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SAWDUST AS LIGHTWEIGHT FILL MATERIAL

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16. Abstract

Unstable embankments and potential slide areas have always been an expensive maintenance problem. The Washington State Highway Department recently developed a unique solution to this problem by utilizing a lightweight waste produce: Sawdust. By removing existing high density fill material and replacing it with Sawdust, they successfully repaired an unstable roadway section reducing the driving weight of this potential slide by 71 percent. The asphalt sealed slope should inhibit deterioration and give the sawdust a life expectancy of at least 15 years as a stable fill. This application of a waste product appears particularly suited to secondary and country roads with unstable soil conditions where economics often prohibit major slide repair solutions.

17. Key Words
Sawdust, Lightweight, Water level, Potential slide, Compaction, Deterioration, Leachates

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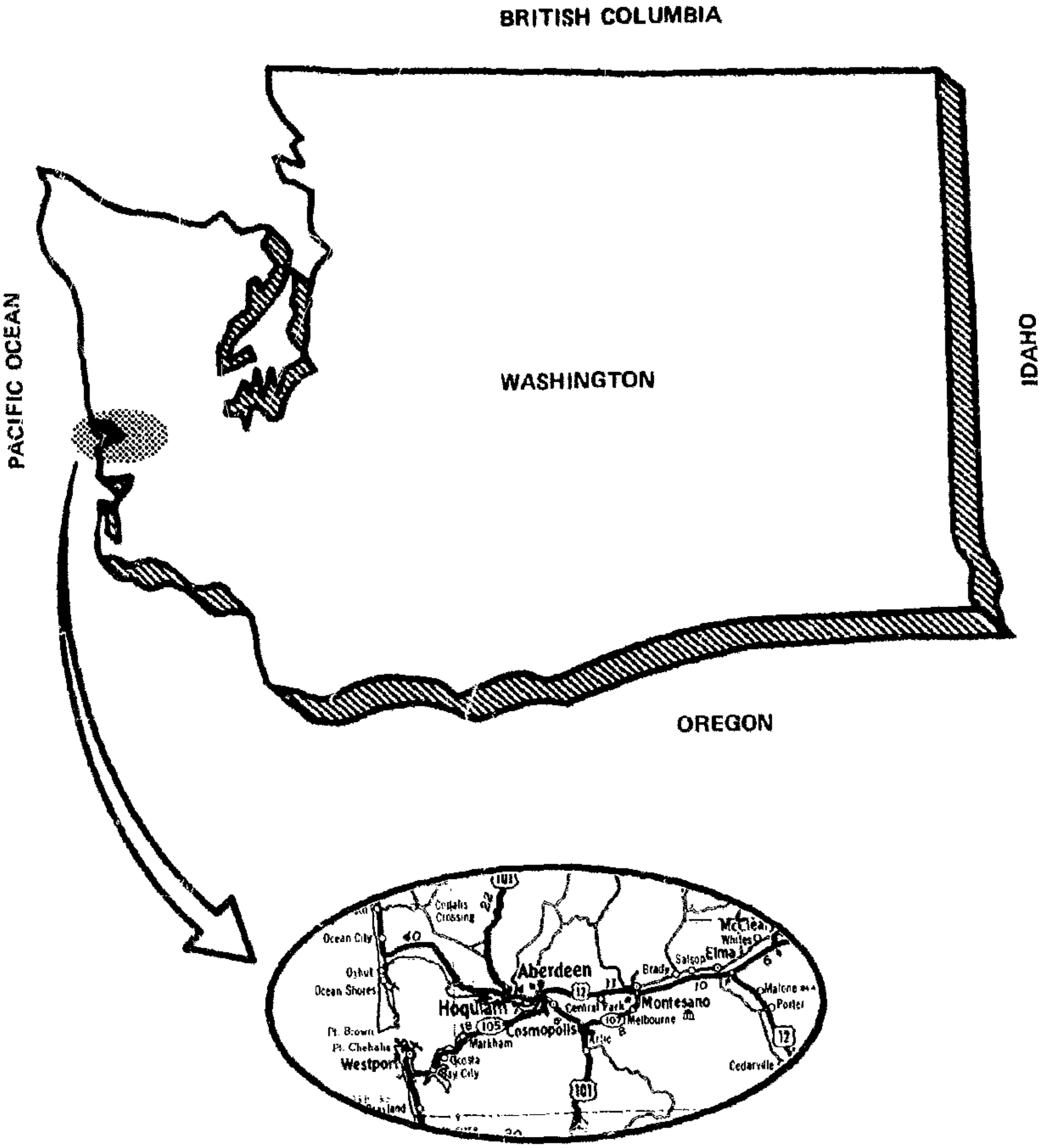


Figure 1 - Vicinity map.

SAWDUST AS LIGHTWEIGHT FILL MATERIAL

Unstable embankments and potential slide areas have always been an expensive maintenance problem. The State of Washington recently developed a unique solution to this problem by utilizing a new kind of fill material that is a lightweight waste product: Sawdust! This lighter weight material will greatly reduce the driving weight of the slide mass and in some cases result in an appreciable unloading of the landslide.

Sawdust, for many years, has been used by timber companies as a lightweight fill material for reclaiming peat and swamplands. The City of Aberdeen, Washington, used sawdust mixed with quarry rock as a base material for many of their city streets. The British Columbia Department of Highways used sawdust to traverse a peat deposit with their Burnaby Freeway. In Norway, sawdust was used instead of conventional embankment fill on a road built over 30 feet of peat where severe settlements had occurred. In all cases, however, the sawdust remained below the water level after settlement and, therefore, was not subject to the decay process.

