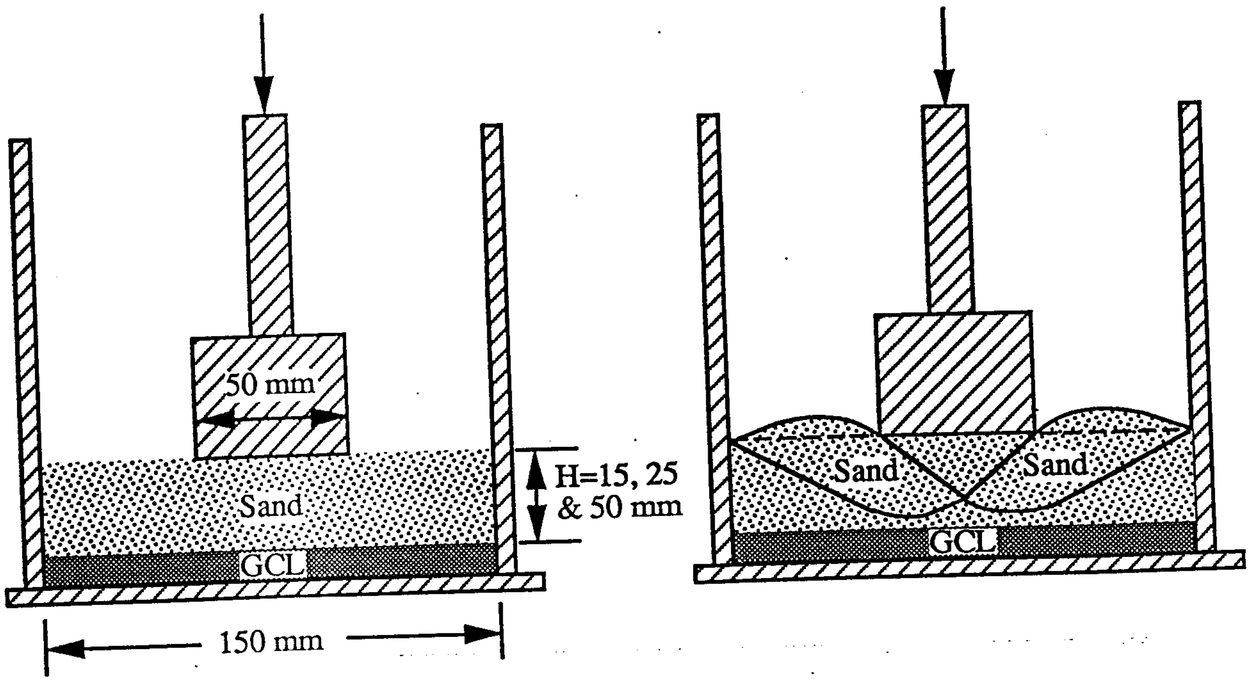
Three types of commercially available GCLs have been used in this study. GCL-1 consists of an adhesive bonded bentonite between two geotextiles. There are no yarns or fibers extending between the upper and lower geotextiles. It is typical of Claymax® 200R and for this type of test Gundseal® as well. GCL-2 consists of bentonite powder which is contained by needle punching with a high density of fibers extending from the upper geotextile through the bentonite and the lower geotextile. It is typical of Bentomat® and Bentofix®. GCL-3 consists of bentonite powder which is contained by stitch bonding in the machine direction connecting the upper and lower geotextiles. It is typical of Claymax® 500SP and NaBento®. The stitched rows for this material are at 25 mm spacings.

The various GCLs described above were hydrated in a 150 mm diameter CBR mold under a light seating load of 0.68 kPa. The entire unit with porous upper and lower platens was submerged in a water bath for 24 hours. This type of hydration is actually a proposed field conformance test method used to quantify the amount of swelling of a GCL. It is under review in ASTM Committee D35.04. After the 24 hour hydration period, the seating load was removed, the entire unit was placed in a compressing testing machine and a 50 mm diameter piston was applied to the GCL at a load rate of 0.25 mm/min. Figure 1(a) shows the before and after cross sections with the load piston placed directly on the surface of a GCL. The load versus deformation response of each of the GCLs was measured accordingly.

