

**PERFORMANCE SPECIFICATIONS FOR WOOD WASTE MATERIALS  
AS AN EROSION CONTROL MULCH AND AS A FILTER BERM**

By Kenneth R. Demars and Richard P. Long

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16. Abstract <p>The filtration properties of wood waste mulch were evaluated for use in an erosion control berm application. Four wood waste materials were subjected to laboratory testing to determine their hydraulic properties in the unaltered state and the modified state. The modifications consisted of adding small particles to the grain-size distribution of the wood waste. The filtration behavior of these materials was evaluated for the 1-D condition in a permeameter and for the 2-D flow condition in a sloping Plexiglas box. The 2-D tests simulated field use of wood waste as an erosion control berm. The tests used a series of glass beads of known size and an erodible soil from the field test site, consisting of a filty fine sand, which was mixed with water and passed through the test apparatus. The suspended solids content of the effluent used as a measure of filter effectiveness. The results of this study and the earlier phases were used to prepare model procurement specifications for wood waste material as erosion control mulch and as erosion control filter berm, which are appended to the report.</p>			
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## SI\* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

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Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>									
in	inches	25.4	millimetres	mm	mm	millimetres	0.039	inches	in
ft	feet	0.305	metres	m	m	metres	3.28	feet	ft
yd	yards	0.914	metres	m	m	metres	1.09	yards	yd
mi	miles	1.61	kilometres	km	km	kilometres	0.621	miles	mi

<b>AREA</b>									
in <sup>2</sup>	square inches	645.2	millimetres squared	mm <sup>2</sup>	mm <sup>2</sup>	millimetres squared	0.0016	square inches	in <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	metres squared	m <sup>2</sup>	m <sup>2</sup>	metres squared	10.764	square feet	ft <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	metres squared	m <sup>2</sup>	ha	hectares	2.47	acres	ac
ac	acres	0.405	hectares	ha	km <sup>2</sup>	kilometres squared	0.386	square miles	mi <sup>2</sup>
mi <sup>2</sup>	square miles	2.59	kilometres squared	km <sup>2</sup>					

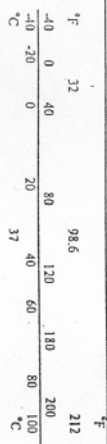
<b>VOLUME</b>									
fl oz	fluid ounces	29.57	millilitres	mL	mL	millilitres	0.034	fluid ounces	fl oz
gal	gallons	3.785	litres	L	L	litres	0.264	gallons	gal
ft <sup>3</sup>	cubic feet	0.028	metres cubed	m <sup>3</sup>	m <sup>3</sup>	metres cubed	35.315	cubic feet	ft <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	metres cubed	m <sup>3</sup>	m <sup>3</sup>	metres cubed	1.308	cubic yards	yd <sup>3</sup>

NOTE: Volumes greater than 1000 L shall be shown in m<sup>3</sup>

<b>MASS</b>									
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T

<b>TEMPERATURE (exact)</b>									
°F	Fahrenheit temperature	(F-32)/9	Celsius temperature	°C	°C	Celsius temperature	1.8C+32	Fahrenheit temperature	°F

\* SI is the symbol for the International System of Measurement



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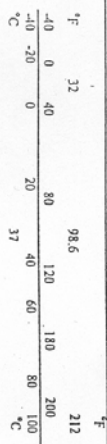
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## **1.0 Introduction**

Field tests have shown that wood waste materials can be effective as mulch for erosion control or as a filter berm at construction sites to prevent eroded soil from leaving the site. When used as a mulch at a thickness of  $\frac{3}{4}$  inch or greater, the amount of soil eroded can be reduced to 1/50 or less than the erosion from an untreated surface. Good results are attained for an erosion control filter berm prepared from wood waste materials and the filter berm has shown that wood waste with the proper particle sizes can work well (Demars and Long, 1998; Demars et al, 2000). For wood waste materials to be used effectively on large-scale projects, procurement specifications, based on the physical properties of the materials, are needed to insure that the proper effect is achieved. Since the materials in a berm function primarily as a filter, permitting water movement but retaining particles, it is the filtration behavior that is of greatest interest. Design requirements for soil-filter systems in dams and dikes have existed for many years and filters are used in many commercial and industrial processes. The primary objective of the study is to investigate design requirements for wood waste materials. The important properties that effect filtration are particle size distribution, organic content, unit weight or density.

This project is an extension of last year's project which focused on field testing of wood waste materials when used as erosion control mulch and erosion control berm. Three materials were tested and their performance compared to the alternatives of no treatment, geosynthetic silt fence, and hay bale berm for 11 rainfall events. The physical and chemical properties of these materials were also measured in the lab but the lack of student help and time constraints prevented the development of filtration testing and the development of procurement specifications.

## **2.0 Scope of the Investigation**

All of the wood waste materials that have been used in the field to prevent erosion from exposed surfaces have shown good results. The particle size distributions of these materials serve as a basis for writing specifications for mulch to prevent erosion from soils surface. There have been only limited opportunities to test wood waste materials in the configuration of a filter berm. Preliminary specifications were prepared by CONEG (1996). These CONEG specifications do not clearly cite particles of wood waste whose sizes are less than 1 inch. It is possible to prepare a wood waste that has 100% of particles between 1 to 3 inches and meets the CONEG specification but would not filter out erodible soil particles.

Two filter berms had been tried successfully in the field. A very effective berm was formed with Paper Mill Wood Waste on a slope in Willington, CT (Demars et al, 2000). In a previous study Glastonbury Wood Mulch was shown to contain eroded soil at the base of the slope from which it came (Demars and Long, 1998). The objective of this investigation was to compare the behavior of other wood wastes with these two in the laboratory and in this way develop specifications to insure the proper selection of these materials for berms.

There have been several studies of the filtration process with soils. The results and conclusions from these studies have been summarized (Taylor, 1948; Das, 1983). The conclusion of these studies is that the filtration process is related to particle sizes in both the filter and the material to be filtered. Using these previous works as a guide, an approach to the laboratory investigation was developed.

### **3.0 Research Approach**

When the field tests at Willington, CT were completed (Demars et al, 2000), the eroded soil that was trapped behind the berm made from the Paper Mill Wood Waste was collected and brought to the laboratory for subsequent testing. This sample contained the particle sizes that were eroded down the slope by a series of storm events. These are the particles that must be prevented from leaving the site by the filter berm. The particle size distribution of this sample is shown in Figure 4.2. As can be seen from this Figure, the storm water was effective in removing a range of particle sizes. A model study of sheet flow over bare soil showed that the rain water could reach a velocity of 20 cm/s which is sufficient to erode these soils particles. These particle sizes are present in most of the soils in New England.

There are two aspects of filtration: retain the soil particles and allow the water to drain away. The retention of particles is a function of the opening sizes in the berm and the sizes of the soil particles. The opening sizes in the berm are in turn related to the sizes of the wood particles. The ultimate filtration achieved is actually a function of both the opening sizes and the particle sizes. A berm will retain certain sized particles, the retained particles will in turn retain smaller sized particles.

One can expect that most New England soils contain some silt and some fine to medium sand. It was decided to test the filtration properties of the wood waste with particles between 0.075 and 0.152 mm. Particles between these sizes will be present in most New England soils, and, when retained, are capable of subsequently filtering silt-sized and then finer clay-sized particles. One-dimensional flow was considered the most direct method of testing the filtration properties.

A two-dimensional flow model was built and used to test the actual filtration process which develops a filter cake of the eroded soil behind the wood waste berm. The eroded soil recovered from the Willington site was used in these tests. For most of these tests the model was sloped at 2 horizontal to 1 vertical. One test was run at 8 horizontal to 1 vertical to determine the filtration prospects if there was less tendency to erode the larger particles.

## 4.0 Test Materials

### 4.1 Materials “As-Received”

Four wood waste materials were used in this study including three materials from the field phase of this project (Demars and Long, 2000). The fourth was the Glastonbury ground brush mulch, which was successfully used as a filter berm in a previous study (Demars and Long, 1998). Some physical properties for these wood wastes materials are shown in Table 4.1 for materials tested in the “as received” condition. Three of the materials consist primarily of shreaded / chipped wood, brush or bark that has a high organic matter content. Only the paper mill wood waste contains a significant portion of inorganic particles and thus has a lower water content and organic matter content than the other test materials. The presence of soil minerals tends to increase the dry unit weight of the material.