In March, 1972 a serious landslide occurred on U.S. 101 south of Cosmopolis, Washington which forced closure of the highway. A 200-foot section was lost as a 1 1/2 lanes of this 2 lane highway slid downward 40 feet. A temporary detour was set up while the repair crews went to work. Because of the unusually heavy rainfall this area experiences (125 inches per year), it was decided that an all-weather material must be used.

Here seemed to be the perfect opportunity to try out this relatively new type fill material. Since an all-weather material must be used to get the highway open immediately and since weight is such a critical factor in slides of this nature, sawdust appeared to fit the need of a well sought after repair material. Because this was the first time sawdust was used in a roadway section above a water table, the Washington State Department of Highways developed a "watch and see" attitude.

After a year's exposure, this experiment in slide repair still remained intact without any noticeable signs of deterioration and thus it was decided to again use sawdust as a lightweight fill material in order to reduce the weight and minimize maintenance costs in other areas. Another potential slide area that demanded continual maintenance attention was a highway section just south of the 1972 emergency repair site. At this second site, the roadway crosses just below the upper scarp line of the large slide mass. As sliding occurs and the highway settles, maintenance crews add asphalt surfacing to bring the riding surface back to grade. This additional dense surfacing compounds the problem by loading the slide mass and inviting further movements.

Previous studies show that the present land mass slides are a result of water susceptible clay shales moving on tilted sedimentary bedding surfaces lubricated by water. Some of the costly and annoying slide movements could be partially stabilized by improving existing drainage patterns with horizontal drains, and if some of the weight of the slide mass could be removed the total effect might be to stop the sliding entirely.

The lightweight fill construction was included in a Washington State contract for repairing and resurfacing of State Route 101 from Cosmopolis to State Route 107. This entire highway was closed to traffic for one week (July 9-14) to allow complete excavation and backfill of the lightweight fill section. The contractor, Interstate Asphalt of Aberdeen, excavated the 250-foot roadway section to a depth of 10 feet. The asphalt pavement section, layered from years of maintenance overlays, was observed during removal, to be 4-feet thick.

As the contractor was excavating the roadway section, Weyerhaeuser Timber Company delivered sawdust, at no charge, to a stockpiled site at the rate of 60 cubic yards per hour. At the end of the second day of hauling, 70 percent of the required 3,650 cubic yards of sawdust were at the construction site. On the third and fourth days, as the stockpiled material was being placed, additional trucks end-dumped the sawdust directly into the excavated site.

The only specification requirement for the lightweight material was that it be 100 percent wood fibers with no particle exceeding 6 inches in its maximum dimension. The sawdust was of three varieties: hog fuel, planer chips, and bark chips. The planer chips and bark chips are both by-products of the Weyerhaeuser sawmill. Hog fuel is pulverized bark that high pressure water has stripped off logs from the Weyerhaeuser pulp mill. The logs are mainly Spruce, Alder, Hemlock and Fir.

The lightweight material was placed in 1-foot lifts which were compacted by the action of construction equipment driving over it in a predetermined pattern. No water was required during placement and only minor effort was needed to attain maximum compaction. Because preliminary observations indicated the moisture density curve very flat over most of the spectrum of the curve, no field compaction control tests were taken. As the material was compacted [illegible] appreared quite resilient, that is, it would deflect 2 to 3 inches under the load of a front-end loader and then spring back when the load was released. However, as each additional lift was applied, the magnitude of deflection or resiliency under the compacting load remained constant: 2 to 3 inches.

To keep air from deteriorating the sawdust, an emulsified asphalt sealer was applied on the 1:1 fill slope with each lift of sawdust. The sealer was sprayed over a 2-foot width at a rate of 1.3 gallons per square yard. Laborers then mixed the wood fibers with the heated asphalt using pitchforks along the slope to the required 1-foot sealer widths. A small tractor then compacted the slope and spread more sawdust over it to repeat the process. The seal was designed to be somewhat permeable and allow trapped water to escape, thus reducing any hydrostatic pressures.

It appears the 125-inch annual rainfall has a dramatic affect on the water table which, in turn, has a significant affect on the embankment stability of the highway section. Slope stability calculations indicate that if the water table reaches 10-feet below the as-constructed pavement surface, sliding will occur and after years of maintenance repair overlays the water table need only reach 15-feet below the pavement surface to affect sliding. Reconstructing the highway section with a 10-foot layer of sawdust places the factor of safety of the embankment well above the sliding break point of 1.0 (see Firgure 18).

The problem of deterioration of the fill material is a major concern, but sawdust piles over 20 years old have been observed in the Western part of Washington to be still intact. Apparently the outer layer of the sawdust pile deteriorates and forms a "crust" that keeps air from reaching the interior of the pile.

In a similar manner, the asphalt-sealed slope will act as a "crust" that inhibits air from causing deterioration, and should give the material a life expectancy of at least 14 to 15 years as a stable fill. Norman D. Lea and Associates, who did some of the research in Canada's use of sawdust as a fill material, estimates sawdust above a water table to last at least 15 years.

The possible effects of leachates on the environment is an important consideration. If sawdust is buried too close to a flowing stream, removal of the nutritive elements of water, namely oxygen, will cause a pollution that is very detrimental to underwater life. Thus an impermeable material must be used to seal off the harmful effects of sawdust when these conditions demand it.

