Long-Term Performance of Wood Fiber Fills

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The results of a research project to determine the long-term performance of 21 wood fiber embankments, constructed by the Washington State Department of Transportation (WSDOT) beginning in 1972, are presented. The wood fiber was placed above and below the water table and in fluctuating groundwater conditions. At the time the embankments were constructed, there was concern that they would only provide a 15- to 20-year service life. Performance of existing wood fiber fills was evaluated on the basis of the quality of the wood fiber material, quality of the effluent, and condition of the pavement. A visual classification system rating the wood fiber from fresh to completely decomposed was developed and used to establish a criterion from which all wood fiber material could be rated. Visual examination and laboratory tests were used as determining aspects for the effluent quality. The WSDOT pavement management system was used to evaluate relative pavement performance. Site descriptions giving specific characteristics and properties of inventoried fills are presented. An analysis of this information was done to determine the effectiveness of the fills. Over half the wood fiber samples were found to be nearly fresh or fresh after 15 years, and none after 5 to more than 19 years was found to be completely decomposed. In all but one case the pavement quality over the wood fiber fills surpassed the entire comparative milepost section rating, indicating that the wood fill performance exceeded that of the adjoining area. Generally, the surface water in the vicinity of the wood fiber was found to be clean and pure, indicating no adverse impact of effluent. Given the above findings, embankments constructed of wood fiber were found to perform well over an almost 20-year period. Service life of more than 50 years can be expected of wood fiber fills.

In 1972, the first wood fiber fill was constructed on the Washington State highway system as an emergency repair on SR-101 to repair a landslide that had destroyed a section of roadway. Wood fiber was selected for two primary reasons. The first had to do with constructability as an all-weather material. Rain does not affect the placement and compaction of the embankment. Second, a lightweight fill was used to lessen the driving forces of the unstable ground that was causing the instability. In addition, wood fiber material was readily available at low cost and could be obtained on short notice from local sawmills. Historically, timber areas such as the cities of Raymond, Aberdeen, and Hoquiam along the Washington State coast have used wood fiber material to construct non-engineered fills over very weak marine sediments.

The primary disadvantages of wood fiber are leachate and short-term settlement of the wood fiber. Methods used to control leachate are (a) reduce the water flow into the wood, control the type of wood fiber, or (b) entrap the leachate. Controlling the effects of wood fiber compressibility involves surcharging or delay periods or both, to allow settlement to take place before the pavement section is placed.

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Another concern is the possibility of spontaneous combustion. Known conditions such as warm, rainy weather and large-size piles of sawdust have been cited as possible reasons behind spontaneous ignition (*1*). It is believed that spontaneous combustion occurs because of a combination of mechanisms. Biological reactions initially raise the temperature to a level at which physiochemical processes take over. From this point the physiochemical reactions continue until ignition occurs (*2*). Suggested precautions include initially restricting height of wood fiber to 5 m and reducing ventilation or air to the wood fiber.

A long-standing concern has been the durability and life of wood fiber as an engineering material for use in highway embankments. Therefore a research project was undertaken to examine existing wood fiber fills to determine their long-term performance.

GENERAL

The Washington State Department of Transportation (WSDOT) had two critical concerns about the use of wood fiber as embankment material for permanent roadways. First, Would wood fiber resist decay and rotting sufficiently to provide an embankment life of more than 75 years? Some estimates gave wood fiber a design life of only 15 to 30 years. Old investigations by WDOT, reportedly 70 years old, of sawdust piles found a decomposed outer zone 0.61 to 0.91 m thick with an inner core in which no decomposition had taken place.

The second critical concern was the risk of spontaneous combustion, which could cause the wood fiber fill to catch fire. Biological oxidation increases the fiber temperature to approximately 75°C, followed by a chemical reaction that increases the temperature to ignition. Controlling the fill temperature and reducing the availability of oxygen are methods of preventing a fire (*1*).

A number of terms are used to describe the wood fill material. In this paper, wood fiber is used as a generic term. The actual fill material may be hog fuel, sawdust, or woodwaste. Hog fuel is defined as the ground wood and bark that is burned in a steam boiler. The small particles of wood generated when logs are cut into lumber are classified as sawdust. Woodwaste is made of sawdust, hog fuel, bark chips, or a combination of the three. This material is generated from handling the logs at the saw mill.

Since the first WSDOT fill, 20 additional fills were constructed between 1973 and 1986. They were all built in areas of western Washington with high to moderate rainfall. The average age of these fills is 15 years.