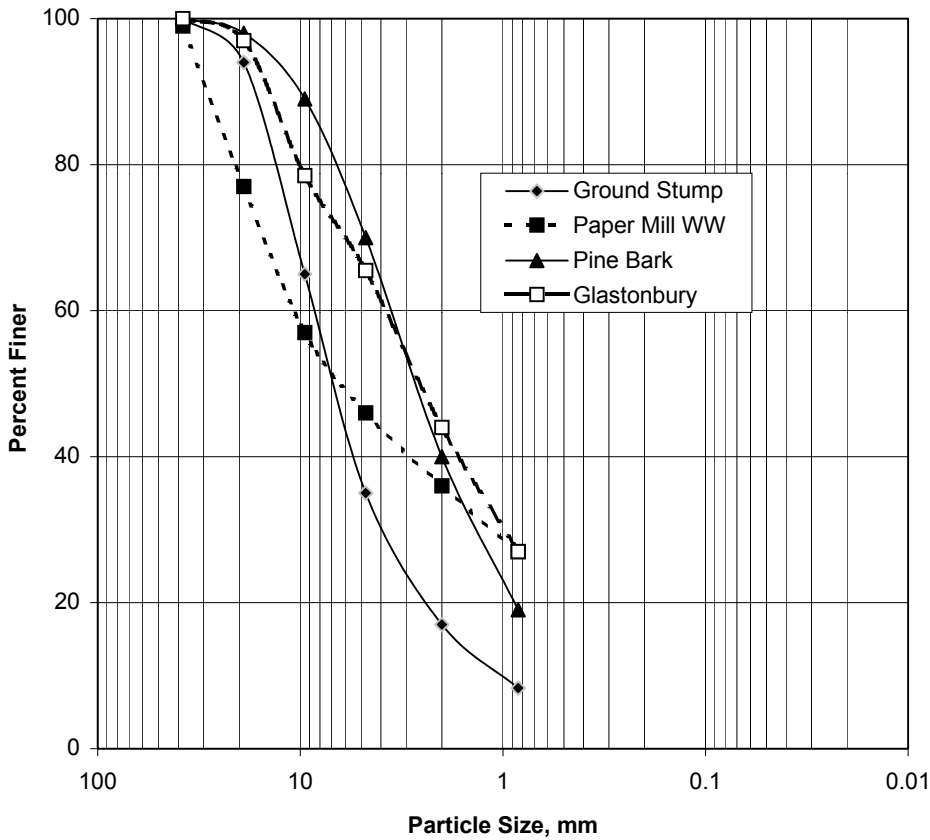
**Table 4.1. Physical Properties of Wood Waste Test Materials**

Test Material	Water Content,* %	Organic Matter Content,* %	Dry Unit Weight, pcf	Permeability, cm/s
Ground Stump Mulch	154.7	55.9-93.9	11.2-15.0	3.88
Pine Bark Mulch	187.5	91.4-95.6	9.6-14.4	4.80
Paper Mill Wood Waste	44.3	22.9-43.0	36.1-48.6	0.24
Glastonbury Mulch	93.7	60.9-70.4	15.5-16.3	--

- \* - by dry weight

. Gradation curves for the test materials in the “as-received” condition are shown in Figure 4.1. The largest sieve available for testing is a 1 1/2-inch (38 mm) mesh and the smallest sieve used is a #20 mesh at 0.84 mm. While smaller sieves are available, it is difficult to get small, organic rod-shaped particles to pass through finer sieves and provide accurate gradation data. Each of the materials contains a large range of sizes from more than 30 mm to less than 0.84 mm. The percentage of particles finer than the #20 mesh sieve are important because they affect the size of pore openings in the mulch through which suspended solids may be transported. The Paper Mill Wood waste and Glastonbury mulches contain the largest portion of particles finer than 0.84 mm at about 26% each based on dry weight. The Pine Bark Mulch has about 16% fines and the Ground Stump Mulch about 8% fines.





**Figure 4.1: Gradation Curves for Wood Waste Materials – “As-Received”**

Other test materials included a silty sand which was used to evaluate the effectiveness of the wood waste materials as a filtration medium. The silty sand was collected from the Willington, CT test site where the field phase of this study was performed. Material that was successfully retained by the Paper Mill Wood Waste filter berm at the field site was considered representative of an erodible material. This material was eroded from the base soil at the site and collected upstream of the berm. Gradation curves for both the base soil and erodible portion of base soil are shown in Figure 4.2. The silty sand contains about 25% silt and the rest is fine to medium sand with a maximum particle size of about 1-2 mm.

**4.2 Materials “As Modified” for 1-D Testing in the Laboratory**

Particles greater than 0.75 in (19mm) were removed for 1-D and 2-D testing, because of size limitations of the apparatus. The resulting particle size distributions of the wood waste samples are shown in Figure 4.3. In addition the Pine Bark Mulch and the Ground Stump Mulch were ground a bit finer to increase the amount of fines present. Some of the properties of these materials as used in the 1-D tests are shown in Table 4.2.

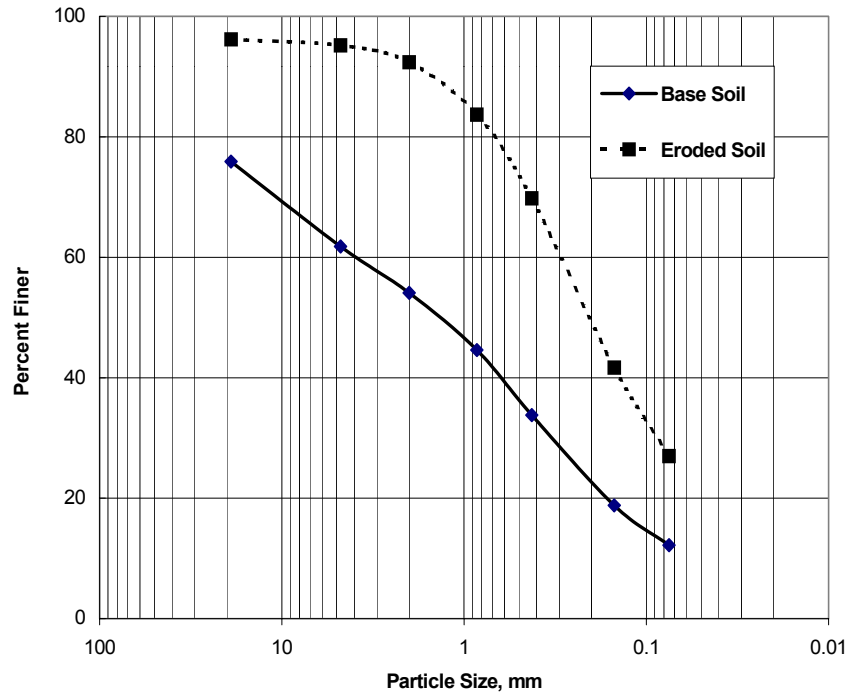


Figure 4.2 Gradation Curves for Erodible Test Material from Field Site

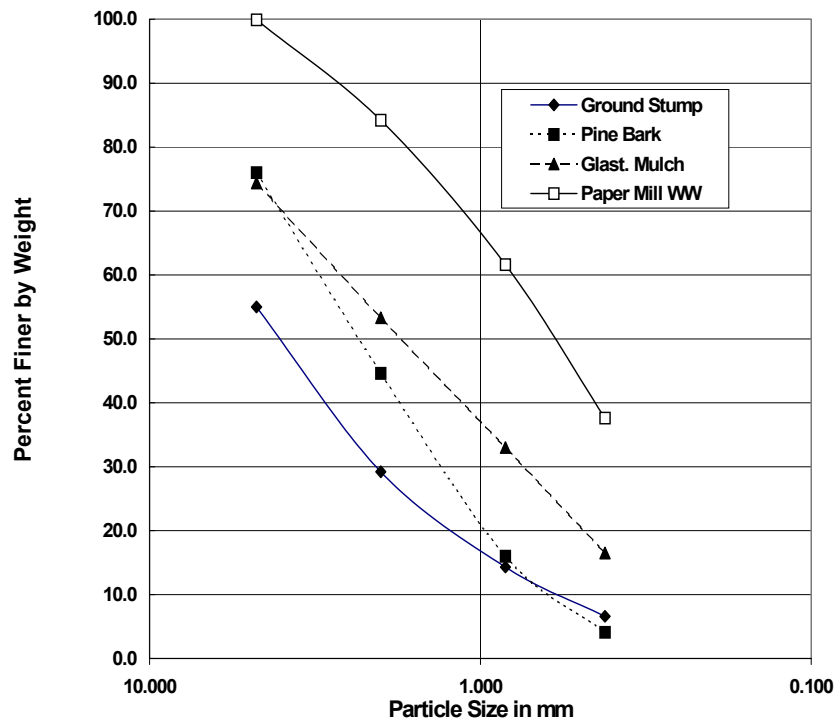


Figure 4.3 "As Received" Particle Sizes of Wood Waste in 1-D Testing

**Table 4.2 Properties of Mulches used in the 1-D Tests**

Material	Dry Unit Weight (pcf)	Permeability (cm/s)	Percent passing 0.84mm
Ground Stump		1	14.3
Pine Bark Mulch	14	0.8	16.0
Glastonbury Mulch	19	0.2	16.0
Paper Mill Wood Waste	50	0.06	61.6
Modified Ground Stump	15	0.04	37.2
Modified Pine Bark Mulch	15	0.1	29.5

## 5.0 1-D Flow Tests and Results

The wood waste, passing the 0.75 in. (19 mm) sieve, was placed in an acrylic cylinder 68mm in inside diameter and about 200 mm long. Each wood waste sample, approximately 50 mm long, was placed in the bottom of the cylinder. A screen retained the sample. The sample's permeability to water was first measured either by constant or falling head test, whichever was appropriate. The 1-D test results are shown in Table 4.2 for permeability and dry unit weight.

