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Project Summary

Evaluation of Retorted Oil Shale as a Liner Material for Retorted Shale Disposal Sites

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This study has considered the possibility of using a spent oil shale itself as a water barrier or "liner" beneath a spent oil shale waste embankment. Pertinent properties of unburned Tosco II spent shale and an average mixture of Lurgi spent shale have been measured. Materials consisting of 1, 20, and 30% burned spent Tosco shale admixed into unburned Tosco II shale have also been considered. Two autoclave mellowed materials admixed into their respective unmellowed spent shales have also been studied.

This work indicates the difficulty of having both easy self healing and low permeability of the unmellowed Tosco materials and mixtures thereof, as well as perhaps the unmellowed Lurgi spent shale. Autoclave mellowing of the burned Tosco material, however, produced a high plasticity index material that may be blended with the silty unburned Tosco II spent shale to produce a liner having (at least in the short term) both low permeability and good self-healing possibilities. A similar attempt with the Lurgi spent shale was not successful due to the high permeability produced in the short term aging experiment.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Objectives

An experimental program was conducted to determine the efficacy of using spent oil shale itself as a barrier between a waste pile of spent oil shale and the surrounding aquifer or country rock. The objective of the program was to produce a liner material which had much of the frictional characteristics and volume stability of silt with the impermeability of clay without a tendency for eventual cementation on the one hand or leachability and partial soil skeleton loss on the other. In other words the liner material should be highly impermeable yet have sufficient plasticity to accommodate subsidence without rupturing or, if ruptered, to self heal.

The objectives stated above are difficult criteria to meet and certainly require some modification and admixing of various materials to produce a liner with the desired properties.

Approach

The routine testing approach was centered around the study of rather highly consolidated specimens of various mixtures of spent oil shale at two moisture contents: one at the optimum water content for maximum dry density, and the other at a somewhat wetter than optimum water content. Often wetter than optimum material is used for small dam cores and around abutments for increased flexibility, lower brittleness, and sometimes lower permeability. A vertical consolidation pressure of around 280 psi* was produced by spring loaded oedometers.

* 1 psi = 0.0703 kg/cm²

To simulate a liner placement technique that is sometimes proposed, the specimens were compacted in spring oedometer sheaths to 100% of standard proctor or 100% of modified proctor. These compactions allowed a small additional consolidation in the oedometers. The oedometer consolidation approximately models burial of the material under an embankment of moderate height and allows a standard and somewhat realistic environment for subsequent aging/curing and/or cementation processes in the specimen. The immediate application of the full 280 psi consolidation pressure just after compaction does not simulate real conditions, however, since some time is needed for construction of full embankment height.

After permeability testing a specimen, it was transferred from the spring oedometer to a rubber membrane in a triaxial chamber for torsion testing under a confining water pressure generally selected to produce a value of 0.5 to 0.7 for the ratio of the lateral stress to the vertical stress, K_0. A K_0 of 0.7 is higher than corresponds to a two dimensionally normally consolidated silty material but may be about right for certain specimens. In this way the tendency for swelling in the diameter of a specimen as it is extruded from the oedometer sheath to the rubber membrane in the triaxial chamber is mitigated. Such swelling might break the bonding of cemented specimens. Without the confining pressure even some stiff, partially cemented specimens were crushed when only moderate vertical pressures were applied prior to torquing.

It is desirable to perform shear strength tests on undisturbed specimens. The properties of specimens may be altered by swelling which softens them; by over consolidation during extrusion which hardens them; or by breaking cementation which softens them or fractures them prematurely. In order to mitigate these problems a special triaxial test apparatus was designed and constructed.

The triaxial torsion machine was designed to produce strains under triaxial loads that simulate conditions expected for liners of spent shale piles. In general the expected strains exceed the capacity of most compressive triaxial machines. Hence the machine used in this program was designed to accommodate the anticipated large shear strains. Additionally the fixtures allowed the transfer of samples from the spring oedometer cells used for the consolidation experiments to the triaxial testing apparatus. This prevented either swelling or further densification of soft clays being tested at overconsolidation ratios of unity or above. Also, for the case where cementation may have occurred in the specimen, transfer of the sample while maintaining the confining stresses was possible, thus eliminating any longitudinal or laterial strains that would disrupt the cementation. Hence, the properties of specimens exhibiting cementation could be determined accurately.