A one cubic foot bucket was used to informally determine the density of the sawdust material. One cubic foot in an uncompacted state weighted 23.7 pounds. When compacted in three layers by techniques similar to the actual constructed compaction, the material weighed 36.3 pounds. If the average unit weight of the excavated material is assumed to be 140 pounds per cubic foot, the excavated driving weight approximated 6,899 tons. The weight of the sawdust material put in its place is 1,971 tons. The comparison of the two weights leaves no doubt as to the distinct advantage of sawdust in fill areas: a reduction of 4,928 tons or 71 percent in the driving weight of a potential slide!

The laboratory moisture-density curve of hog fuel is very flat over most of the spectrum of the curve. This was to be expected and was the main reason compaction was not a critical factor in the placement of the fill material. The optimum dry density was 21.3 pounds per cubic foot at a moisture content of 175.0 percent. However, reducing the moisture content to 150.0 percent changes the density to 21.1 pounds per cubic foot, hardly a measureable change. Laboratory test results of the triaxial tests on the hog fuel established the angle of internal friction at 31° with a cohesion of 0 pounds per square inch. The permeability of the material was 1.0×10^{-3} cm/sec which is a reasonably good drainage property.

Class B gravel base was placed directly on top of the compacted sawdust in two 6-inch lifts. The material was graded level with conventional equipment and then compacted with a steel-wheel roller in a standard construction method. The base material behaved as if it were on a conventional fill material and showed no signs of excessive deflection under the roller load. It appears the load of the roller transm[illegible] through the base is distributed over a broader area of sawdust than a conventional fill distributes a load. The fibrous intertwining of the wood particles tend to disperse the load horizonally and thus improve the stability of the base material.

The remainder of the pavement section was placed by conventional means with a 0.5-foot asphalt treated base placed in two lifts. A box spreader was used to place the material and a steel-wheel roller compacted each lift. The 0.15-foot Class B surfacing was placed on top of the ATB for the wearing surface.

All totaled 3,650 cubic yards of sawdust were placed at a unit bid price of $2 per cubic yard. This bid item was full compensation for placing and compacting the fill and asphalt sealing the slope. Because the sawdust is a waste product, the material was delivered to the construction site at no charge from Weyerhaeuser. Excavation of the lightweight fill section was as "Roadway Excavation Including Haul" at a bid price of $2.50 per cubic yard and, of course, the base and surfacing were paid at their own unit costs.

In conclusion the following points should be emphasized:

1. Sawdust is a very workable fill material.
2. Sawdust can reduce the driving weight of a potential slide by as much as 71 percent.
3. The fibrous intertwining of sawdust particles tend to distribute loads in a more lateral direction.
4. Sawdust needs only the compaction of construction equipment driving over it.
5. All indications are sawdust fills can sustain roadway sections for 15 years or longer.
6. The use of sawdust above the water table should be based on economics and availability, comparing the cost of rehabilitation after the lifetime of the material with alternate solutions.

Figure 2 - In March 1972 State Route 101 was closed because of this major slide.

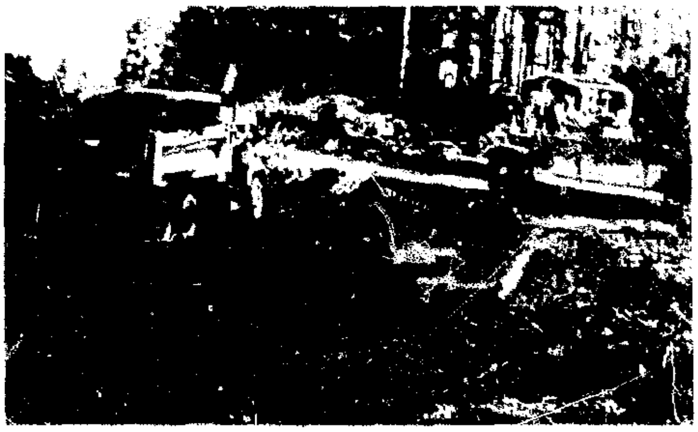


Figure 3 - Sawdust was the all-weather material selected for the emergency repair of this highway.

Figure 4 - The base and pavement section was placed directly on top of the sawdust.

Figure 5 - Preconstruction view of lightweight fill section. Notice crack line indicating sliding.

Figure 6 - Backhoe and tractor excavating at Station 143+00.

Figure 7 - Layered pavement sections are proof of years of maintenance overlays. Up to 4-feet thick on this project.

Figure 8 - As the stockpiled material was being placed additional trucks end-dumped the sawdust into the excavated site.

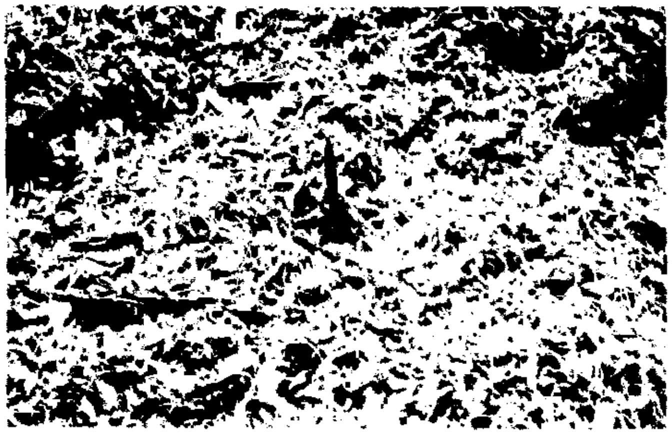


Figure 9 - Planer chips from Weyerhaeuser sawmill.

Figure 10 - Hog fuel from Weyerhaeuser pulp mill.