The basic filtration properties of each wood waste were measured by applying a suspension of 1000ml containing 50 g of glass beads to each sample, and measuring the fraction of the beads passing through the sample and comparing the amount passing to the amount applied.

The glass beads applied to the wood waste passed the No.100 sieve (0.152mm) and were retained on the No. 200 sieve (0.075mm). These size particles were selected because of their presence in most soils in New England. Glass beads were used because of their availability in narrow size ranges, allowing more control in the experiments. After the application of the suspension, the sample was washed with one liter of water so

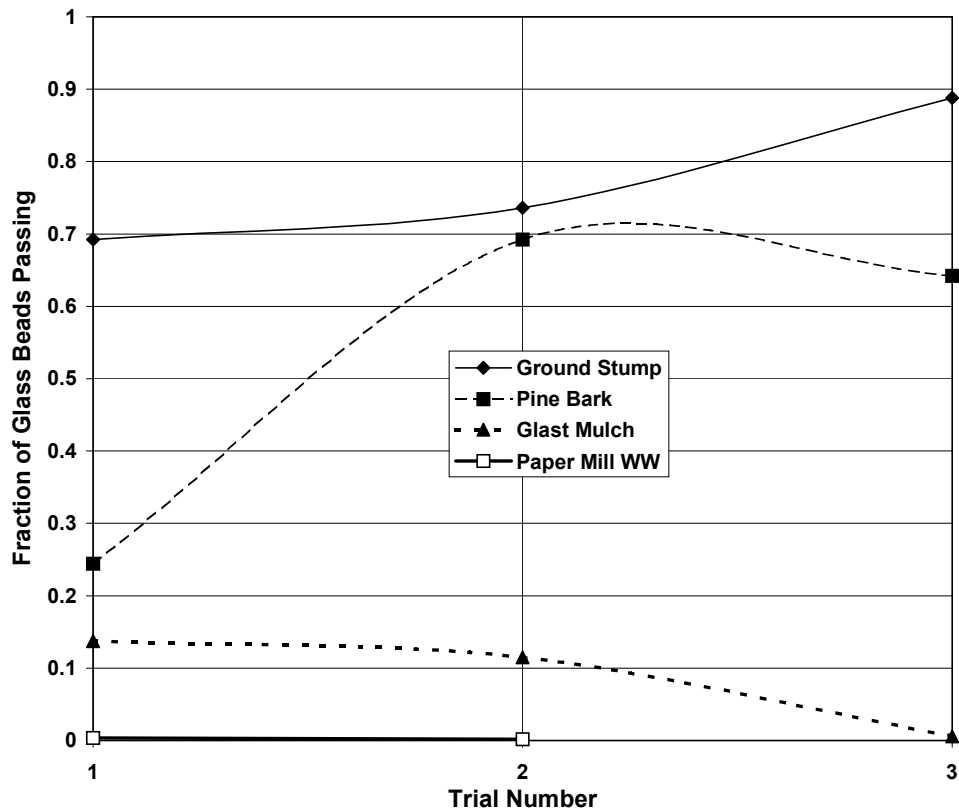
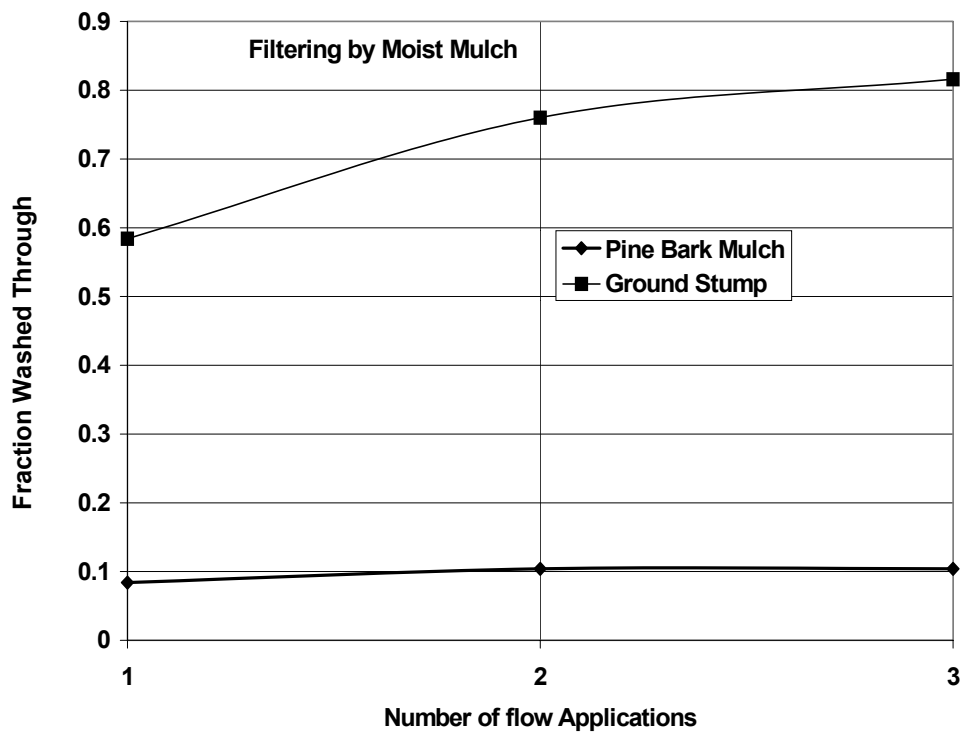


Figure 5.1 Fraction of Glass Beads Passing Wood Wastes

that unfiltered particles had sufficient opportunity to pass through the sample. The particles washed through the sample were captured, dried, and weighed. This process of applying the suspension and washing was repeated two more times to get some idea of the long-term filtration characteristics.

The fractions of the glass beads passing are shown on Fig. 5.1 for the four basic wood wastes. As can be seen from Fig. 5.1 the Paper Mill Wood Waste was most effective in retaining the glass beads. The Glastonbury Mulch was also effective and its effectiveness improved with each application of glass beads. Both of these materials have been used in the field as filter berms.

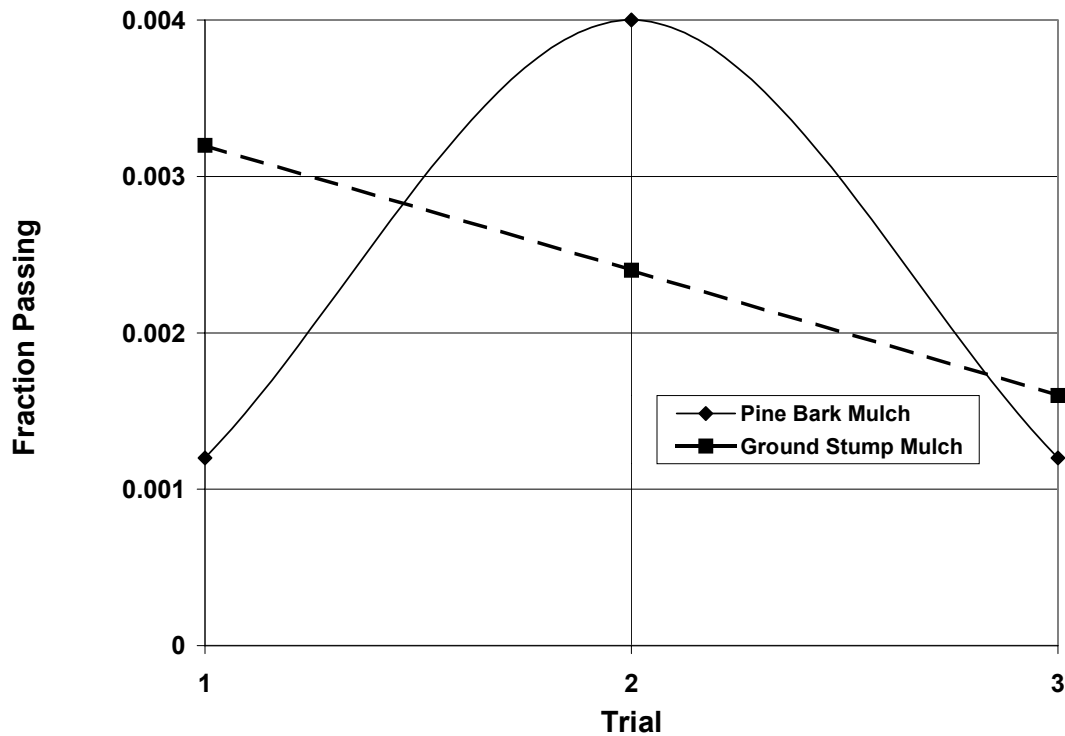
The Ground Stump and the Pine Bark Mulches were not very effective in retaining glass beads in this size range, passing in most cases more than half of the applied particles. The retention showed no decrease with additional applications. It is questionable if these materials would be very effective in the field without some modification or special handling. It was decided, therefore, to investigate these materials further.



**Figure 5.2 Fraction Passing Wood Wastes Placed Wet**

The first testing was done on mulch that had been placed dry then wetted in the process of measuring the sample's permeability. It was decided to determine if the filtration characteristics of these mulches could be improved had they been placed wet.