The goal of this research was to evaluate the general long-term performance of existing wood fiber fills. To evaluate the performance of the fills, the investigation focused on the quality of the wood fiber material and the leachate and the performance of the pavement section.

An evaluation of the quality of the wood fiber fills was done by classifying the fill material primarily by observation, because no testing method is presently available to measure the degree of rotting. No existing classification system was identified in the literature. A system was developed, as part of this project, using five classifications to rate the amount of decomposition. The classification criterion developed to rate the wood fiber's current condition was based on four categories. These categories followed a progressive description from fresh to completely decomposed. "General Appearance" was used to describe the wood fiber on a macroscale, compared with the "appearance of decay" that considered the microscale.

Visual observations of the wood fiber's grain quality were the basis for determining the general appearance rating. Appearance of decay used descriptors indicating the odor of the wood, the amount of decomposition ranging from fresh to completely decomposed, and in-depth visual observations such as the color and amount of disintegration. Of these four descriptors, the primary emphasis was on the amount of disintegration. However, not all of the descriptors may apply to a specific sample of wood fiber. If this situation arose, the remaining descriptors determined the quality of the wood fiber.

Wood fiber's material properties were determined by its strength and stiffness. Selected pieces of wood fiber that were not saturated or dry, but were wet to touch, and approximately fit the dimensions 5.1 × 1.3 × 1.0 cm were used to test material properties by applying finger force. Some samples may not have pieces fulfilling the moisture content and dimension requirements. If this situation occurred, the remaining criteria were used to determine the wood fiber's quality.

Because no previous classification system existed before this research, there is no information stating the freshness of the wood fiber at time of original construction. The given ratings can only indicate the quality of wood fiber at the time of this field work.

The second performance measure is a determination of the quality of leachate. When water interacts with the wood fiber an extraction of the wood occurs and a solution is formed. This solution is known as leachate or effluent and is an environmental concern when near streams or surface water. Characteristics of this aqueous solution composed of extractions of cellulose and lignin include high oxygen demand, low pH, dark color, and foul odor. Methods of controlling leachate are reducing water flow through the fill, treating the effluent that exits the fill, and controlling the type of material placed in fill (*3*).

Pavement performance was evaluated by comparing the existing condition of the pavement with the previous WSDOT pavement management system rating. Adjacent areas without wood fiber fills were compared to evaluate relative performance. The pavement rating system considered the following four major features when developing a rating: (a) alligator, longitudinal, and transverse cracking; (b) patching; (c) raveling; and (d) flushing. Alligator cracking was further defined by hairline, spalling, and pumping. Depending on the width of a crack or the length of a patch, or both, points were subtracted from 100 to give an overall score of the roadway section.

The pavement rating provided in this research is a representation of the pavement directly above the lightweight fill. Generally, this is a small percentage of the milepost section that receives a WSDOT Pavement Management system rating. Table 1 gives the research rating for the fill section followed by the comparative WSDOT rating for the highway segment in parentheses. It should be noted that maintenance patch areas can cause local variances from the average roadway rating.

FIELD STUDIES

Each of the 21 existing sites having wood fiber fill was reviewed in the field to evaluate the long-term performance of the wood fiber. Table 2 gives a listing of the sites, year built, application, and size of fill. The wood classification criteria shown in Table 3 were used in the field to evaluate the overall quality of the wood fiber. Pavement ratings were made following the established criteria of the WSDOT pavement management system.

Temperature readings were taken to determine whether they were an indication of decomposition. Generally it was found that temperature indicated that biological processes were still active but not necessarily indicative of the quality of the wood fiber.

BOD levels were measured at 11 of 21 sites. They were useful as a site-specific reference to adjacent water not affected. Because it was summer when samples were taken, there was difficulty locating water for the samples. Therefore some sites were not tested. In addition, there are some limitations on use of BOD test results because a national standard does not exist for the condition of a given site, because each body of water must be evaluated individually to determine its allowable BOD level. Therefore the actual BOD values for the sites tested are not used for analysis but are useful for further reference and comparative site-specific studies.