Figure 11 - Barkchips from Weyerhaeuser sawmill.

Specifications called for 100 percent wood fiber with no particle exceeding 6 inches in its maximum dimension.

Figure 12 - Sawdust was placed in 1-foot lifts and was compacted with construction equipment in a predetermined pattern.

Figure 13 - On the fill slope, an emulsified asphalt sealer was applied with each lift of sawdust while in the background laborers hand mix the wood fibers with the heated asphalt.

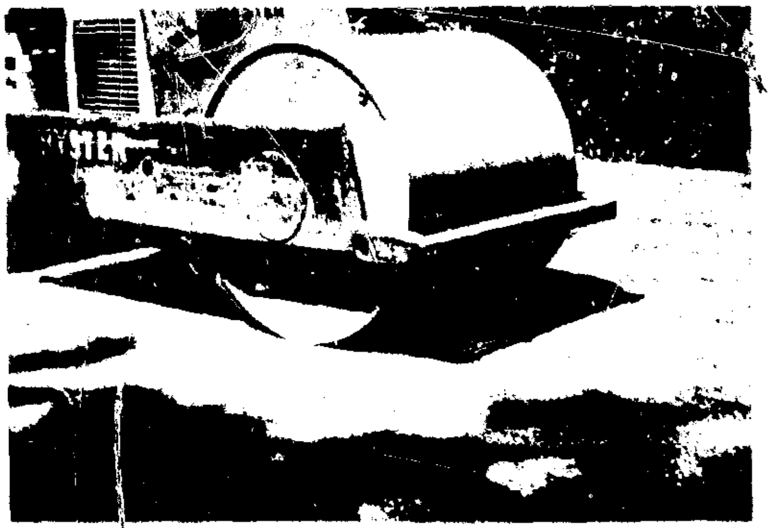


Figure 14 - Class B gravel base was placed directly on top of the compacted sawdust in two 6-inch lifts. This closeup of the roller shows that the amount of deflection is not discernable through the camera's eye.

Figure 15 - Highway open to traffic. Within a few months natural revegetation of sawdust fill had occurred.