The results are shown in Fig. 5.2. Placing the Pine Bark Mulch wet improved its filtration characteristics, but did nothing for the Ground Stump Mulch. The Pine Bark Mulch had fine particles that adhered to each other when wet. These little mats may have been more effective in filtration.



**Figure 5.3 Fraction Passing With 20-30 Filter**

A filter medium need not retain all the particles in the soil. It must only retain the larger particles reaching it. If the medium can do this, then these soil particles will help filter the smaller particles. The soil at the Willington site was a typical of an erodible soil found in New England and the eroded soil showed many particles greater than about 1.0 mm. It was decided, therefore, to see if the filtration characteristics could be improved after soil particles passing the No. 20 sieve but retained on the No. 30 sieve first reached the wood waste. After applying 50g of soil in the 20-30 sieve range in turn to each of the Pine Bark and Ground Stump Mulches, the process with the smaller glass beads was repeated. The results are shown in Fig. 5.3. When viewing Fig. 5.3 note that the vertical scale is several orders of magnitude smaller than the previous figures. This process of adding sands in this range has greatly improved the filtration properties of the wood waste.

The Pine Bark Mulch and the Ground Stump have a much smaller fraction passing the No. 20 sieve than the Paper Mill Wood Waste or the Glastonbury Mulch. It was decided to increase the amount of finer particles in these two mulches by additional grinding. A layer of mulch approximately 1.5 cm thick was placed in the bottom of a compaction mold and

impacted with a 10 lb compaction hammer for 10 blows. The particle size changes for the Ground Stump are shown in Fig. 5.4 and those for the Pine Bark Mulch are shown in Fig. 5.5. As can be seen from these figures, the fraction passing the No. 20 sieve has been about doubled.

The samples thus modified were run through the same permeability and glass bead tests as the original material. The results are shown in Figures 5.6 and 5.7. As can be seen from these figures the increased amount of fines makes the mulch much more effective in filtering out the glass beads.

