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NSY PORTSMOUTH
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DEPARTMENT OF THE NAVY
NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
10 INDUSTRIAL HIGHWAY
MAIL STOP, #82
LESTER, PA 19113-2090

IN REPLY REFER TO
5090
Ser 1823/dec

23 December 1992

Mr. Mark Hyland
State of Maine
Department of Environmental Protection
State House Station #17
Augusta, Maine 04333

Re: INTERIM CORRECTIVE MEASURE, SWMU #6 (DRMO STORAGE YARD)
NSY PORTSMOUTH, KITTERY, MAINE

Dear Mr. Hyland:

As discussed on 10 December 1992, enclosed is supporting justification on the proposed capping method which the Navy is pursuing as an interim corrective measure for the DRMO storage yard (SWMU #6) at Portsmouth Naval Shipyard.

The additional design analysis was prepared in response to your 10 November 1992 letter which identified MEDEP concerns with the proposed geocomposite clay liner's integrity given known site conditions. Based on the enclosed, it is still the Navy's preference to proceed with the capping option consisting of 12 inches of stone with the geotextile clay liner.

I would like to emphasize that the primary objective of the interim cap is to minimize human exposure to the contaminants in the soil by reducing inhalation of dust and any direct contact with the soil. As an interim action, the proposed cap (12 inches of stone with a geotextile liner) was considered to be the most effective measure (including cost) which will reduce human exposure and allow current operations to be maintained while final corrective measures are being evaluated.

The option preferred by your office (12 inches of clay with 12 inches of stone) would require removal of contaminated soil to accomodate a cap thickness of 24 inches. This option was not being pursued because of the cost associated with disposal of the soil prior to determining clean-up methods or levels.

Re: INTERIM CORRECTIVE MEASURE, SWMU #6 (DRMO STORAGE YARD)
NSY PORTSMOUTH, KITTERY, MAINE

Upon completion of your review, I would like to setup a conference call with your office and the Navy's technical staff and consultant to discuss the final plan of action which will be acceptable to the MEDEP. Please contact me at (215) 595-0567 when available for the discussion.

Sincerely,

Deborah Carlson

D. E. CARLSON
Remedial Project Manager
By direction of the Commanding Officer

Copy to:
EPA (E. Waterman)
PNSY (Code 121.5)

INTERIM CORRECTIVE MEASURES

at the

DRMO, PORTSMOUTH NAVAL SHIPYARD

KITTERY, MAINE

GEOCOMPOSITE CLAY LINER DESIGN CONSIDERATIONS

December 3, 1992

As you are aware, the Maine Department of Environmental Protection (MDEP) has provided comments on the capping system proposed by McLAren/Hart for the capping of the DRMO. Specifically, the are concerned about the degradation of the Geocomposite Clay Liner (GCL) as a result of several factors listed as:

- Numerous Wetting and Re-wetting Cycles
- Freeze-Thaw Cycles
- Differential Settlement of Underlying Soil Material
- The Force of Heavy Equipment Pressing the Crushed Stone into the GCL

In response to the Maine Department of Environmental Protection's concerns, McLaren/Hart is providing various technical data and design calculations which address these concerns and demonstrate that the GCL will be appropriate for the DRMO cap.

Numerous Wetting and Re-wetting Cycles

The MDEP is concerned that the GCL will lose its low permeability characteristics due to numerous wetting and drying cycles. M/H feels that the wetting and drying of the GCL will not be an issue at this site because of the flatness of the site and the fact that the GCL will be buried by 1 foot of cover material. Once the GCL becomes hydrated there will little potential for desiccation.

In addition, several studies on the effects of wetting and re-wetting of GCL's have been completed. Two references are included in Attachment A. One of the studies was performed using a Claymax GCL and the other using Bentomat. Both of the studies indicate similar results in that there is no effect on the permeability of the GCL due to wetting and drying cycling. The studies showed that when the GCL was desiccated, cracks as wide as 2 mm developed, however because of the self-healing properties of the GCL, the cracks sealed upon rewetting and there was no appreciable change in the permeability of the GCL.