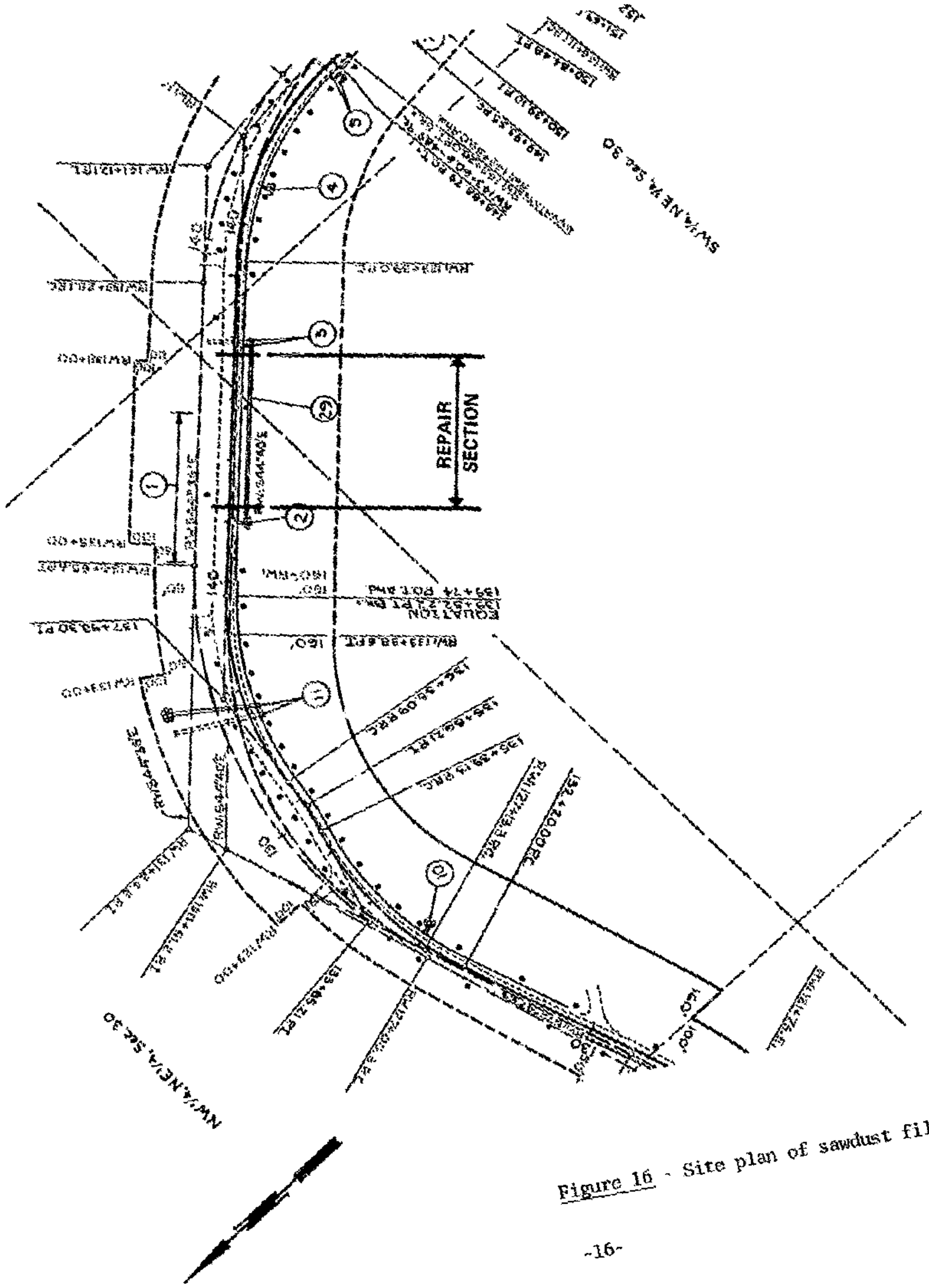
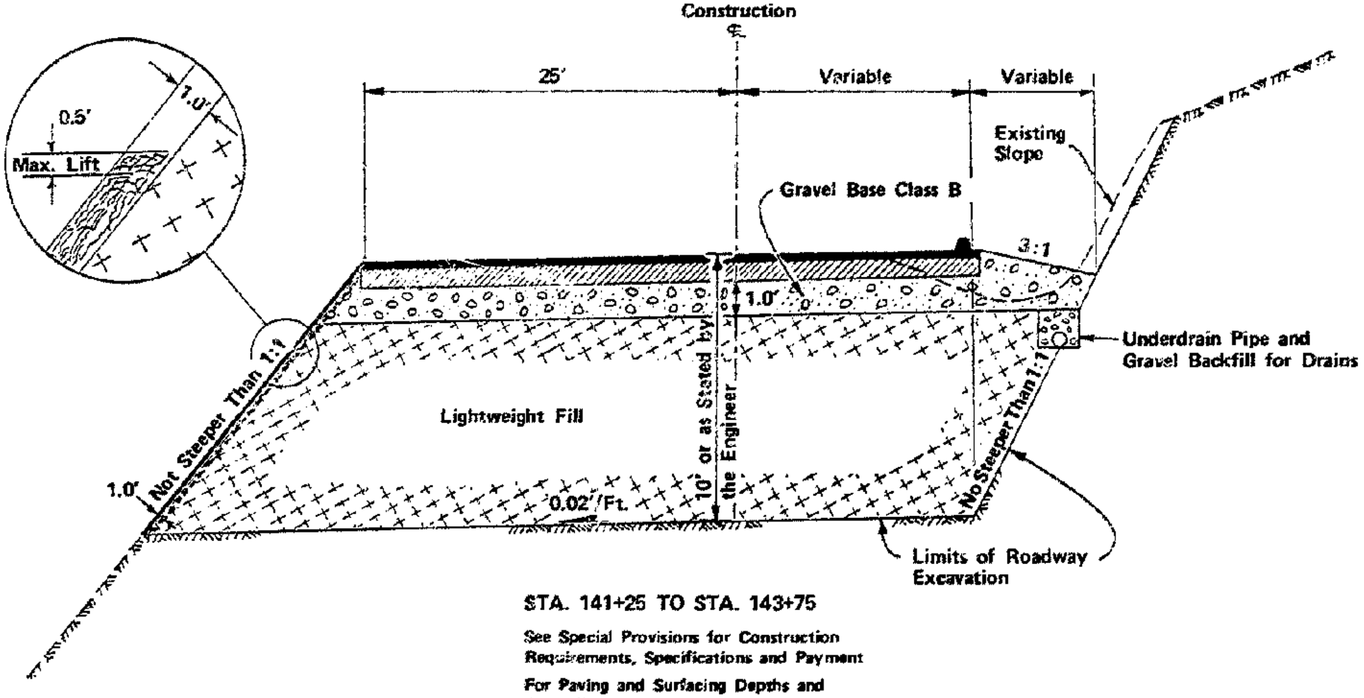


Figure 16 - Site plan of sawdust fill section.

Asphalt Seal of Slope

Build outer one foot of slope face by hand, mixing wood fiber with heated emulsified asphalt undiluted to provide an impervious seal satisfactory to the Engineer. Each lift shall be mixed to a maximum depth of 0.5' as shown.



STA. 141+25 TO STA. 143+75

See Special Provisions for Construction Requirements, Specifications and Payment

For Paving and Surfacing Depths and Other Details, See Roadway Section C.

Figure 17 - Excavation and lightweight fill detail.