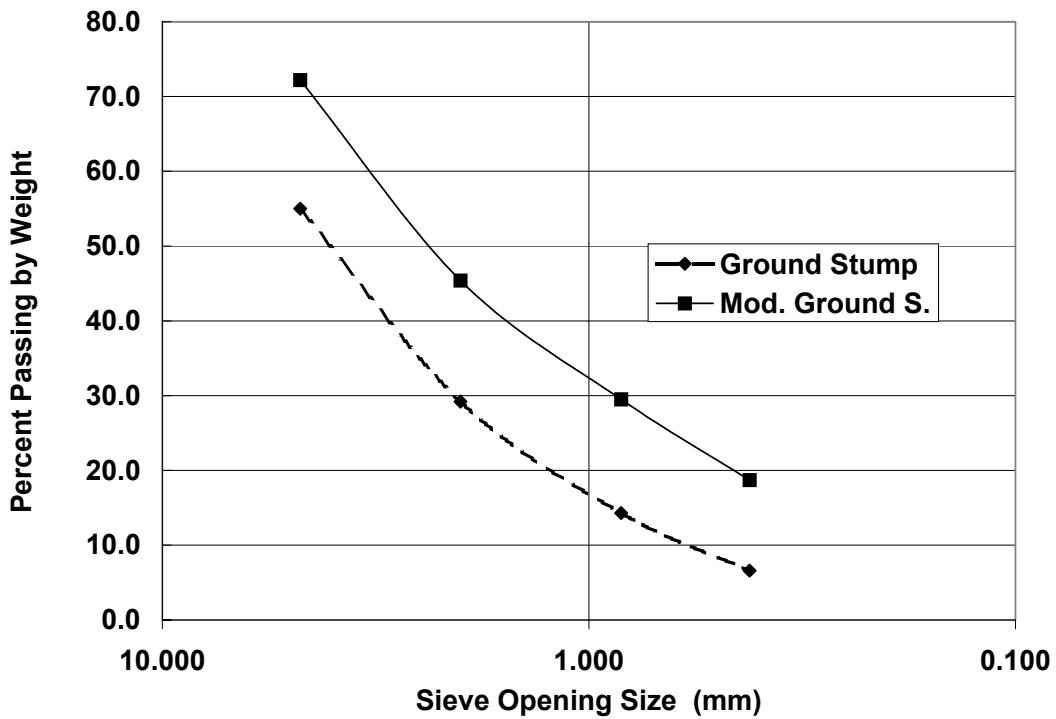


Figure 5.4 Comparison of Particle Sizes in Original and Modified Ground Stump

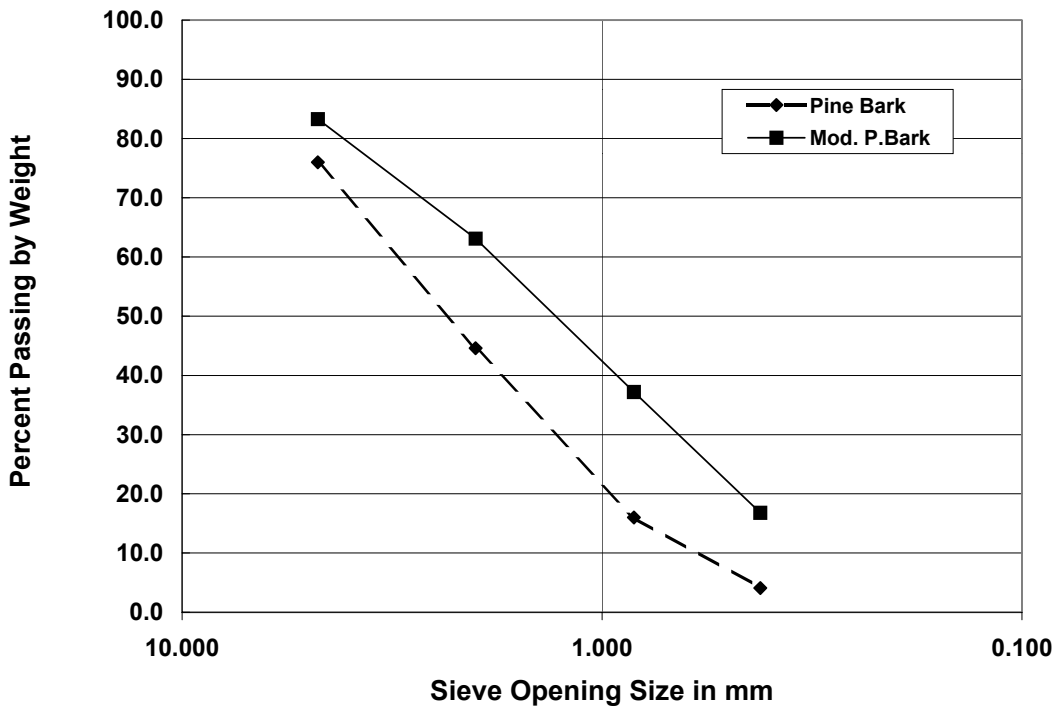


Figure 5.5 Comparison of Particle Sizes in Original and Modified Pine Bark Mulch

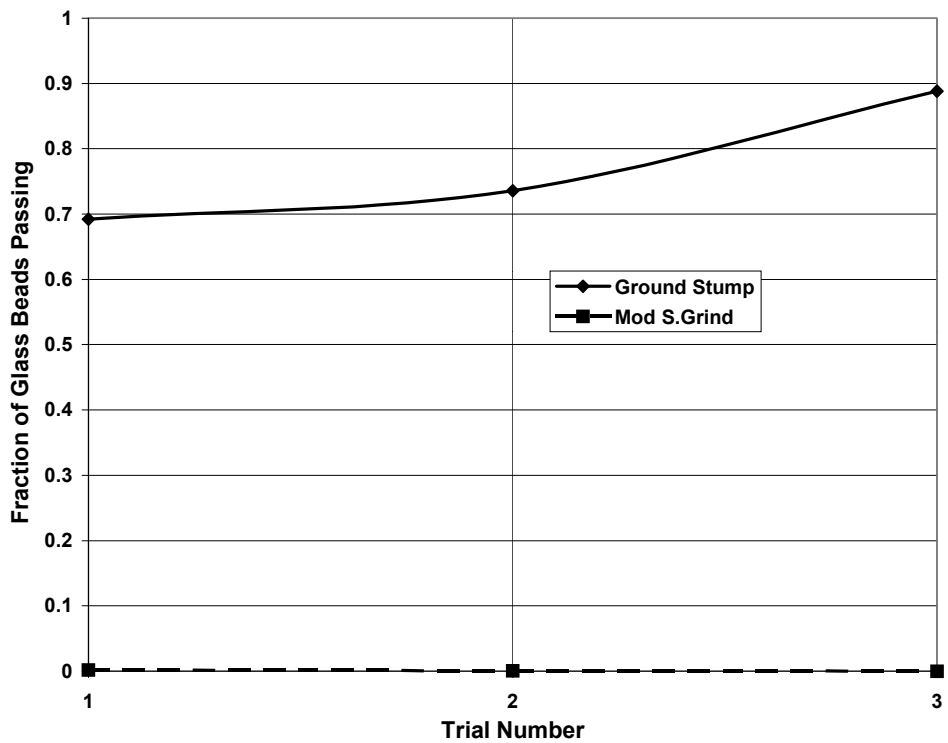
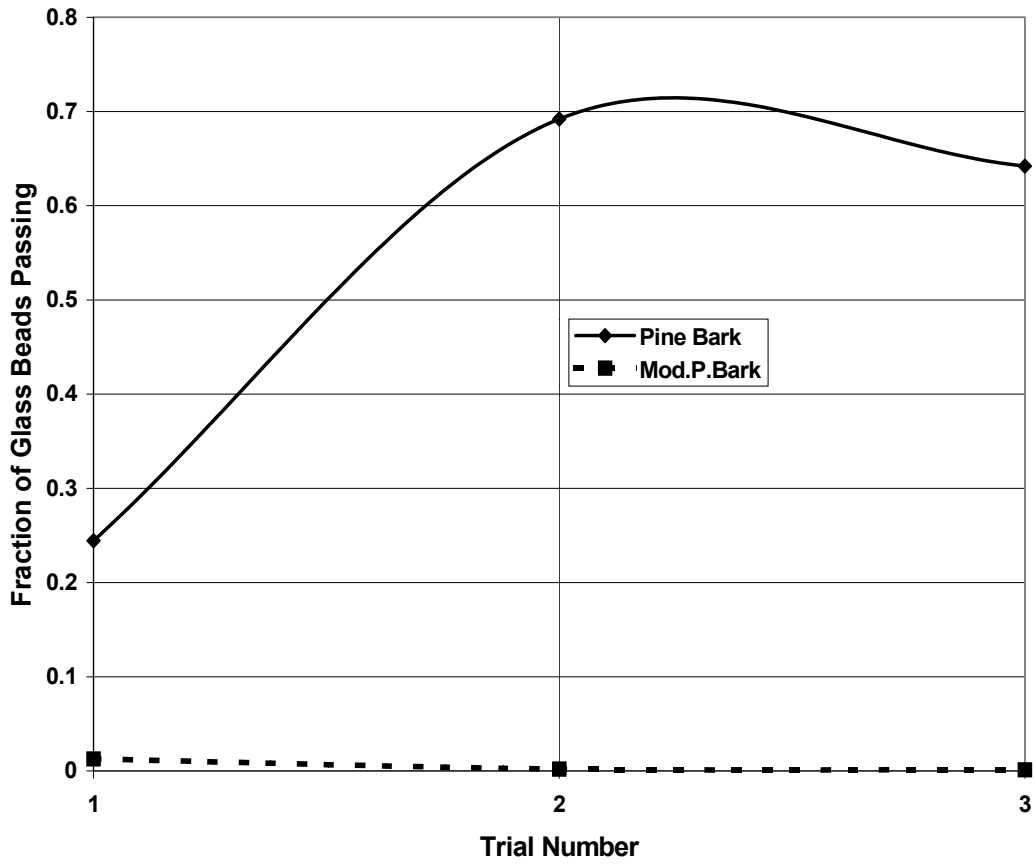


Figure 5.6 Comparison of Glass Bead Filtering by Ground Stump Mulch





**Figure 5.7 Comparison of Glass Bead Filtering by Pine Bark Mulch**

## 6.0 2-D Flow Tests

### 6.1 Equipment

A series of 2-D flow tests were performed to evaluate the findings of the 1-D series of tests in a configuration that simulates the conditions in the field. Specifically, the effects of wood waste's particle size gradation on the berms ability to filter suspended solids from runoff were investigated. A plexiglas box was constructed for these tests.

A photo of the test apparatus is shown in Figure 6.1 with a berm in place as a test is performed. The flow box was 6 inches (15 cm) wide by 18 inches ((45 cm) high and 36 inches (90 cm) long. The box was open at one end but contained a wire mesh at the other end so that a model filter berm could be built from wood waste material. Sand particles were cemented to the bottom of the box to develop a roughness similar to soil on soil.



**Figure 6.1 Photo of 2-D Test Apparatus with Wood Waste Berm**

## **6.2 Test Method**

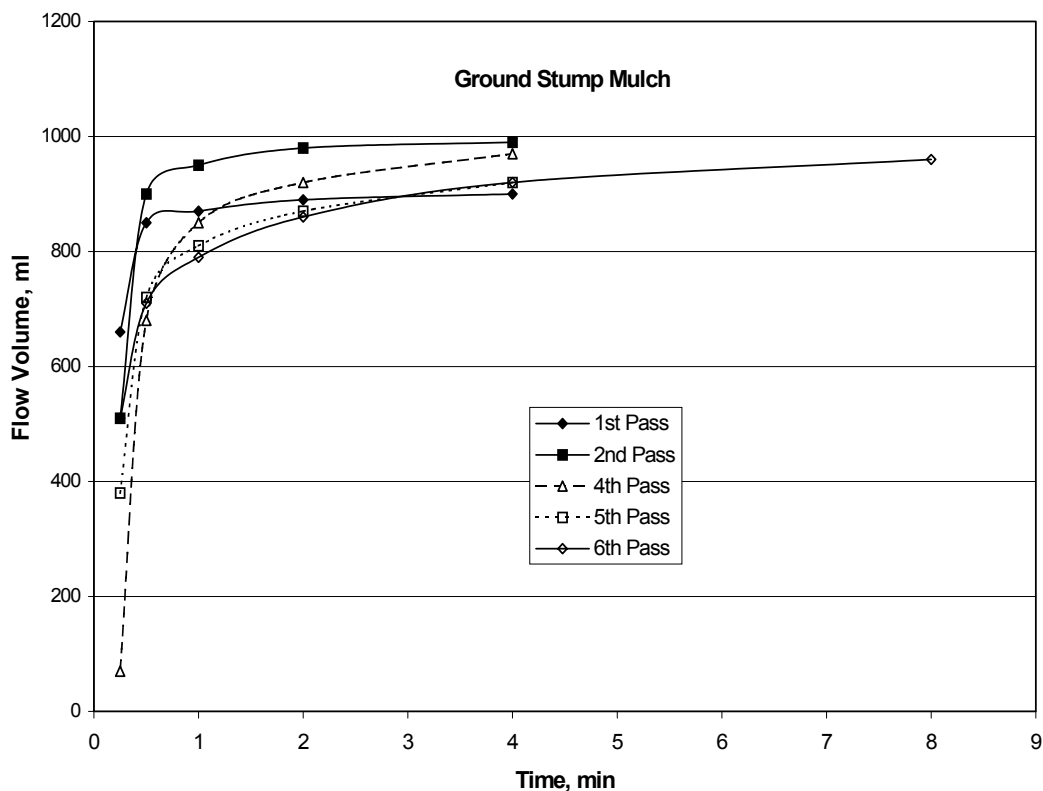
About 3 liters of dry to moist wood waste material was placed in the test box up against the wire mesh to create a model berm that is about 8 inches (20 cm) high by about 12 inches (30 cm) long at its base. The material was lightly patted by hand to form a good contact at each side of the box with no large voids. After tipping the box so the bottom had a slope of 1 vertical to 2 horizontal, the material was hydrated by rapidly pouring one liter of water into the open end of the box and allowing it to flow through the model berm. The flow through the berm was timed and collected in a graduated cylinder as a quantitative measure of the berm's performance. This step was repeated a second time.

Five hundred grams of erodible silty fine sand was spread over the slope surface and was then washed down slope by one liter of water applied dropwise to the surface with a sponge to simulate rain in a field condition. A filter cake formed on the berm's surface. The wash water that flowed through the berm was again collected in a graduated cylinder (un-timed) along with suspended solids that were not filtered out by the berm. The contents of the graduated cylinder were then treated with alum to flocculate and settle the suspended solids. When the suspended solids were completely settled in the cylinder, the excess water was separated from the solids and the solids were dried in the oven and weighed to determine the suspended solids content of the flow through the filter. This process was repeated for several liters of flow to examine flow volume effects. This test procedure was performed on model berms made of the four wood waste materials and of modified versions of the materials to which more fine particles are added. Oversize particles greater than a  $\frac{3}{4}$  inch sieve were removed from each material so that the berm would have a packing similar to field conditions.

## **6.3: Test Results**

### **6.3.1: Tests on Original Materials**

The two primary functions of the berm are to accommodate flow while retaining soil solids. Typical flow volume measurements for the Ground Stump mulch are shown in Figure 6.2. About one liter of water was applied during each pass. The sediment was eroded from the slope during the third pass and no volume-time measurements were made. The filter cake was in-place for passes 4-6. In each instance where water was added to the model, the flow through the berm which was essentially complete after 1 to 2 minutes. The time lengthened somewhat when the filter cake was in place. Similar flow results were observed for each of the wood waste materials and each material easily accommodated the flow. In instances where the filter cake was developed on the face of the berm, some of the flow would pass over the top of the cake and into the berm where no cake had yet formed.