The tests on the three unprotected GCLs were then repeated on new GCL test specimens using a 15 mm thick layer of well graded sand placed between the upper surface of the GCL and the load piston. The left sketch of Figure 1(b) shows the cross section and the location of the sand layer. In a bearing capacity context, this is a height to breadth ratio of 15/50, or 0.30. Upon completion of this series of tests, the sand covering the GCL was increased to a height of 25 mm, thus the ratio of H/B was 0.50. A fourth and last series of tests was then performed with the sand covering layer at a height of 50 mm, thus the ratio of H/B was 1.0. At this point, the mode of failure occurred entirely within the sand layer as illustrated on the right sketch of Figure 1(b). In total, four series of tests were performed on three different types of GCLs for a total of 12 tests.



(a) Before and After Cross Sections for Load Imposed Directly on GCL



(b) Before and After Cross Sections for Adequate Sand Cover Above GCL

Figure 1 - Experimental Setup for Bearing Capacity Tests on Hydrated GCLs

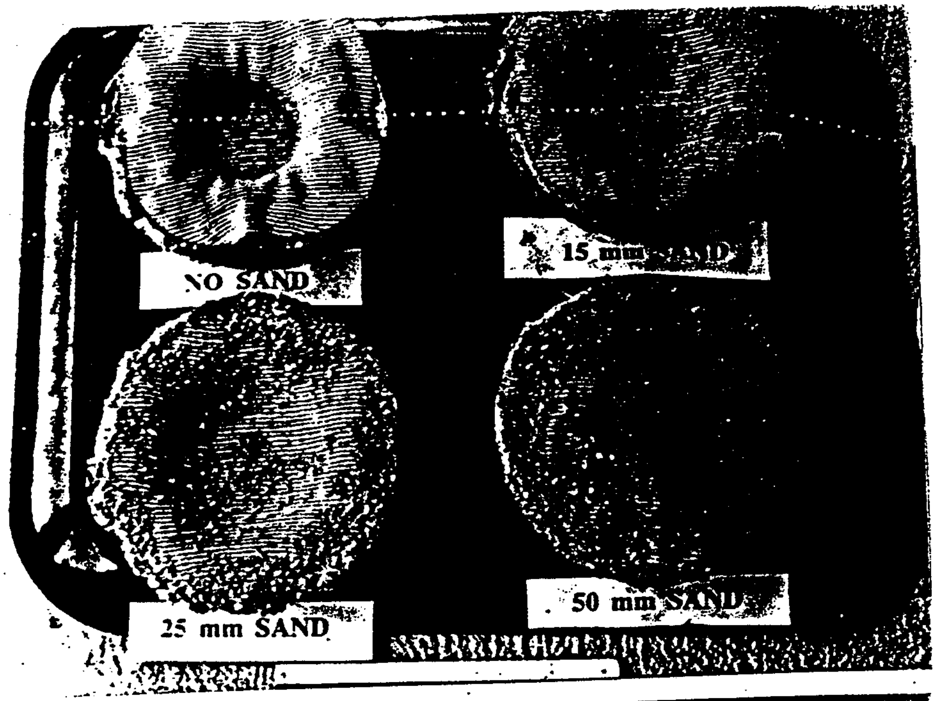
TEST RESULTS

The visual appearance of the exhumed GCLs after the individual tests were concluded is shown in Figure 2. Here the three different types of GCLs can be seen at each of the four conditions described previously, i.e., without sand cover and then with sand cover at H/B values of 0.30, 0.50 and 1.0. Clearly, with no sand covering the GCLs, the hydrated bentonite was laterally squeezed out from beneath the load piston for all types of GCLs. There was very little bentonite remaining in the area directly beneath the load piston. However, as a sand layer was placed above the GCLs with gradually increasing thicknesses, a height was reached at which no deformation nor squeezing of bentonite within the GCLs was observed for any of the products. This height was seen to be at a value of 50 mm, which is equivalent to an H/B value of 1.0. The bentonite thickness was essentially the same as it was at the beginning of the test. Between these two extremes of no sand covering and H/B = 1.0, the products behave slightly different, with the needle punched GCLs indicating only minor deformation at an H/B value of approximately 0.50.