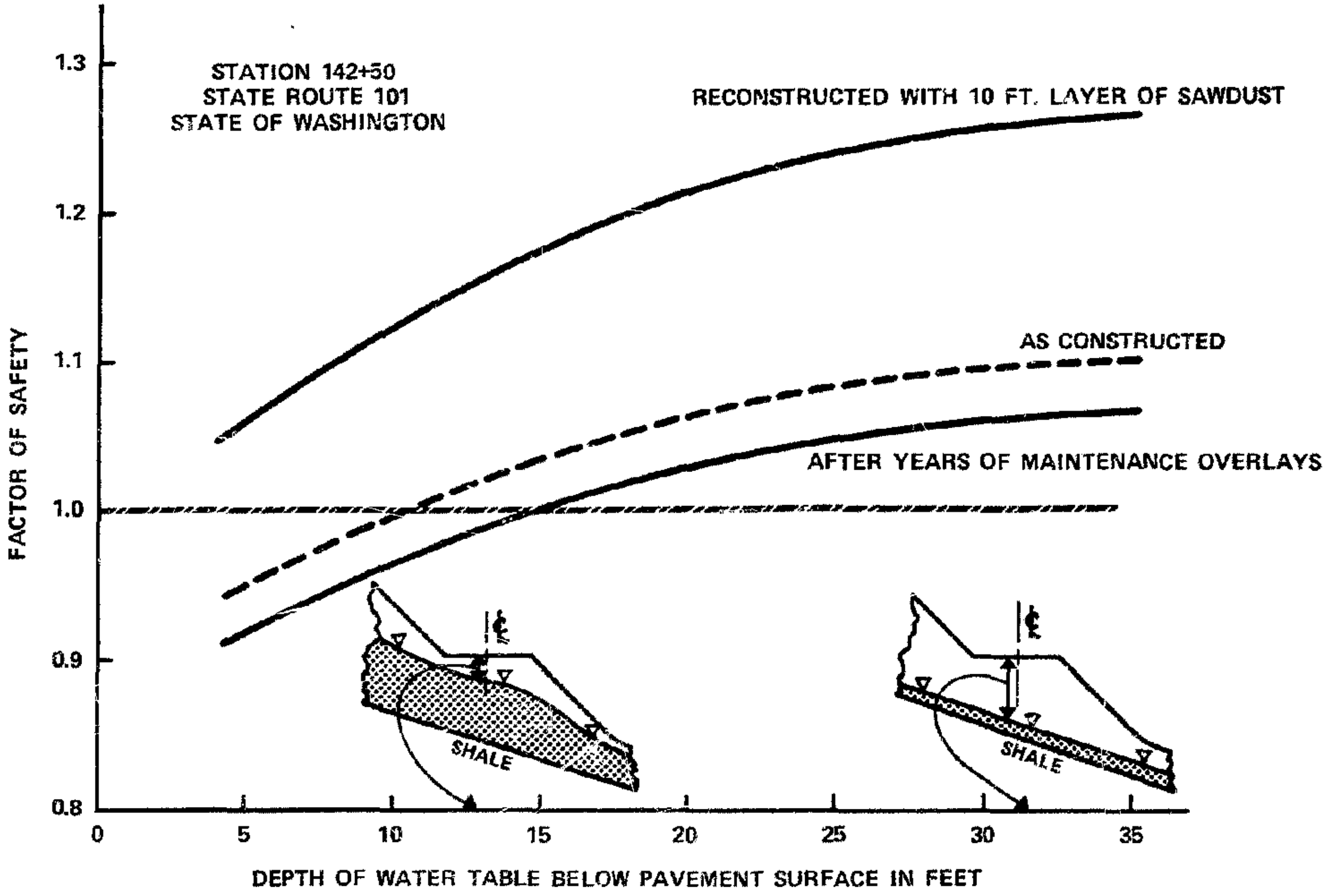


Figure 18 - Water table's influence on embankment stability.

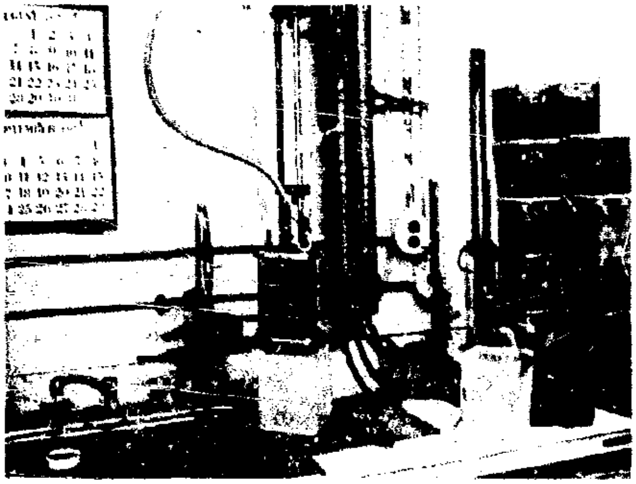


Figure 19 - Hog fuel undergoing triaxial stresses.

Figure 20 - Hog fuel triaxial specimen

PROJECT
PROJECT NO.
DATE TESTED
TESTED BY
CHECKED BY

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION EIGHT
MATERIALS BRANCH LABORATORY
FHB- 85 (10-69) 5

LABORATORY CONTROL NUMBER
Andy Research
FIELD SAMPLE NO.