Freeze-Thaw Cycles

Since the GCL will not be placed beneath the frost level in this application, the GCL will be susceptible to freeze-thaw cycles at various times during its design life. The references included in Attachment A also include study of the effect of freeze-thaw on the GCL's. In both studies it was found that there is no effect on the permeability of the GCL due to freeze-thaw.

Also, it appears the MDEP is in favor of 12 inches of compacted clay in place of the GCL as a more appropriate capping option. We have provided a reference in Attachment B which demonstrates that compacted clay liners are much more susceptible to freeze-thaw cycles than GCL's.

Differential Settlement

I assume that the MDEP is concerned about the potential of "rutting" or similar type damage when they are referring to differential settlement of the underlying material. The underlying

materials, as shown in the boring logs, consist of primarily dense, coarse to fine sands with varying amounts of gravel and some silts. The materials are primarily non-cohesive which means they have little settlement potential. In addition, these soils have been compacted for many years by past operations in the yard. The surface of the yard is presently very dense and there are little soft areas.

During the excavation and filling which will be required to regrade the site, the soils will be compacted to 95% of the Maximum Dry Density as determined by the Modified Proctor Test. The types of soils present when compacted to 95% density will have very little settlement potential. Quality Control during construction will assure that a well compacted fill will be placed.

The Force of Heavy Equipment Pressing the Crushed Stone into the GCL

The MDEP is concerned over the ability of the GCL to withstand the force of heavy equipment traffic in the yard. They are concerned that over time the GCL will be damaged.

In order to evaluate the GCL for puncture and tear resistance, I have used design procedures developed by Dr. Robert M Koerner for this type of application. The design calculations can be found in his book "Designing with Geosynthetics" (1990, Prentice-Hall Inc.).

Three critical properties of the GCL are necessary for its survivability. These are burst resistance, tensile strength, and puncture or tear resistance of the GCL. Dr. Koerner has developed a design analysis which evaluates each of these critical functions. These can be found in Chapter 2 of his book which is included in Attachment C.

Burst Resistance

Koerner has developed an analysis to evaluate a geotextile placed on a subgrade with stone placed above it. In this scenario there are voids in the stone fill that are available for the geotextile, or in our case, the GCL to enter into. This mechanism is shown in Figure 1. As shown, the pressures on the GCL cause the GCL to enter the voids formed by the stone. If the pressures are high enough or the voids are large enough, the GCL can burst. Koerner developed a required burst strength formulation which models this mechanism and this is given as:

$$F.S. = (3.6)(P_{test})/(d_a)(p')$$

where:

F.S. = Factor of Safety, typically 3.0
P_{test} = the Mullen Burst Test pressure
d_a = the average stone diameter
p' = the stress at the GCL's surface

In applying this relationship for analysis of the DRMO cap, we can check to see if the