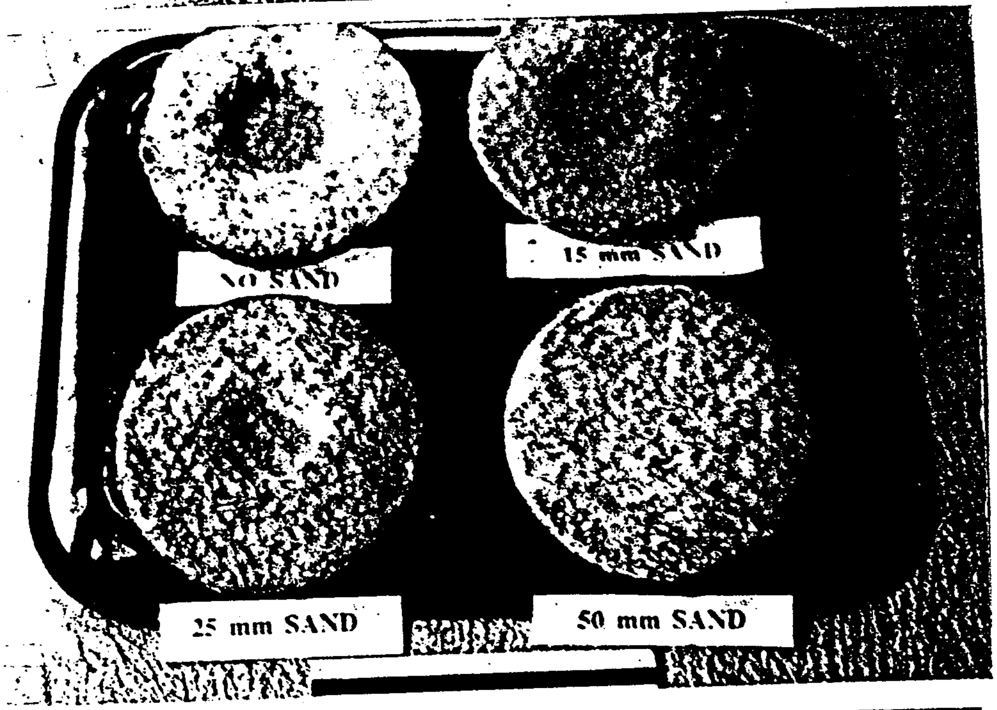
The resulting load versus deflection curves of the twelve tests that were conducted corroborate the visual findings just described. Figure 3(a), for the adhesive bonded GCL-1, shows an abrupt change in response between H/B values of 0.50 and 1.0. Bearing capacity failure via squeezing of the bentonite was seen for the tests at H/B values of 0.0, 0.30 and 0.50, while a general shear failure was entirely contained within the sand layer at an H/B value of 1.0. GCL-1 was not influenced at all for the applied load at an H/B value of 1.0.

Figure 3(b), for the needle punched GCL-2, shows a somewhat "stiffer" response for all tests with a subtile difference in response between tests at H/B of 0.30 and 0.50. The trends have some anomalous behavior in that the H/B = 0.50 curve appeared to fail abruptly and there is a crossover of trends between the 0.0 and 0.30 response curves. Most importantly, however, was that GCL-2 was not influenced at all for the applied load at an H/B value of 1.0. The visual identification of the exhumed test specimens in Figure 2(b) substantiates this behavior.

