DON'T SAY IT --- *Write It!*

DATE: August 4, 1992

TO: Cathy Massimino - EPA
Dan Duncan - EPA

FROM: C. E. Clark

Telephone: (509) 376-9333

cc: R. C. Bowman w/o enclosures H4-57
D. L. Flyckt R3-45
S. M. Price w/o enclosures H4-57
[redacted] H4-57

SUBJECT: DRAFT CALCULATIONS FOR LINER PHYSICAL STRENGTH

At a teleconference on June 15, 1992, EPA requested that DOE-RL provide them with calculations demonstrating that the secondary containment liner material has sufficient strength to perform under the conditions expected at the Waste Water Pilot Plant. Attached are copies of the calculations for liner seam strength, impact failure, compression failure, and puncture failure.

The calculations of soil strength as well as foundation design is continuing. The results of these analyses will be forwarded to you when completed.

This is an informal transmittal of draft information. A formal transmittal of the information will follow.

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July 27, 1992

Berm Liner Impact Failure Analysis

Purpose

The purpose of this analysis is to determine the limitations of the Seamans XR-5 8130 geomembrane secondary containment liner with respect to impact strength.

Assumptions

1. The "Technical Data and Specifications for XR-5" included in Appendix 4E describe this geomembrane as a polyester fabric with an ethylene intermolecular alloy coating. Mr. Kent Sogge, the Seamans representative in Bellevue, Washington, has indicated that this coating is a polyvinyl chloride (PVC) polymer with an Elvaloy modifier. 'Elvaloy' is a trademark of the E. I. DuPont de Nemours & Company. The modifier replaces the plasticizer that is normally added to flexible PVC. The Elvaloy provides the flexibility normally supplied by a plasticizer while also providing increased chemical resistance.

2. Impact resistance test data is not available for the XR-5 geomembrane. The general literature also does not contain any impact resistance values for flexible PVC. However the April 17, 1986 issue of Machine Design gives the Izod impact resistance of rigid PVC as 0.4 to 20.0 foot pounds per inch (ft-lb/in) of notch (ASTM D256).

   The upper value of this range for rigid PVC will be used for this analysis. No credit will be taken for the polyester fiber reinforcement present in the XR-5 geomembrane.

3. Accidental dropping of a heavy tool with a pointed edge will be considered the most likely scenario for impact damage to the liner. No credit will be taken for the 100 mil geotextile and the 5/16 inch neoprene rubber mat that will be covering the upper surface of the berm.

Analysis

The value of 20 ft-lb/in indicates that a heavy pointed object, dropped from a sufficient height, could fracture the unprotected fabric. For purposes of analysis, a 5 pound crow bar, with 1 inch wide chisel end will be used.

If the crow bar is dropped from a height equal to or greater than 4 feet, impact failure of the berm liner would be expected.

Berm Liner Impact Failure Analysis
(continued)

Conclusions

Based on the above analysis, a procedural requirement will be established prohibiting the use of tools heavier than 1 pound with pointed edges over the berm without a written waiver from the Engineering and Environmental Development Laboratory manager. The issuance of this waiver will include the counseling of the user of the tool on the impact damage risk associated with the use of this tool.

July 27, 1992

Portable Berm Puncture Failure Analysis

Purpose

The purpose of this analysis is to determine under what conditions the Seamans XR-5 8130 geomembrane secondary containment liner could fail due to puncture.

Assumptions

1. The trailer tire pressure is 125 pounds per square inch (psi).

2. The XR-5 8130 geomembrane puncture resistance is 350 pounds (lbs) as determined by procedure Federal Test Method Standard (FTMS) 101B, method 2031. (Technical Data and Specifications for XR-5)

Analysis

A sharp pointed rock lying above or below the geomembrane and driven over by a trailer tire will be considered the most likely mechanism for geomembrane puncture failure.

Assuming that a force of 350 lbs must be applied on the rock to cause puncture, the size (diameter) of the rock necessary to generate this force can be calculated as follows:

$$F = PA \quad (Equation\ 1)$$

where F = the force exerted at the rock point
A = the cross-sectional area of the rock
P = the pressure exerted on the rock by the trailer tire.

F = the puncture force at failure = 350 lbs

P = tire pressure = 125 psi

Rearranging Equation 1,

$$A = \frac{F}{P} = \frac{350\ lbs}{125\ p.s.i.} = 2.8\ square\ inches$$

Portable Berm Puncture Failure Analysis
(continued)

Then the diameter of the rock is

$$D = \sqrt{4\frac{A}{\pi}} = \sqrt{4\frac{2.8}{\pi}} = 1.89\ inches$$

For a safety factor of 15, the applied force, and consequently the rock cross-sectional area, would be reduced by a factor of 15. The maximum diameter of the rock, then, would be

$$D = \sqrt{4\frac{A}{15\pi}} = \sqrt{4\frac{2.8}{15\pi}} = 0.5\ inches$$

This analysis does not take credit for the load distributing properties of the 100 mil geotextile that will be placed above and below the liner, or the 5/16-inch neoprene mat that will be placed over the upper geotextile.