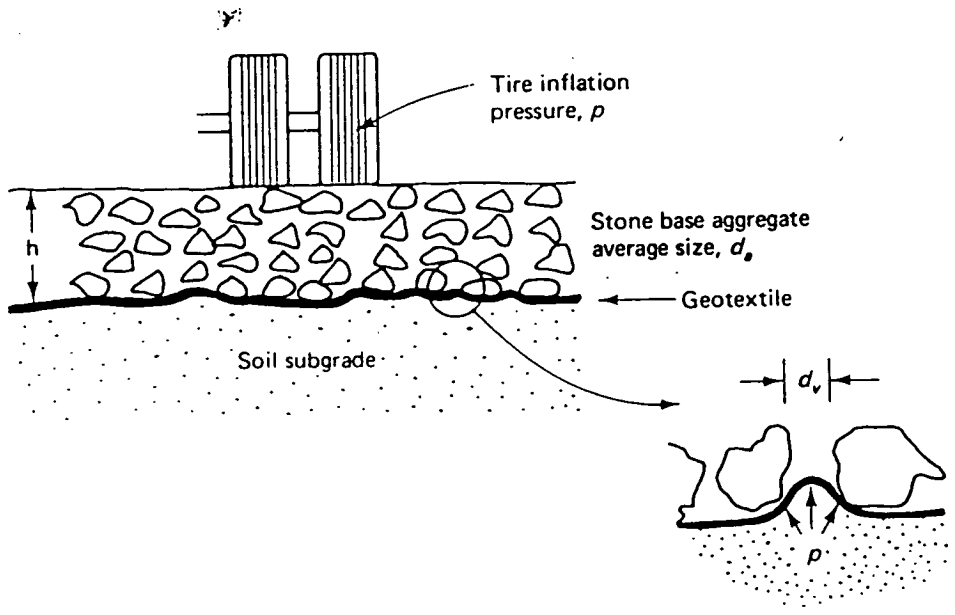


FIGURE 1 Geotextile being forced up into voids of stone base by traffic tire loads.

GCL has sufficient burst strength for this application. The critical input parameters are the pressure at the surface of the GCL and the diameter of the stone to be used.

The pressure at the surface of the GCL can be determined using the operating data from the hydraulic crane which is used at the yard. The crane is a Koehring Model 6644 hydraulic excavator fitted with a clamshell crane. This equipment is track mounted and the contact pressure is only 9.33 psi. This is a low contact pressure especially considering that normal car traffic has a bearing pressure of approximately 35 psi and truck traffic can have bearing pressures as high as 100 psi.

The diameter of the stone proposed for the cap will be approximately .75 inches.

In performing the calculations for one layer of GCL alone without cushioning from the geotextiles above and below, it can be seen that the required Mullen burst strength to support the crane with a factor of safety of 3.0 is only 5.8 psi. Also, in calculating the Mullen burst strength needed to support heavy truck traffic (i.e., contact pressure = 100 psi), the required strength is 62.5 psi.

Since the Mullen Burst strength of GCL's is typically in the range of 200 psi, the GCL alone will not be susceptible to bursting in this application. Given the fact that a geotextile will be placed both above and below the GCL the likelihood of damage is even lessened.

Tensile Strength Requirement

There is another mechanism acting on the GCL at the same time as the tendency to burst. This is a tensile stress caused by two pieces of aggregate locking into the GCL and moving laterally in-plane. This scenario is shown in Figure 2. The GCL must posses sufficient tensile strength to prevent damage due to this mechanism.

Koerner developed a relationship between the required tensile force and the applied pressure and this is given as:

$$T = p'(\epsilon)^2$$

where:

T = the mobilized tensile force
p' = the applied pressure
ϵ = the strain of the geotextile between contact points, typically 75%

Applying this relationship it can be shown that the required tensile force is 14 lbs. based on a contact pressure of 100 psi, and 50% slippage between the stone and geatextile (a typical assumption which Koerner recommends). Again, the crane only has a contact pressure of 9.3 psi, therefore the GCL alone has much more tensile strength than is required to support the crane. The two layers of geotextile also provide protection from damage due to tensile stresses.