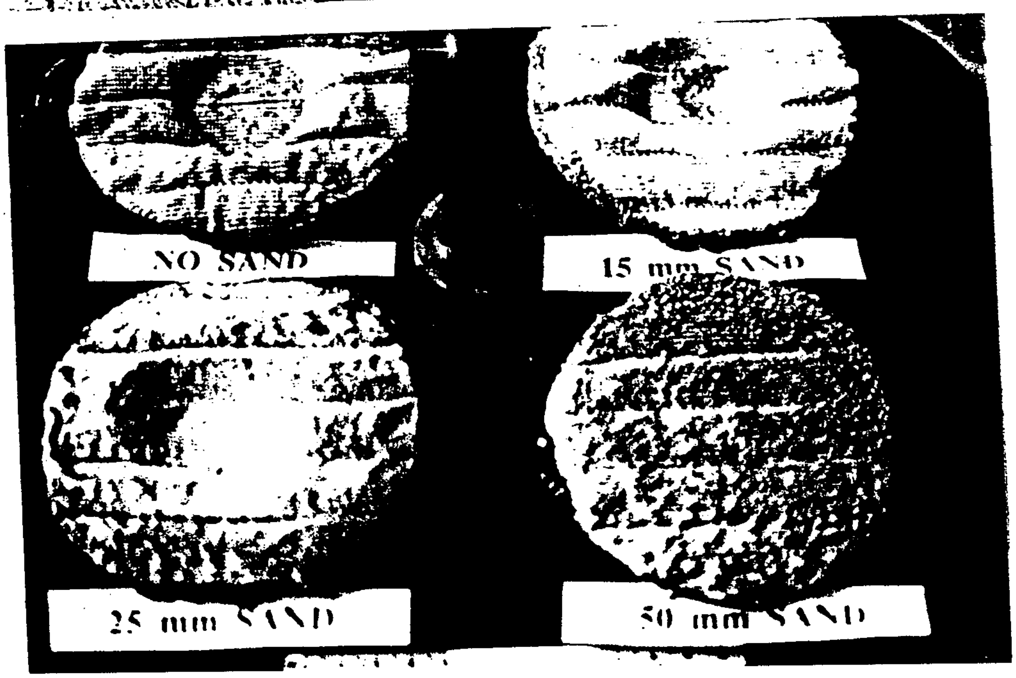
Figure 3(c), for the stitch bonded GCL-3, indicates a behavior intermediate between the adhesive bonded and needle punched GCLs. Close observation of Figure 2(c) shows that the hydrated bentonite could not move freely in a direction perpendicular to the rows of stitch bonding, but could move parallel to the stitching direction. As with the other tests, GCL-3 was not influenced at all for the applied load at an H/B value of 1.0.