The well mixed moistened spent shale batches were compacted by a miniature proctor system to either standard or modified proctor and consolidated under a spring force equivalent to around 280 psi vertical pressure. Data for secondary consolidation curves were obtained during curing of the specimens until they were tested (still under the same 280 psi vertical soil skeleton pressure) for permeability under a water pressure of usually 20 psi. Lower water pressures were found to sometimes give unusually low permeation rates or erratic rates. This may have been due to the "oily" hydrophobic nature of some specimens. At 20 psi hydraulic pressure the permeability values seemed internally consistent with each other. Some specimens were not subjected to water permeation in order to compare them with permeated ones in later shear strength testing.

Several modifications of the testing procedures were required during the preliminary experimental methods development in order to produce consistent results. These procedures were subsequently used to produce the data required for the torsion stress vs strain curves.

All specimens were transferred from their individual spring oedometers to a triaxial confining water pressure apparatus in a way to minimize disturbance causing overconsolidation or breaking the bond between specimen and pore stones and vanes. After the transfer, each 1 in.* high by 2.5 in. diameter specimen was retained between drained pore stones and its cylindrical surface was covered by a thick gum rubber membrane. Brass vanes embedded in the pore stones aided torsioning the specimen for obtaining peak shear strength, "residual" shear strength, initial stiffness, and twist to peak strength.

Availability of the peak and "residual strength" of a specimen allowed computation of a brittleness index. Since the normal or vertical pressure on the ends of the specimen is known (in some tests this was made equal to the prior consolidation pressure during torsioning), angles of internal friction for peak and residual strengths corresponding to the high overburden load of around 280 psi were calculated.

*1 in. = 2.54 cm.

After obtaining the torsion stress/strain curve, the specimens were removed from the triaxial container and their enclosing gum rubber membranes were cut away so previously transferred longitudinal acrylic paint stripes on the specimens could be examined and the specimens photographed.

Some physical and chemical properties of the specimens were determined on dried fragments left from the torsion test, including evolved gas analysis (EGA) for hydrate water of species formed during curing. Some of these species are of a cementing or potentially leachable nature. X-ray diffraction scans for confirmation or identification of these species were also made.

The Atterberg limits of beginning materials and blends of spent shale materials are a parameter important in soil mechanics correlations. These were obtained for some raw material spent shale and mellowed spent shale. Atterberg limits on cemented specimens were not made.

Spent Shale Treatment

Both Lurgi and Tosco II spent shales were evaluated as potential liner materials. The evaluation included the following material: (a) unburned Tosco II, (b) 10% burned Tosco, 90% unburned Tosco II; (c) 20% burned Tosco, 80% unburned Tosco II; (d) 30% burned Tosco, 70% unburned Tosco II; (e) 75% mellowed burned Tosco, 25% burned Tosco; (f) 50% mellowed burned Tosco, 50% unburned Tosco II; (g) Lurgi; (h) 75% mellowed Lurgi, 25% unmellowed Lurgi; and (i) 50% mellowed Lurgi, 50% unmellowed Lurgi.

The two component samples were admixed uniformly prior to compacting.

The mellowed material was produced by treatment in an autoclave at various steam pressures (and therefore at various temperatures). This treatment reduced the cementation tendency of the material.

Samples with both optimum moisture and "wet of optimum" moisture were tested. The optimum moisture was determined as that moisture content necessary to produce the maximum dry density in the compacted sample. For the wet of optimum samples the moisture contents ranged from 3 to 9% above the optimum moisture.

The aging times for the various specimens ranged from 2 weeks to 9 months.

Results and Conclusions

The Lurgi and burned Tosco material, including all the two-component mixtures containing burned Tosco material, was too brittle to be considered as serious candidates for liner material. The Lurgi/mellowed -Lurgi mixtures had the highest permeabilities; therefore, they also were not suitable as liner materials.

The Tosco II unburned material and the 50% mellowed burned Tosco, 50% unburned Tosco II both exhibited some plasticity while retaining relatively low permeability. Hence both of these materials are candidate liner materials since they have some self-healing characteristics and the low permeability necessary to prevent contamination of the ground water outside the spent shale pile.

The samples which were wet of optimum showed the higher plasticity.

In all cases the permeability decreased with time as confirmed by the long term tests.

There was little change in plasticity with time.

The mineral grain density tended to continue to decrease with time.

Note that only two varieties of shale, with modifications and mixtures of them, were included in this investigation. Of the nine variations studied, only two are considered as candidates for liner material.

Further work is necessary to determine the efficacy of other shales as liner material. For example, Union shale was not included in this study. Furthermore no optimization investigations were carried out.

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***Edward R. Bates** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation of Retorted Oil Shale as a Liner Material for Retorted Shale Disposal Sites," (Order No. PB 87-165 270/AS; Cost: $18.95, subject to change) will be available only from:
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