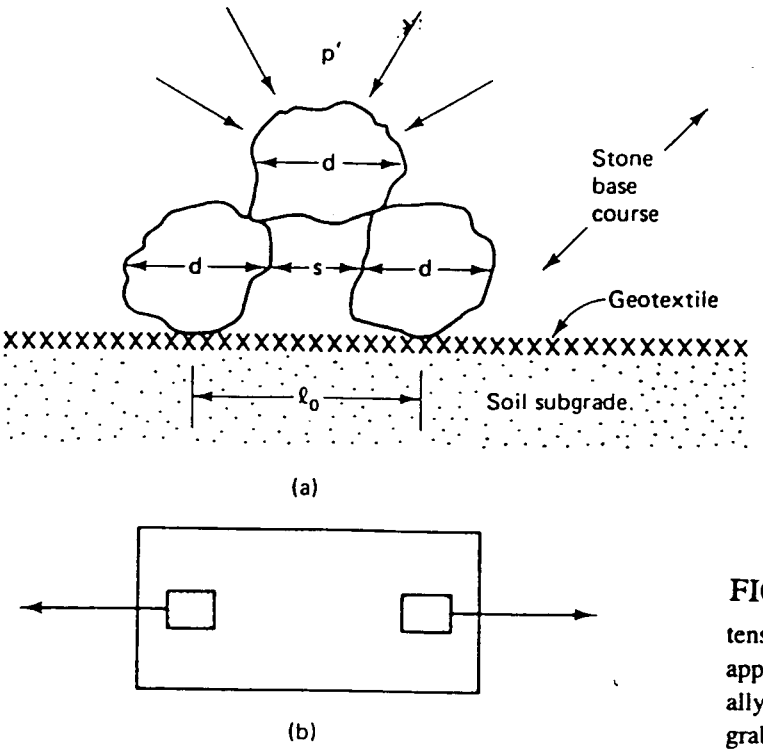


FIGURE 2 Geotextile being subjected to tensile (Grab) stress as surface pressure is applied and stone base tends to spread laterally. (a) Actual situation. (b) Analogous grab tension test.

Puncture (Tear) Resistance

The GCL is susceptible to puncture from stones and miscellaneous debris as traffic loads are imposed on it. Koerner has developed an analysis method to determine if the GCL has sufficient puncture resistance for the imposed loads and the size and shape of the stone fill. The design method is shown schematically in Figure 3 and is given as:

$$T_{req} = (\pi d_i d_a) p' \; S'$$

where

T_{req} = the required tensile force
d_i = the initial average void diameter of the GCL
d_a = the average diameter of the stone
p' = the pressure exerted on the GCL (usually 75% to 100% of tire inflation pressure at the ground surface)
S' = the shape factor varying from 0 for rounded blunt objects to 1.0 for sharp angular objects

Making conservative assumptions and assuming a contact pressure of 100 psi, an average stone diameter of .75 inches, and a sphericity of 1.0 (i.e., the stones are very sharp), the required tensile force is calculated to be less than 1 pound. All GCL's have much higher puncture resistance, therefore, this calculation demonstrates that the GCL alone will not be damaged by puncture.

Protective Cushioning

The design of the DRMO cap includes two layers of 16 ounce, non-woven, needlepunched geotextile placed above and below the GCL for protective cushioning. Koerner has shown the benefits of geotextiles as a protective cushioning layer. Figure 4 shows the relationship between puncture resistance for various types of geomembranes both alone and with adding either one or two 600 g/m^2 needlepunched geotextiles. The results indicate that there is an increase in puncture resistance of as much as 8.7 times greater when the geomembrane is protected by two geotextile. One could expect similar type of behavior for the GCL's. Given the fact that the previous calculations indicate that the GCL alone has the required structural integrity to perform, adding the two geotextiles as a protective cushioning layer provides a factor of safety for performance and assures that the GCL will not be damaged by the imposed loads on it.

Summary

The information provided in this report addresses the technical concerns of the MDEP and demonstrates that the GCL can perform satisfactorily in this application. We can appreciate the MDEP's concerns relating to the long term integrity of the GCL in this application because of the operations in the yard, however, we point out that geosynthetics have been used successfully in roadway applications which present much of the same type of structural integrity concerns. In addition, we realize that the use of GCL's is a somewhat new technology, however, leading