(a) GCL-1: Adhesive Bonded

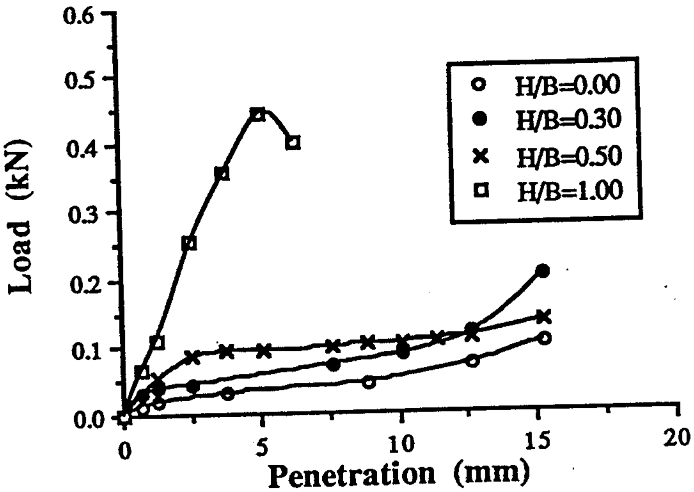


(b) GCL-2: Needle Punched

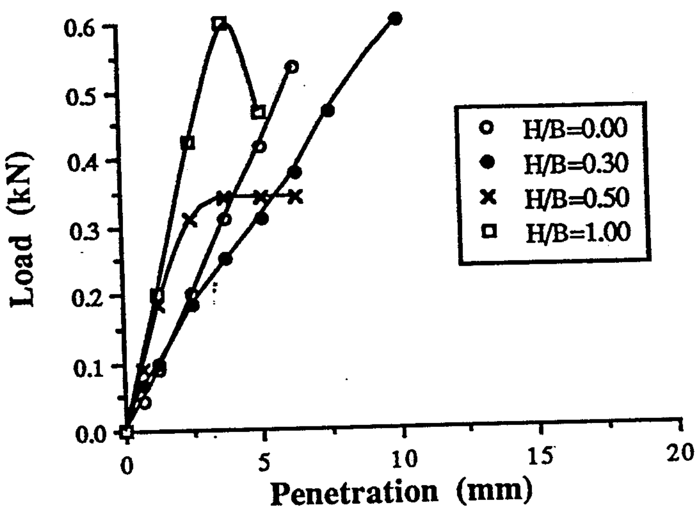


(c) GCL-3: Stitch Bonded

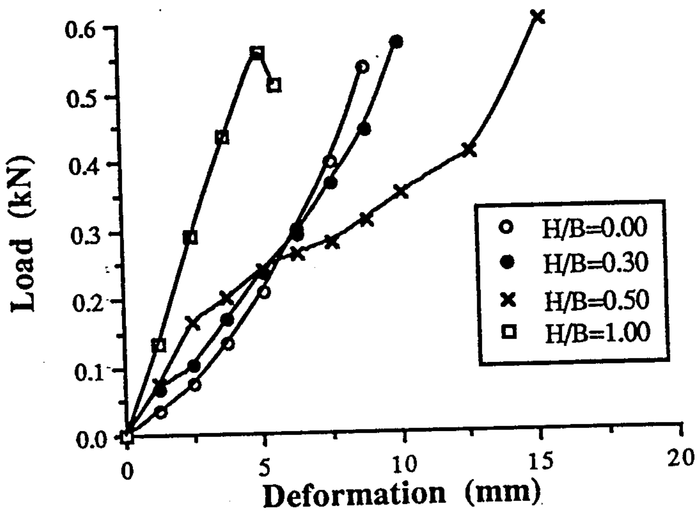
Figure 2 - Exhumed GCL Test Specimens after Bearing Capacity Testing in a CBR Setup



(a) GCL-1: Adhesive Bonded



(b) GCL-2: Needle Punched



(c) GCL-3: Stitch Bonded

Figure 3 - Response Curves of GCL Bearing Capacity Tests in a CBR Setup

SUMMARY

The concern over the hydrated bentonite contained in GCLs being laterally squeezed out of the materials by concentrated loads was addressed in this technical note. Loading was achieved using a constant rate of deformation load press although it is recognized that a constant stress (creep) test would also be an alternative test.

What the results of these tests show is that hydrated GCLs will loose their bentonite by lateral squeezing if load is applied directly on top of them. Needed, to protect against such bentonite loss, is a suitably thick layer of cover soil. For these tests, a soil thickness at least equal to the diameter of the load piston was required. Thus, an H/B ratio of 1.0 was seen to be adequate in all cases and for all of the GCLs evaluated. This includes non-structured, needled and stitch bonded GCLs. By having such a soil covering layer, a potential bearing capacity failure would be entirely contained within the covering soil and the underlying GCL would not be affected. Obviously, the cover soil should be designed accordingly.

As with all geosynthetics, such soil covering layers must be site specifically designed and then be followed by proper installation and monitoring in the field. In this way, the various GCL products can function as they are designed and intended.

APPENDIX - REFERENCES

Daniel, D. E. and Boardman, B. T. (1993), "Report on Workshop on Geosynthetic Clay Liners," U.S. Environmental Protection Agency, EPA/600/R-93/171, August.

Daniel, D. E. (1993), "Geosynthetic Clay Liners in Landfill Covers," Proc. SWANA Conference, San Jose, CA, July.

Estornell, P. and Daniel, D. E. (1992), "Hydraulic Conductivity of Three Geosynthetic Clay Liners," Jour. of Geotech. Engr., ASCE, Vol. 118, No. 10, pp. 1592-1606.

Koerner, R. M.and Daniel, D. E.(1994), "Technical Equivalency Assessment of GCLs to CCLs," Proc. 7th GRI Conference, IFAI Publ., St. Paul, MN, Dec. 14-15.