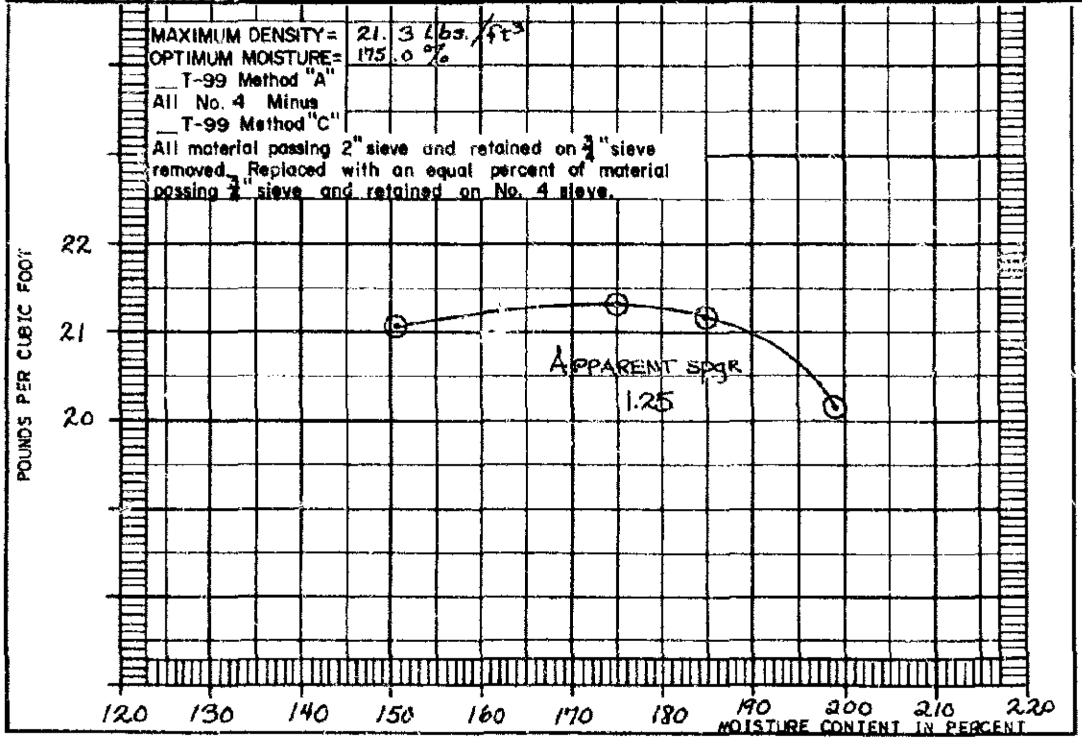
MOISTURE DENSITY RELATIONS AASHO T-99-57 & T180-57

TYPE OF TEST MOLD VOLUME NO. OF LAYERS NO. OF BLOWS

DETERMINATION NO.	1	2	3	4	5	6	7
VOLUME OF MOLD CU. FT.							
WT. MOLD LBS.							
WT. MOLD + COMPACTED SOIL GRAMS	886.7	914.4	911.2	797.8			
WT. MOLD + COMPACTED SOIL LBS.							
WT. COMPACTED SOIL LBS							
MOISTURE DETERMINATION							
CONTAINER NO.	30	1	8	40			
WT. CONTAINER + WT. SOIL	861.6	912.8	905.8	797.1			
WT. CONTAINER + DRY SOIL	313.0	319.8	304.0	318.1			
WT. WATER							
WT. CONTAINER							
WT. DRY SOIL							
MOISTURE CONTENT %	175.3	185.4	198.0	150.6			
WET DENSITY LBS/CU. FT.	58.6	60.5	60.3	52.8			
DRY DENSITY LBS/CU. FT.	21.3	21.2	20.2	21.1			

MAXIMUM DENSITY LBS/CU. FT.
OPTIMUM MOISTURE %
PCT FIELD COMPACTION

FOR COMPUTER USE ONLY
ACCOUNTING COST NO. T-99
TLBA DATE
MALL DATE



MAXIMUM DENSITY = 21.3 Lbs./ft³
OPTIMUM MOISTURE = 175.0 %
__T-99 Method "A"
All No. 4 Minus
__T-99 Method "C"
All material passing 2" sieve and retained on ¾" sieve removed. Replaced with an equal percent of material passing ¾" sieve and retained on No. 4 sieve.

Figure 21 - Hog fuel moisture-density curve.

LATERAL PRESSURE PSI	10	20	30	
$Y_1 - Y_3$ A	20.11	42.24	17.37	
Y_3 B	10	20	30	
Y_1 A+B	30.11	62.24	47.37	
RADIUS $1/2\ (Y_1 - Y_3)$	10.06	21.12	8.69	
CENTER $Y_3 + 1/2 (Y_1 - Y_3)$	20.06	41.12	38.69	

Shear Strength	% Strain	Lateral Pressure	Dry Density lb/ft^3	Moisture Content
20.11	20.32	10	18.3	231.3
42.24	20.32	20	23.1	161.6
17.37	20.37	30	18.1	234.5

Angle of internal friction = 31°

Cohesion = 0 P.S.I.

Permeability = 1.0 x 10-3 cm/sec.