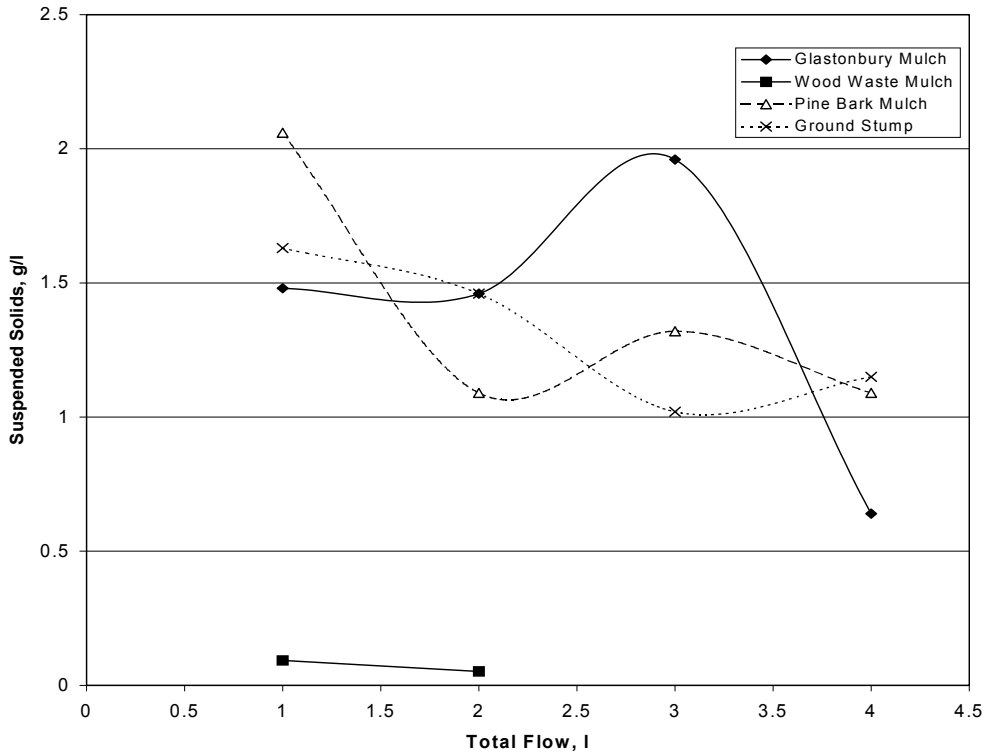


**Figure 6.2 Flow Volume-Time Measurements for Ground Stump Berm**

The water collected from each dosing was evaluated for suspended solids. These solids passed through the berm and the amount is an inverse measure of the effectiveness of that material for filtration. Figure 6.3 shows the suspended solids content that results from passing water through each of the 4 test materials. As can be seen from Figure 6.3, the Paper Mill Wood Waste is most effective in filtering the soil particles. The Glastonbury Mulch appears to be in the process of developing a good filter. The pine Bark Mulch and the Ground Stump Wood Wastes appear to be in a steady state situation passing a greater amount of soil particles.

### 6.3.2 Tests on Modified Materials

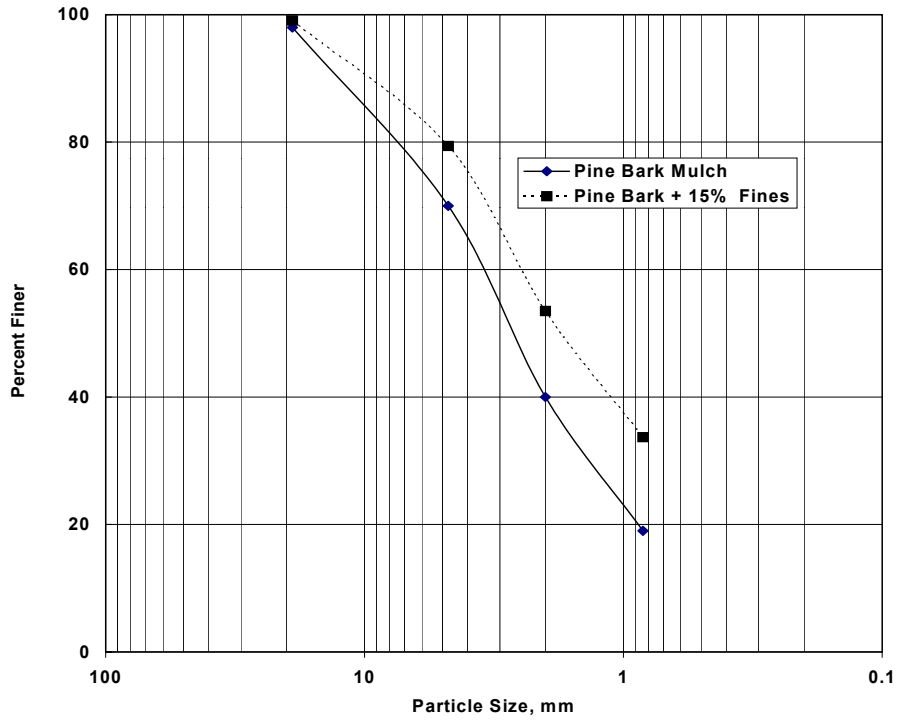
To evaluate the findings from 1-D tests it was decided to use various treatments with the Pine Bark Mulch. In one test, the surface of the Pine Bark Mulch berm was treated by spreading 50g of Ottawa sand on the surface ( about 10% of the berm weight) to fill the areas between the larger particles. This trial is referred to as PBM + 10% Sand A. In another trial 50g of Ottawa sand was mixed into the Pine Bark Mulch. This trial is referred to as PBM + 10% Sand B. In another trial ground Pine Bark Mulch was added so that the berm would contain an additional 15% more particles passing the No. 20 Sieve that is a total of 37.5% of fines. This trial is referred to as PBM + 15% Fines. Its particle size distribution is shown in Figure 6.4



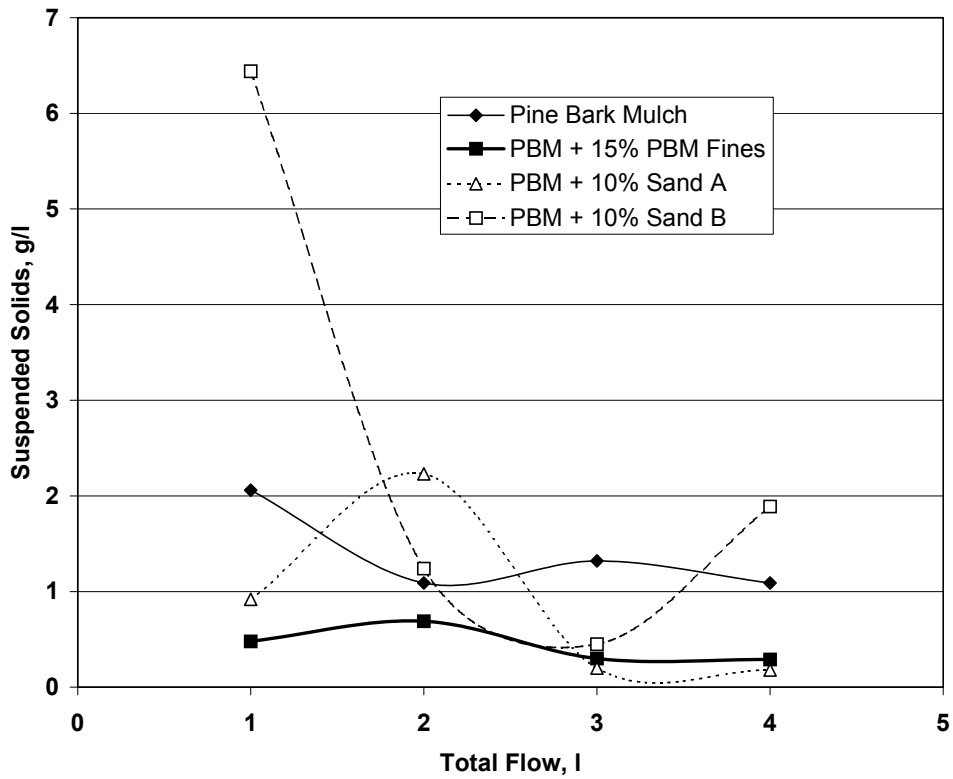
**Figure 6.3 Suspended Solids Content of Water Flowing Through Berm**

The test procedure was identical to that used for the original materials. The results are shown in Figure 6.5. As can be seen from Fig.6.5, increasing the amount of fines by 15% was most effective in reducing the amount of eroded soil that passed through the berm. Applying 10% of Sand A to the surface was also effective in helping the berm develop effective filtering capacity. Mixing 10% of Sand B with the mulch did not improve the filtration, because the included soil was washed out.

. In one instance, the berm was evaluated at a slope of 1 on 2 and then the slope was reduced to 1 on 8 and re-evaluated. There was no measurable difference in the filtration or erosion characteristics at the two slopes.