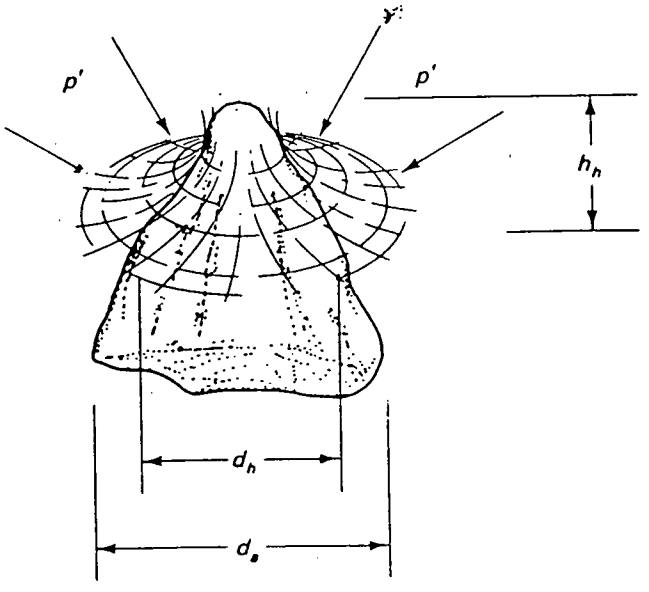
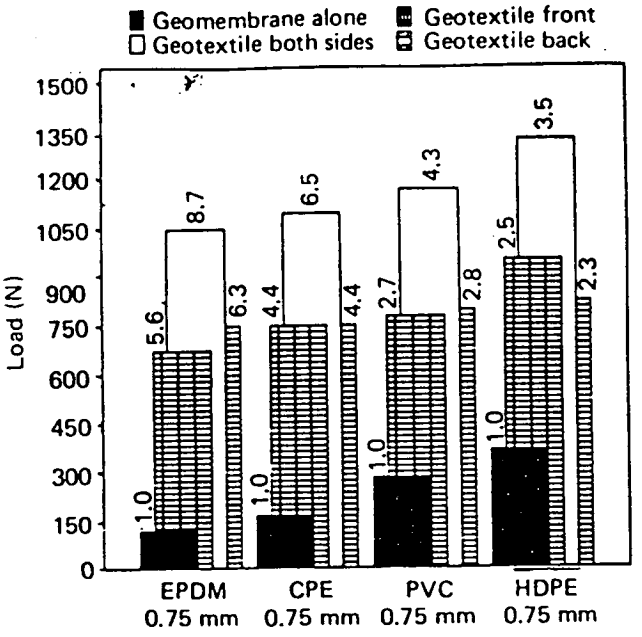


FIGURE 3 Visualization of a stone puncturing a geotextile as pressure is applied from above.



(c) Puncture test results of 600-g/m^2 geotextile with various geomembranes

FIGURE 4 Puncture test results illustrating the cushioning benefit of various geotextiles to different geomembranes (after Koerner, et al. [45]).

edge researchers in this area, such as Dr. Robert M. Koerner have recently become great proponents of this new technology and feel that GCL's offer many advantages over traditional compacted clay liners.

ATTACHMENT A

Vince Luciano

AMERICAN COLLOID COMPANY

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(312) 966-5720 • TWX 910-223-0738 • TELEX 724-413

VOLCLAY - FREEZE THAW CYCLE

When bentonite is mixed into the top layer of soil and thoroughly prehydrated it breaks down into myriads of fine, micron size particles. When properly prehydrated with a sufficient quantity of water each of these fine particles is surrounded by a shell of water. This water is physically bound to the bentonite and cannot be driven off except under extreme heat. Thus, each bentonite particle is separated from the adjoining particles by a layer of water. As the temperature drops below the freezing point of water this bound water will freeze. The individual shells of water will freeze together forming a solid, impenetrable barrier of ice. As the temperature continues to drop and the freezing zone moves down through the soil, eventually the entire sealed area will be frozen solid. Let us now reverse the procedure. As heat is applied to the upper layer of the bentonite seal the water frozen into the top layer of the bentonite seal will thaw. As soon as this thaw takes place, the water that has thawed will become bound to the bentonite particles with which it was originally associated. Thus, you are progressing from a solid frozen mass to a jelly-like consistency in one step. As the top layer becomes a gel, the lower layers will begin to thaw out. At no point will there be a loss in the seal.

VOLCLAY - FROST HEAVES

When bentonite is intimately mixed with the base soil the bentonite and its bound water fills the void spaces within the soil, preventing the passage of outside fluids. However, since the bentonite is expanded and because it does not fill 100% of the voids within the soil, there is more than enough room to contain the minor expansive forces of frost heaves without causing any buckling of the seal.