Figure 22 - Triaxial test data for Mohr's diagram

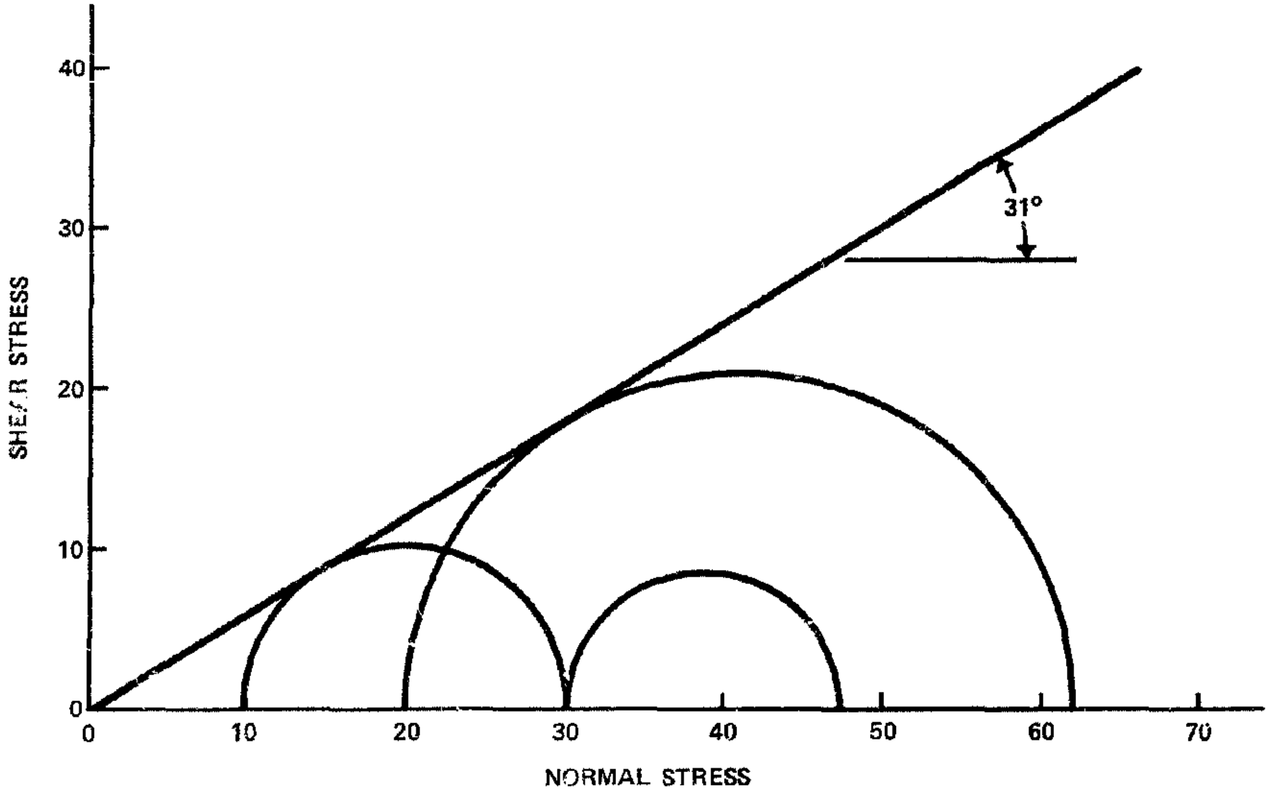


Figure 23 - Mohr's diagram of hog fuel.

LATERAL PRESSURE PSI	10	20	30	
$Y_1 - Y_3$ A	20.11	42.24	17.37	
Y_3 B	10	20	30	
Y_1 A+B	30.11	62.24	47.37	
RADIUS 1/2 $(Y_1 - Y_3)$	10.06	21.12	8.69	
CENTER $Y_3 + 1/2(Y_1 - Y_3)$	20.06	41.12	38.69	

Shear Strength	% Strain	Lateral Pressure	Dry Density lb/ft^3	Moisture Content
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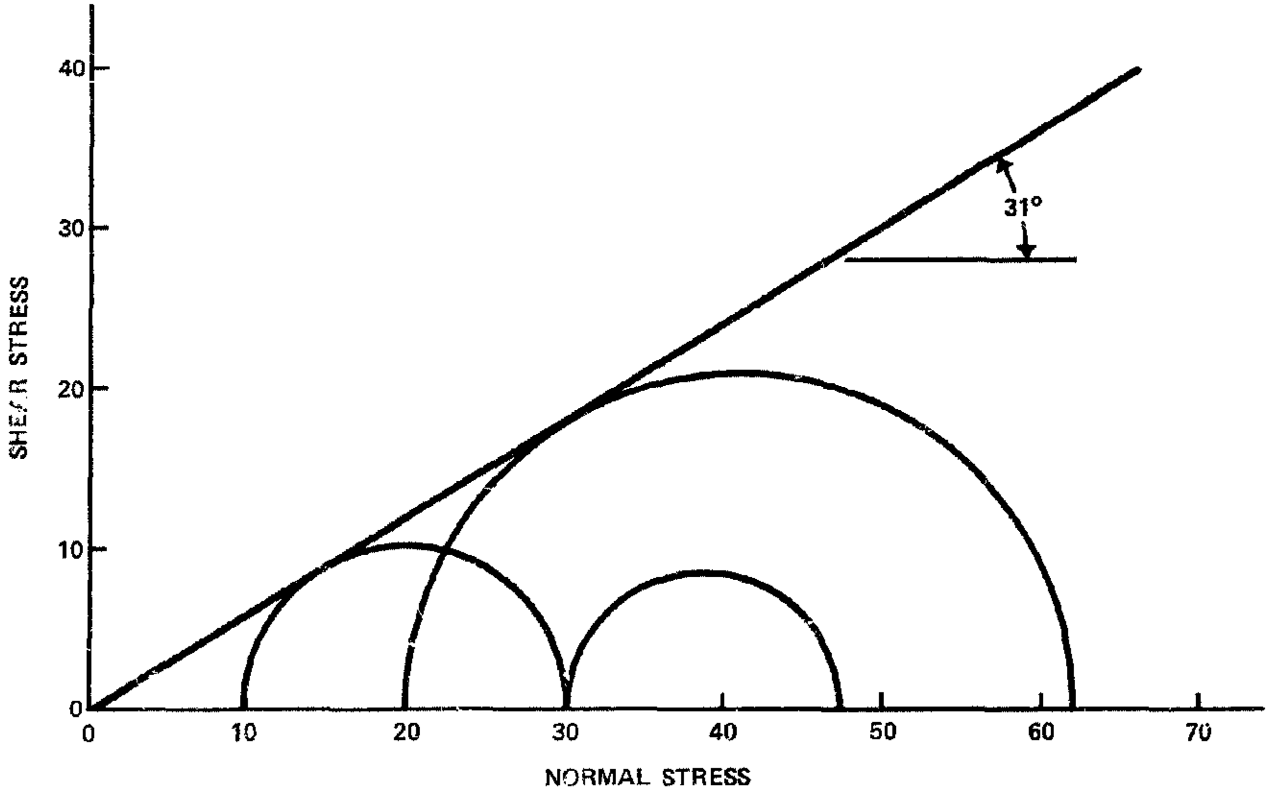

Figure 23 - Mohr's diagram of hog fuel.