**Figure 6.4 Gradation Curves for Pine Bark Mulch: Original and Modified**



**Figure 6.5 Suspended Solids in Water Flowing through Modified Berm**

## 7.0 Discussion of Test Results

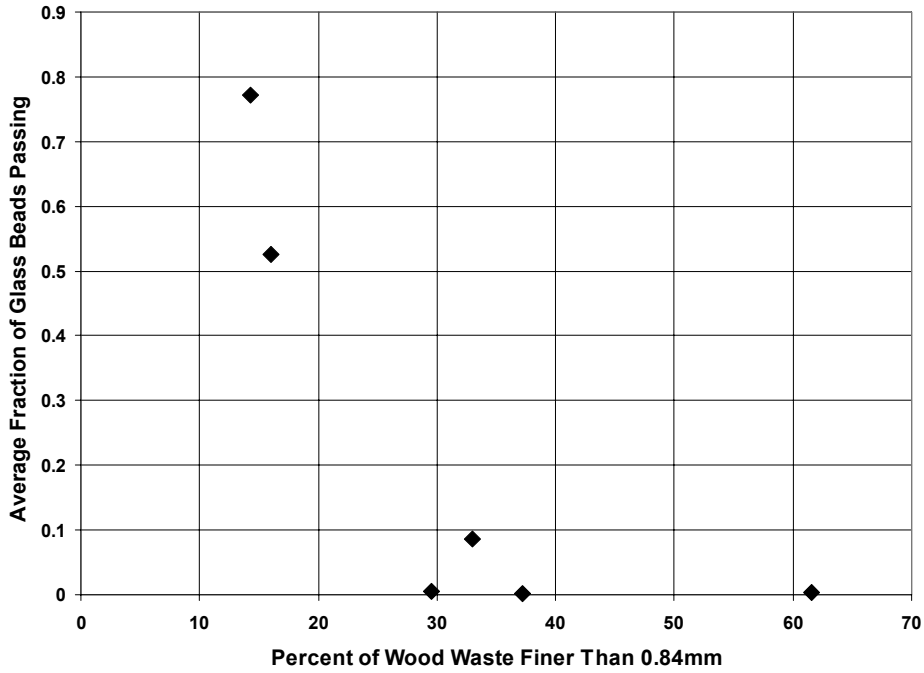
The wood waste tests show the importance of having some finer particles in the filter media. Due to the fact that the wood waste particles are rod-like in shape, the relation between particle size and filtration is not as clear as it is for the bulky, 3-D shape of sand particles or glass beads. The most common method of measuring particle sizes for filters is the standard sieve, square openings. This sifting process works well for soil but has certain limitations for wood waste because of the oblong shapes. Nevertheless, in this research we attempt to study and fix the criteria for filtering with wood waste using the same standard sieves, because of their widespread use and availability .

Filter berms should be designed to retain most of the larger particles of the eroded soil. Filtration is a progressive process in that the particles retained will in turn retain smaller particles, and the smaller particles will retain even smaller particles. The limitation of this process is that the smaller particles reduce the permeability of the system so that the reduced permeability will eventually cause the system to be overtopped during severe rain events, allowing some sediment to escape.

The selection of particles between the No.100 sieve (0.152mm) and No.200 sieve (0.075mm) is arbitrary but based on several considerations. Particles in the range of these sieves are present in most New England soils, and were shown to be erodible at the Wilington site. This particle size has also been shown to be readily erodible by water running off much gentler slopes(NCEL, 1971; Mangalsdorf and Weiss,1980). If the wood waste berm can retain this size particle, then the berm will quickly develop a filter capable of handling silt sized particles..

The 1-D tests showed that this reasoning was sound, and that the wood waste must have enough small particles to begin the soil retention process. The filtration capabilities of the wood waste were correlated with the amount of particles finer than 0.84mm (No.20 Sieve) in each sample tested. The results are shown in Figure 7.1. As can be seen from this figure, the wood wastes in these tests required about 30% finer than 0.84mm to be effective.

The smaller particles in a wood waste can be increased several ways. The wood waste can be composted for a time, so that the particles break down producing an increased amount of smaller particles, or they can be ground finer. In the case of grinding, the grinding process may be adjusted to produce more smaller particles. If neither of these techniques is feasible, the filtering properties of the berm can be improved by placing some soil particles, about the 0.84mm size, directly on the 'upstream' side of the berm. These soil particles should be sprinkled onto the surface of the berm so that they lightly cover all of the area between the larger particles. This process can be done after the berm is in operation and it is determined that the filtration properties must be improved. .



**Figure 7.1 Retention Properties of the Wood Waste vs % finer than 0.84mm**

The 2-D tests confirmed the results of the 1-D tests, that the filtration of the berm depends on the amount of finer particles in the wood waste. If a wood waste does not contain enough finer particles then a layer of soil particles can be added to the surface of the berm.



## **8.0 Summary, Conclusions and Recommendations**

### **Summary**

The filtration properties of wood waste mulch were evaluated for use in an erosion control berm application. Four wood waste materials were subjected to laboratory testing to determine their hydraulic properties in the unaltered state and the modified state. The modifications consisted of adding small particles to the grain-size distribution of the wood waste. The filtration behavior of these materials was evaluated for the 1-D condition in a permeameter and for the 2-D flow condition in a sloping plexiglas box. The 2-D tests simulated field use of wood waste as an erosion control berm. The tests used a series of glass beads of known size and an erodible soil from the field test site, consisting of a silty fine sand, which was mixed with water and passed through the test apparatus. The suspended solids content of the effluent was used as a measure of filter effectiveness. The results of this study and the earlier phases were used to prepare model procurement specifications for wood waste material as erosion control mulch and as erosion control filter berm, which are appended to the report.

### **Conclusions**

- 1.) This study and the earlier field test phase have shown that the wood waste erosion control filter berm can be effective at controlling erosion. The paper mill wood waste used in this research was more effective than geosynthetic silt fence or hay bales.
- 2.) The well-established principles of aggregate filtration apply to the filtration behavior of wood waste materials in the filter berm application, although selecting sizes of wood waste materials is not as straight forward. A typical wood waste material requires at least 20-30% by dry weight passing the No. 20 sieve to be an effective filter berm which will retain fine sand to silt sized particles.
- 3.) For coarse wood waste materials having between 10 and 30% passing the No. 30 sieve, the filtration properties and performance of a filter berm can be improved by adding to the upstream face a thin layer of soil containing particle sizes 80% of which are greater than the No. 30 sieve.
- 4.) The moisture content of the wood waste material is not critical, but it is best placed when it is slightly damp to help compact the material.
- 5.) Paper mill wood waste performed best as a filter berm because it contained a high portion of fine particles and had a lower permeability than other materials tested.

**Recommendations**

- 1.) There is a need for further field testing to study the degradation rate of wood waste material performance with time and to determine the useful life of a filter berm. Chemical and biological degradation of organics is a continuing process.
- 2.) The spacing and size requirements for wood waste filter berms on the same slope need to be evaluated as a function of slope steepness, soil type/ erodibility and maximum rainfall intensity and runoff.
- 3.) Further research on wood waste particle size distribution is needed to determine factors such as maximum particle length needed to tie and strengthen a berm.
- 4.) Also needed are empirical relations that correlate particle size to permeability and filtration performance

## 9.0 References

Bertram, G.E. (1940), "An Experimental Investigation of Protective Filters," Harvard Graduate School of Engineering Pub. No. 267

CONEG (1996), "Model Procurement Specifications for Source-Separated Compost", prepared for the Northeastern States by The Coalition of Northeastern Governors Source Reduction Task Force, February, 69p

Das, B.M. (1983), Advanced Soil Mechanics, Hemisphere Publishing Corp., New York, 511 pp

Demars, K. R. and R. P. Long (1998), "Field Evaluation of Source-Separated Compost and CONEG Model Procurement Specifications for Connecticut DOT Projects", Connecticut Joint Highway Research Report JHR 98-264, Rocky Hill, CT, Dec. 84 pp

Demars K. R., R. P. Long and J. Ives (2000), "Use of Wood Waste Materials for Erosion Control", The New England Transportation Consortium Report NETCR 20, Storrs, CT, April, 63 pp

Naval Civil Engineering Laboratory (1971), "Environmental Factors Affecting the Emplacement of Seafloor Installations", Technical Report R744, October, 84p

Taylor, D.W. (1948) Fundamentals of Soil Mechanics, J. Wiley and Sons, 700 pp

Terzaghi, K. and R.B. Peck (1967), Soil Mechanics in Engineering Practice, J. Wiley and Sons, 729 pp

U.S. Waterways Experiment Station (1941) Investigation of Filter Requirements for Underdrains", Technical Memo. No. 179-1

## APPENDICES

### **Model Procurement Specifications for Wood Waste Material as Erosion Control Mulch and Erosion Control Filter Berm**

Two applications for wood waste materials are addressed in these model procurement specifications:

- A) Erosion control mulch
- B) Erosion control filter berm

Erosion control mulch was addressed in an earlier phase of this study but specifications for both applications are appended. These specifications are modelled after CONEG (1996).

#### **APPENDIX A. Specifications for Wood Waste Materials used as an Erosion Control Mulch (E.C.M.)**

##### **1. DESCRIPTION**

This work shall consist of providing and placing approved wood waste materials as erosion control mulch (E.C.M.) on designated slopes and other environmentally sensitive areas (i.e., next to streams, rivers, lakes and other bodies of water) in reasonably close conformity with the thickness called for on the plans, specifications or as directed by the project engineer. The function of wood waste is to prevent erosion by dissipating the erosive energy of raindrops, by promoting run-off water in sheet flow and by protecting the soil surface. This specification is not intended as a soil amendment for promoting plant growth. Exemptions to these specifications may be approved for specific applications based on review and possible on-site conditions.