<u>Conclusions</u>

To preclude fabric puncture by a safety factor of 15, all rocks and other extraneous matter larger than 0.5 inch in diameter shall be absent from the surfaces above and below the XR-5 geomembrane liner.

The foundation subgrade upper course shall be composed of aggregate no larger than 0.5 inch minus. The tractor and trailer tires shall be carefully inspected just prior to trailer entry onto the berm floor. Any rocks embedded in the tire treads shall be removed at this time.

July 27, 1992

Compression Failure of Berm Liner

Purpose

The purpose of this analysis is to determine under what conditions the Seamans XR-5 8130 geomembrane secondary containment liner could fail in compression, and the factor of safety for the intended usage.

Assumptions

1. The "Technical Data and Specifications for XR-5" booklet (included in Appendix 4E) does not list the compressive strength of the XR-5 geomembrane. However, the hydrostatic resistance (ASTM D-751, method A) is given as a minimum of 500 pounds per square inch (psi). This indicates that at 500 psi hydrostatic pressure (a compressive stress condition), the geomembrane liner can fail. The value of 500 psi will be taken as the compressive strength of the XR-5 geomembrane.

2. The trailer tire pressure is 125 psi.

Analysis

The maximum compressive loading on the XR-5 geomembrane liner is equal to the trailer tire pressure, that is, 125 psi. Therefore, the geomembrane liner is not expected to fail in compression. The factor of safety is 500 psi divided by 125 psi and is equal to 4.

This analysis does not take credit for the load distributing properties of the 100 mil geotextile or 5/16 inch neoprene mat that will be covering the upper surface of the XR-5 geomembrane.

Conclusions

No geomembrane liner failure due to compressive loading is anticipated. A safety factor of 4 exists.

July 28, 1992

Portable Berm Liner Seam Load Failure Analysis

Purpose

The purpose of this analysis is to calculate the maximum acceleration that a loaded tank trailer can attain before seam failure occurs in the Seaman XR-5 8130 geomembrane secondary containment liner. Limits on trailer acceleration are to be calculated to provide a safety margin for the prevention of seam failure.

Assumptions

1. The maximum shear stress on the geomembrane liner occurs during acceleration during starting. The failure mode is assumed to be shear of the geomembrane fabric seam weld lying under the driven axle.

2. The dead load seam shear is 210 pounds per inch (lbs/in) at 70^{o} F and 105 lbs/in at 160^{o} F as determined using procedure Mil-T-52983E, Para. 4.5.2.19, 2 inch overlap seam. This is reported in the "Technical Data and Specifications for XR-5" by the Seaman Corporation (Appendix 4E).

   The seam shear strength for this analysis is conservatively assumed to be the smaller of these two reported values (105 lbs/inch). Since the area of welded seam for the test specimen is 1-inch wide by 2-inches deep (the overlap), the bonded area is 2 square inches. Therefore the 160^{o} F seam shear strength is equal to 105 lbs per 2 square inches. The seam strength is equal to 52.5 pounds per square inch (psi).

3. The loaded weight of the combined tractor and trailer is 78,000 pounds (lbs).

4. The weight over the driven wheels is 17,000 lbs.

5. The tire pressure is 125 psi gage.

Analysis

1. Contact area (A) of the driven wheels:

   A = 17,000 lbs/125 psi = 136 square inches.

2. Mass (m) of the tractor and trailer:

   m = 78,000 lbs force/32.2 ft/sec^2 = 2422 lbs force - sec^2/ft

Portable Berm Liner Seam Load Failure Analysis (continued)

3. Force needed to accelerate the tractor and trailer to an acceleration (a) is equal to the reaction shear force in the berm (F). $F=m\cdot a$. Then $a=F/m$.

4. Shear at the berm seam (τ) is equal to the reaction force (F) divided by the area of contact (A) of the driven tires. $\tau = F/A$. Then $F=\tau\cdot A$.

5. Combining statements 3 and 4: $a = F/m = \tau\cdot A/m$.

6. Assuming that the maximum shear allowable is 52.5 psi, the maximum allowable acceleration can be calculated as follows:

$$a = \tau\cdot A/m$$
$$= (52.5 \text{ psi})(136 \text{ square inches})/(2422 \text{ lb force-second}^2/\text{foot})$$
$$= 2.9 \text{ feet/second}^2$$

Conclusions

As shown in the analysis in Step 6, shear stress failure occurs in the liner seam at an acceleration of 2.9 feet/second^2. Stopping (deceleration) is of less concern because the stress would be distributed between 5 axles, instead of the 1 axle assumed for acceleration.

Operating procedures will limit truck speed when entering or leaving the berm to 5 miles per hour (mph) maximum. The maximum acceleration or deceleration will be limited to 1 mph per sec. One mph/sec is equivalent to:

$$(1 \text{ mph/sec})\times(5280 \text{ ft/mi})/(3600 \text{ sec/hr}) = 1.5 \text{ ft/sec}^2.$$

The 1.5 ft/sec^2 is below the maximum allowable acceleration of 2.9 ft/sec^2 calculated above, and will provide a safety factor of approximately 2.

This analysis does not take credit for the load distribution that will be provided by the 100 mil geotextile and the 5/16 inch neoprene mat that will cover the upper surface of the geomembrane liner.