The results of the field work are given in Table 1. Generally the wood fiber was found to be in good to excellent condition with most ratings from 1 to 3. Four sites had samples that exhibited Class 4 ratings. At the Kelso site it was only the wood fiber immediately under the topsoil cover that had the low rating. Below that, wood fiber was fresh with a Class 1 rating. Two of the Cosmopolis Hill sites built in 1976, MP 71.9 and 77.27, showed signs of decomposition. It is not documented but is well known within WSDOT that during that time it was preferred to have the wood fiber fills built of aged wood fiber. This was to reduce the potential for spontaneous combustion possibly by reducing the active biological processes. Records of which fills were built of the aged wood fiber were not kept. The fourth site, at Victor on SR-302, was built with fresh wood fiber. The advanced aging at this

TABLE 1 Wood Fiber Project Summary

SR	PROJECT	DEPTH (m)	CLASS	TEMP C	DENSITY * kN/m3	PAVEMENT RATING SECTION(SEGMENT)
2	Skykomish Wye	0.52	2	14.8	8.1	80 (68)
		soil		23.4		
5	Kelso Frontage Rd	0.82	4	21.9		99 (NA)
		2.0	1	17.4		
		soil		18.9		
12	Washout at Aberdeen	0.67	2	21.1		100 (100)
		soil		22.0		
12	Baila Dip	0.82	2	17.2		none
	site 1	new	1	21.7		
		0.46	3			
	site 2	0.92	2			
		air		16.7		
16	Burley Olalla Rd.	0.76	1	21.7	4.6	94 (89)
		1.3	1	--		
		soil		15.6		
101	Port Dock to Fowler	0.82	2	16.7	5.5	RT 80 (46)
		1.2	2	17.4		LT 80 (65)
		soil		16.6		
101	Rock Crusher Hill	0.73	3	17.8		92 (65)
		0.98	2	16.7		
		soil		16.1		
101	Cosmopolis Hill					
	MP 71.77	1.5	3	28.9	9.7	100 (46)
		rocks		25.5		
	MP 71.9	0.55	4	23.5	5.2	84 (46)
		1.2	2	23.2		
		soil		18.3		
	MP 77.27	0.40	4	24.1	6.0	84 (46)
		1.0	4	24.7		
		soil		22.3		
	MP 77.35	#1 0.15	3	none		88 (46)
		0.76	2			
		#2 0.15	3			
		0.98	2			
	MP 77.61	0.92	3	none		88 (46)
	MP 77.97	0.98	1	19.3		90 (46)
		soil		20.4		
101	Emergency Repair	0.64	2	28.4		92 (60)
		0.92	2	29.6		
		soil		22.4		
101	Cosmopolis to SR 107	0.76	3	19.4		90 (60)
		soil		18.7		
101	SR 107 to Cosmopolis	0.92	1	none		92 (44)
		1.2	1			
109	West Hoquiam	0.82	2	22.9	6.0	100 (100)
		1.1	2	22.5		
		1.4	2	21.1		
		soil		18.8		
109	Bob Wain Hill					99 (100)

(continued on next page)

TABLE 1 (continued)

SR	PROJECT	DEPTH (m)	CLASS	TEMP C	DENSITY * kN/m3	PAVEMENT RATING SECTION(SEGMENT)
109	Pt. Grenville	0.4	1	15.8	3.2	none
		soil		15.9		
302	Victor Cutoff Rd.	0.46	4	none		none
		0.92	3			
505	Cedar Creek Slide	0.46	2	22.2		none
		1.07	2	26.7		
		soil		17.8		

* In-place, wet density
1m = 3.28ft, C = (F-32)/1.8, 1N = 0.2251b

site may be due to exposure of the wood fiber. Most of the wood fiber was placed in an excavated cavity created by removing landslide debris. The upper portion was sealed from the air with an asphalt emulsion. Subsequently the landslide continued to move. This exposed the upper portion of the wood fiber allowing access to air. This may account for the advanced aging, but this is not certain.

Temperature variations did not prove to be particularly significant in that temperature could not be correlated to wood aging. It was, however, interesting to find wood fiber fills of 16 years having elevated temperatures in the wood fiber, indicating a relatively high level of biological activity. The implication was that the decay process is still active.

The variance of in-place unit weights was significant. The moist unit weights varied from 5.2 to 8.3 kN/m^3. The compactive effort specifications for all the fills was similar. Required compaction was specified as two passes with a D8-Caterpillar tractor or equivalent on a maximum 1-ft lift.

Pavement ratings were generally excellent in the wood fiber areas. All pavements are flexible asphalt concrete. It appears that the combination of a 0.6-m flexible pavement section with the elastic wood fiber fill worked well as a system.

CONCLUSION

The research conducted during this study verified the generally excellent performance of wood fiber used in engineered fills for up to 20 years. It was found that some sites had significant degradation of the wood fiber. Questions about the quality of the wood fiber initially placed arose. Although not formally documented it is known that particularly during the 1970s the use of aged wood fiber was encouraged to lessen the danger of fire.