##### **2. MATERIALS**

**Wood Waste Material** shall be an organic substance produced by reducing wood pieces to small sizes. It can consist of a mixture of bark, wood shavings, wood chips, wood scraps and mineral grit that is an approved by-product of the lumber, paper or other industries. It also may include source-separated compost derived from leaves and yard trimmings. No manure, bio-solids or kiln dried wood are allowed.

**E.C.M. (for slopes to be mulched only)** shall consist of coarse wood waste materials such as clean wood, bark and other materials that meet the testing parameters outlined below. It shall be capable of being applied evenly to provide 100% initial soil coverage, adhering to the soil surface, not slipping on slopes during rain or when watered, not blown off site, and dissipating raindrop splash. Materials used to manufacture erosion control mulch shall be reasonably free of refuse (subject to the approval of the engineer), other physical contaminants, and any material toxic to plant growth. E.C.M. shall meet the following additional specifications:

- A) Organic matter content shall be between 20 – 100% (dry weight basis) as determined by ASTM D2974 (method A) Standard Test Methods for

Moisture, Ash and Organic Matter of Peat and Other Organic Soils (Loss on ignition).

B) Moisture content shall be < 150% by dry weight (< 60% by wet weight) as measured by ASTM D2216 Standard Test Method for Laboratory Determination of Water Content of Soil and Rock; and ASTM D2974 (method A) cited above. The product shall be loose, friable and not dusty.

C) Particle size as measured by sieving shall be:

<u>Square Mesh Sieve</u>	<u>% Passing by Weight</u>
Pass 3.0 inch	100%
Pass ¾ inch	70 – 100%
Pass #4	30 – 75%

The sieving should be patterned after ASTM D422 Standard Test Method for Particle Size Analysis of Soils or some other mutually agreed upon method of particle size determination. The sieving process tends to separate rod-like particles on the basis of their smaller dimension. Therefore the 3.0 inch and ¾ inch sieves should be visually inspected to insure that enough longer length particles are present.

D) Soluble salts content shall be  $\leq 4.0$  mmhos/cm (dS/m); This can be similar to ASTM D4542 Standard Test Method for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer. Alternately, the liquid extracted from a mixture of 20 cc of moist wood waste added to 150 ml of de-ionized water. The mixture is stirred in a beaker, sits for 15 minutes and a conductivity probe is inserted into the mixture (as per manufacturers instructions). If the wood waste has been dried, it should be moistened and allowed to soak overnight.

E) pH shall be between 5.5 – 8.0. Testing is similar to ASTM D2976 Standard Test Method for pH of Peat Materials. Samples prepared for the soluble salts test can also be used to test for pH. The wood waste material shall be soaked in a beaker for 30 minutes followed by use of a pH meter as per manufacturers instructions. A dry wood waste sample shall be soaked overnight before testing.

### 3. CONSTRUCTION REQUIREMENTS

Only slopes with a 2-1 grade or flatter will be acceptable for spreading E.C.M. Spreading should be performed to ensure adequate compaction and contact with

underlying soil; the engineer may require additional compaction if needed. Thickness should be based on project plans.

4. **METHOD OF MEASUREMENT**

*Standard state language such as:*

Composted erosion control mulch will be measured by the cubic yard complete in place after finishing to the required depths shown on the plans, specifications or directed by the project engineer. The volume in cubic yards will be determined by actual surface measurements of the length, width, and depth of the mulched areas.

5. **BASIS OF PAYMENT**

*Standard state language such as:*

The accepted quantities of E.C.M. will be paid for at the contract unit price per cubic yard.

Payment shall be full compensation for furnishing, placing and maintaining the E.C.M.

.....Pay Item	Pay Unit
(_____) Erosion Control Mulch	xxx cubic yards

**APPENDIX B. Specifications for Wood Waste Material used as an Erosion Control Filter Berm (E.C.F.B.)**

1. **DESCRIPTION**

This work shall consist of furnishing, installing, maintaining and regrading a water permeable windrow of a wood waste materials to remove suspended particles from water moving off-site and into the adjacent waterways, as required by the plans, specifications, or as directed by the project engineer. This can be a substitute for silt fences under controlled sheet flow conditions.

2. **MATERIALS**

**Wood Waste Material** shall be an organic substance produced by some process of reducing wood pieces to small sizes. It can consist of a mixture of bark, wood shavings, wood chips, wood scraps and mineral grit that is a by-product of the lumber, paper or other industries. It may also include source-separated compost derived from leaves and yard trimmings and other organic products. No bio-solids, manure or kiln dried lumber are allowed.

**Erosion control filter berm (E.C.F.B.)** shall consist of coarse wood waste material including clean wood, bark and other materials that meet the testing parameters outlined below. Wood waste materials used to manufacture E.C.F.B. shall be reasonably free of refuse (subject to the approval of the project engineer), other physical contaminants, and any material toxic to plant growth. Erosion control filter berm shall meet the following additional specifications:

A) Organic matter content shall be between 20 – 100% (dry weight basis) as determined by ASTM D2974 method A Standard Test Methods for Moisture, Ash and Organic Matter of Peat and Other Organic Soils (Loss on ignition).

B) Moisture content shall be < 150% by dry weight (< 60% by total weight) as measured by ASTM D2216 Standard Test Method for Laboratory Determination of Water Content of Soil and Rock; and ASTM D2974 (method A) cited above. The product shall be loose and friable, not dusty.

C) Particle size measured by sieving shall be:

<u>Square Mesh Sieve</u>	<u>% Passing by Weight</u>
Pass 3.0 inch	100%
Pass ¾ inch	70 – 95%
Pass #4	30 – 75%
Pass #20	20 – 40%

The sieving should be patterned after ASTM D422 Standard Test Method for Particle Size Analysis of Soils or some other mutually agreed upon method of particle size determination. The sieving process tends to separate rod-like particles on the basis of their smaller dimension. Therefore the 3.0 inch and ¾ inch sieves should be visually inspected to insure that enough longer length particles are present.

D) Soluble salts content shall be  $\leq 4.0$  mmhos/cm (dS/m); This can be determined in a manner similar to ASTM D4542 Standard Test Method for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer. Alternately, the liquid extracted from a mixture of 20 cc of moist wood waste added to 150 ml of de-ionized water. The mixture is stirred in a beaker, sits for 15 minutes and a conductivity probe is inserted into the mixture (as per manufacturers instructions). If the wood waste has been dried, it should be moistened and allowed to soak overnight.

E) pH shall be between 5.5 – 8.0. . This test is similar to ASTM D2976 Standard Test Method for pH of Peat Materials. Samples prepared for the soluble salt test can also be used to test for pH. The wood waste sample shall be soaked in a beaker for 30 minutes followed by use of a pH meter as per manufacturers

instructions. A dry wood waste sample shall be soaked overnight before testing.

### **3. CONSTRUCTION REQUIREMENTS**

- 3.1 General. The E.C.F.B. shall be placed uncompacted in a windrow at locations shown on the plans or as directed by the engineer. The berm shall be a minimum of 12 inches and a maximum of 24 inches in height and a minimum of 48 inches in width. On slopes of 2 to 1 with a length greater than 50 feet, the spacing of berms shall be a maximum of 50 feet or as directed by the engineer. The E.C.F.B. may be applied by a bucket loader with shaping to be done by hand. At the discretion of the project engineer, E.C.F.B. may stay in place indefinitely regardless of whether it is needed. If the berm material is to be removed, it shall be distributed over an adjacent area not to exceed a depth of three (3) inches and immediately seeded and mulched.
- 3.2 Maintenance. The contractor shall maintain the erosion control filter berm in a functional condition at all times and it shall be inspected after each rainfall and at least daily during prolonged rainfall. All deficiencies shall be immediately corrected by the contractor, such as overtopping, clogging with sediment, erosion or becoming ineffective. The contractor shall make a daily review of the location of the berm in areas where construction activity causes drainage runoff to ensure that the berm is properly located for effectiveness. Where deficiencies exist, such as overtopping or wash-out, additional berm material shall be installed as approved or directed by the project engineer.

Sediment deposits shall be removed when directed by the project engineer. Any sediment deposits remaining in place after the berm is no longer required shall be graded to conform with the existing ground, seeded and mulched immediately.

### **4. METHOD OF MEASUREMENT**

*Standard state language such as:*

Erosion control filter berm will be measured complete in-place after finishing to the required depths shown on the plans, specifications, or as directed by the project engineer. The volume in cubic yards will be determined by actual surface measurements of the length, width and depth of the mulched areas.

### **5. BASIS OF PAYMENT**

*Standard state language such as:*

The accepted quantities of E.C.F.B. will be paid for at the contract unit price per cubic yard. Payment shall be full compensation for furnishing, placing, maintaining, and removing the E.C.F.B. material.



Pay item	Pay Unit
(____)Erosion Control Filter Berm	xxx cubic yards