To evaluate the long-term performance of wood fiber, the site locations were separated into three categories, ranging from more than 15, 10 to 15, and 5 to 10 years old. The first range, or oldest, included three areas that remained nearly fresh. Although the wood fiber at Baila Dip was replaced with fresh wood fiber material, the old wood fiber remained intact with only some degradation. Although the remaining two sites had wood fiber exposed on the side slope face, the material performed well with minimal amount of decomposition in one area and a little more in the other.

The middle category ranged from fresh to almost decomposed. The classification scores varied between site locations

TABLE 2 Wood Fiber Project Inventory

SR	PROJECT	DATE	APPLICATION	WOOD DEPTH(m)	FIBRE LENGTH (m)
002	SKYKOMISH WYE	1980	Soft soils	3.35	244
005	KELSO FRONTAGE ROAD	1977	Soft soils	9.15	392
012	WASHOUT AT ABERDEEN	1976	Landslide correction	6.10	30.5
012	BAILA DIP	1974	Landslide correction	4.57	94.6
016	BURLEY OLALLA ROAD	1976	Soft soils	6.10	275
101	PORT DOCK TO FOWLER	1976	Soft soils	6.10	290
101	COSMOPOLIS HILL MP 71.77	1976	Landslide correction	2.55	27
101	COSMOPOLIS HILL MP 71.90	1976	Landslide correction	2.55	40.3
101	ROCK CRUSHER HILL	1978	Landslide correction	7.62	110
101	COSMOPOLIS HILL MP 77.27	1976	Landslide correction	5.60	36.6
101	COSMOPOLIS HILL MP 77.35	1976	Landslide correction	4.07	83.0
101	COSMOPOLIS HILL MP 77.61	1976	Landslide correction	2.55	54.3
191	COSMOPOLIS HILL MP 77.97	1976	Landslide correction	2.55	79.3
101	COSMOPOLIS EMERGENCY REPAIR	1972	Landslide correction		
101	COSMOPOLIS TO SR 107	1973	Landslide correction	3.05	76.3
101	SR 107 TO COSMOPOLIS	1982	Landslide correction	3.05	21.4
109	WEST HOQUIAM	1986	Soft soils	10.7	247
109	BOB WAIN HILL	1979	Soft soils	3.05	191
109	PT. GRENVILLE	1976	Landslide correction	1.22	275
302	VICTOR CUTOFF RD.	1978	Landslide correction	3.05	137
505	CEDAR CREEK SLIDE	1982	Landslide correction	4.57	153

TABLE 3 WSDOT Wood Fiber Classification Criteria

CLASS	GENERAL APPEARANCE	APPEARANCE OF DECAYa,b	PARTICLE STRENGTH (BREAKING)c,d	PARTICLE STIFFNESS (BENDING CAPACITY)d
1	WOODLIKE, SHARPLY DEFINED GRAININESS	FRESH: SHARP COLOR, FRESH WOODY SMELL, NO DISINTEGRATION	CANNOT BE BROKEN WITH FINGERS	RETAINS ITS SHAPE WITH FORCE
2	3/4 MATERIAL IS WOODLIKE, WELL DEFINED GRAININESS	INITIAL SIGNS OF DECOMPOSITION: DISTINCT COLOR, DEFINITE WOOD SMELL, VERY LITTLE DISINTEGRATION OF WOOD FIBRES	VERY DIFFICULT TO BREAK WITH FINGERS	EASILY RETURNS TO ORIGINAL SHAPE WITH RELEASE OF FORCE
3	1/2 MATERIAL IS WOODLIKE, COMPLETE, BUT POORLY, DEFINED GRAININESS	MIDDLE STAGE OF DECOMPOSITION: FADING COLOR, WEAK WOOD SMELL, SOME DISINTEGRATION OF WOOD FIBRES	BREAKS WITH FIRM FINGER FORCE	SHAPE IS PERMANENTLY, BUT SLIGHTLY DISTORTED WITH FORCE
4	1/4 MATERIAL IS WOODLIKE, ONLY PARTIAL GRAININESS REMAINS	ADVANCED STAGE OF DECOMPOSITION: FADED COLOR, ORGANIC SMELL, MOSTLY DISINTEGRATED	BREAKS EASILY WITH FINGERS	SHAPE IS PERMANENTLY DISTORTED WITH FORCE
5	NO LONGER WOODLIKE, NO GRAININESS	COMPLETELY DECOMPOSED: DULL COLOR, FOUL SMELL, COMPLETELY DISINTEGRATED	SQUEEZES BETWEEN FINGERS	NO LONGER RETURNS TO ORIGINAL SHAPE, SPONGY

a primary emphasis is on disintegration
b all discriptors may not apply
c standard testing size is 5.1cm x 1.3cm x 1.0cm
d moisture content for tested sample is "wet to touch"

and the depth of the fill from where samples were taken. Most samples taken deeper in the fill were fresher than those from the surface. Soil and earth, asphalt, and asphalt emulsion seals placed on the wood fiber for protection varied in performance. Asphalt seals generally began breaking apart after 10 years, exposing the wood fiber. In general, sites with soil covers had better ratings indicating that quasi-isolation protected the wood fiber and enhanced durability. The 0.3- to 0.6-m topsoil coverings worked well at all locations, removing the danger of fire from cigarettes and glass and reducing water infiltration with resultant reduction in leachate.

Recent fills, in the past 5 to 10 years, have remained intact and nearly fresh. One location was completely fresh, and the remaining two locations were almost fresh. At Cedar Creek difficulties arose when interlock between the wood chips was not achieved. To avoid similar problems in the future, specifications required the wood fiber material to be in various sizes with a maximum dimension of 0.15 m and interlocking.

Although no comparison was available for leachate test results, the values for flowing water were very low and samples looked clean and pure. Of the 21 sites tested for water quality, 10 could not be tested for BOD levels due because there was no water. Two sites appeared to have water flowing nearby. Two of the 21 sites had relatively higher BOD counts. At the SR-109 West Hoquiam site the adjacent downstream water tested better than did the comparative reference sample taken upstream. There was an oily film in some stagnant pools, yet the BOD counts indicated no adverse effect. The other site that had comparatively higher BOD levels was the SR-101 Rock Crusher Hill site. Standing or flowing water was not present. A pit was dug, allowed to fill with groundwater, sampled, and tested. BOD counts were higher but their effect was inconclusive. A definite conclusion about the water quality of these areas was not made because the data were limited.

Pavement condition is one indication of the wood fiber's performance. Overall, a stable roadway was established by the wood fiber. Of the five fills over soft soils, four have pavement scores of 99 and above. Roadways over the landslide fills have some patching or resurfacing, but most scores are in the high eighties and above.

During field sampling, five in situ densities were taken. These values were from approximately 5.2 to 8.3 kN/m^3 for moist wet unit weights. Classification of these samples varied from 2 to 4 but no relationship could be made to relate these scores to the density. Generally, the drier samples had lower densities compared with a higher density for the wetter material. This generalization applied to all but one sample that was set. Its in-place density was only 6.0 kN/m^3.

Research should be done in another 15 to 20 years to evaluate the rate of degradation of the wood. At that time the wood fiber may resemble the old sawdust piles previously studied (J. Hart, unpublished data) that have an outer seal of decomposed material protecting a fresh one. If the fills follow this pattern, possibly significant decomposition will not occur. If more decomposition is occurring, research could be done on the quality and types of seals being used.

Settlement is a factor taken into account when designing a lightweight fill. Installing settlement devices in controlled fills in both the soil and fill during construction is needed to better define settlement characteristics of the wood and provide data for future designs. Data for the soil and fill enable a more precise value of the wood fiber fill's contribution to the overall settlement.

Further research should be done on the effects of water on wood strength. Because some of the fills had a large amount of water, it would be valuable to know whether strength is lost when the wood soaks in the enclosed water.

RECOMMENDATIONS

The 20-year history of successful use of wood fiber on WSDOT projects as engineered fills indicates that its use should continue for lightweight fills. Degradataion of some fills documented in this research indicates wood fiber may have a finite life as an engineered material in some situations. Use on high volume lifeline roadways, where repairs are prohibitive, should be considered carefully. Use on major roadways of moderate volume, or less critical roadways, should be considered as acceptable.

The technical guidelines suggested for continued use of engineered wood fiber fills are

1. For areas with climates similar to western Washington State only fresh wood fiber should be used to build the fill. This will prolong the life of the fill.
2. To mitigate the effects of wood leachate, the volume of water entering the wood should be controlled so that a minimum of water flow occurs.
3. Fill slopes of 1.5H:1V or flatter with a 0.6-m soil cover are recommended to reduce the decay of the wood and lessen danger of fire.
4. A minimum 2-ft pavement section should be used.

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