Extending the logging season in Mountain Pine Beetle damaged stands by using ground wood to surface in-block roads.

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by

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**ABSTRACT**

This paper summarizes the results of a field trial where logging residue was mulched on site to produce a running surface for temporary in-block roads. The results of this trial indicate roads with a mulched wood surface outperform soil roads when the subgrade consists of a saturated fine grained soil. Failure of the mulched wood roads was due to excessive localized rutting, which could be repaired by hand or with a skidder blade under operational conditions.

**KEYWORDS:** Mulched wood, road surface, cyclic loading.
1. INTRODUCTION

Warmer winters and the need to harvest timber killed by mountain pine beetle 
(Dendroctonus ponderosae (Scolytidae)) has resulted in the need to extend the logging 
operating season into periods when the ground is not frozen. In regions where the 
mountain pine beetle is active, inexpensive gravel is not commonly available for 
surfacing in-block roads. Thus, temporary in-block roads are constructed of the local soil 
which can have a high silt and clay content, and these roads perform very poorly if 
hauled on during rainy periods (Arola et al. 1991). Mulched wood has been used as an 
alternative to gravel for surfacing in-block roads. Using mulched wood for the road 
surface will reduce the environmental impact since it does not produce fine sediments, 
the permeability of mulched wood is much higher than for most gravels and sand, and it 
poses less of a barrier for reforestation (Karksy 1993, Bulmer et al 2007). Using mulched 
wood for the road surface will reduce construction costs of all-weather temporary roads 
since it will not be necessary to haul gravel long distances for surfacing (Arola et al. 
1990). In addition, the efficiency of logging operations will be increased by increasing 
the length of the operating season, which will reduce scheduling conflicts and the need to 
stockpile large amounts of timber, and by allowing a higher in-block road density without 
increasing the site degradation due to roads (Tice 1998).

In unpaved roads the term base course refers to the material used to cap the 
subgrade to provide a running surface for traffic. Load spread refers to the phenomenon 
where a load applied to the top surface of the base course radiates laterally as well as 
vertically through the material, this results in the magnitude of the stress field at the 
bottom of the base course being less than the stress field applied to the top surface (Lyons
and Fannin 2006, Lyons and Lansdowne 2006). This is an important attribute of the base course particularly when the road is built over weak subgrades such as fine grained and organic soils. Ground wood has been used as the base course for unpaved roads (Tice 1998, Karksy 1993); however, the performance of waste wood mulched on site has not been documented. It is important to consider the amount of mulched material that can be generated by mulching the right-of-way waste wood, and the ability of this material to support multiple axle passes over weak subgrades.

This paper presents the results of a field trial that was conducted to determine if mulching waste wood from right-of-way logging in-block roads can produce a viable road surface. This paper considers two main questions; 1) does waste wood from right-of-way logging mulched with a mobile mulcher produce sufficient material that is suitable for the running surface of a temporary road, and 2) does a road surfaced with mulched waste wood outperform a soil road during wet conditions when considering rut formation and truck passage.

2. FIELD TRIAL DESCRIPTION

2.1. Site description

The field trial considered in this paper was conducted in cutblock 159 of the Gavin Lake Block of the UBC Alex Fraser Research Forest (ALRF), which is in the moist cool subzone of the Interior Cedar Hemlock biogeoclimatic zone. The site is undulating to gently sloping, with an average slope of 5%. Site series was classified as zonal with deep moraine soils that are silty to loamy in texture (Klinka et al. 2004). Coarse fragments are a minor component of the soil volume. The stand originated after a
fire and had an average stand age at breast height of 96 years, ranging from 80-124 years. Mountain pine beetle attack started to occur in 2002, and a salvage of groups of infested pine was carried out in 2003. Virtually all of the lodgepole pine was killed by 2005, and was in the grey-attack stage by 2007. Pre-harvest cruise results indicated that the average total height was 24.4 m, the average diameter at breast height was 28.2 cm, the average net merchantable volume per tree was 0.49 m$^3$, the average gross volume per hectare was 322 m$^3$/ha, and the net merchantable volume per hectare was 279 m$^3$/ha. A further volume of old redcedar snags resulting from the previous fire were still standing on the block. Twelve percent of the stems were classified as dead useless snags in the pre-harvest cruise.

2.2 Road construction

Three roads were laid out in cutblock 159 (Figure 1), with each road following a constant bearing. The standard right-of-way (RW) used by the ALRF has a total width of 20m; however, in case the standard right-of-way did not produce sufficient waste wood to surface the road, a wide right-of-way of 40m was also considered (Table 1). For the road sections surfaced with mulched wood the right-of-way was harvested using a feller processor and the waste wood was placed on the road centerline, where the soil organic layers and stumps were left undisturbed. A Gyro Tech GT-25 mobile mulcher was used to mulch the waste wood decked at centerline. The mulched material required only minor leveling and this was done by the excavator used to build the soil road section. For the soil road sections the surface organic layer and stumps were removed, and the remaining mineral soil was leveled to form the road surface. Note, no equipment traveled on the
road sections prior to the trafficking trials.

The treatment was to pile waste wood from the identified right-of-way on the centerline of the road in the form of a continuous windrow. The waste wood included culls, and non-merchantable parts of trees such as limbs and tops. For the road sections with 20m and 40m right-of-ways the feller processor was instructed to move the waste material perpendicularly to the road centerline. For all road sections the merchantable logs were forwarded to the landing along trails located outside of the study area. When stacking the waste material on the centerline the feller processor was instructed to form a continuous windrow of waste material, with the width of the base of the windrow less than 6m. Long chunks and logs were oriented in the direction of the road centerline to aid the performance of the GT-25 mulcher. The mulcher started at the beginning of the windrow and worked toward the end; however, depending on the size of the logs and the height of the windrow the mulcher had to work forwards and backwards to process material on the face of the pile. If a finer texture was desired for the mulched material the mulcher could make additional passes over the mulched wood (Figure 2).

2.3 Trafficking Trial.

The second objective of this study was to determine if the mulched wood surface improves the performance of the road during wet periods when the ground is not frozen. It was difficult to schedule logging and hauling phases to coincide with the desired weather conditions, and even if this had been possible using loaded log trucks to explore the serviceability limit of the roads is not advisable. Therefore, a gravel truck was loaded to produce drive axle loads similar to a log truck and this was used in the cyclic loading
of the test road. Using a gravel truck, dedicated to loading the test road, permitted rapid application of multiple axle loads under suitable field conditions. The trafficking trials occurred in October 2007 after a period of rainfall had saturated the subgrade. The gravel truck used in this study had a combined drive axle load of 18750kg and a steer axle load of 6970kg. The gravel truck was instructed to retrace its path for each pass along the road, and no action was taken to repair ruts as they formed. Failure of a road section was considered the point when the gravel truck was unable to move, or when the driver was unwilling to risk damage to the truck.

2.4 Data collection

This was a small field trial interested in the relative performance of roads surfaced with mulched waste wood as compared to soil roads constructed using standard practices. Due to cost and time limitations of the small field trial, detailed subgrade data such as soil shear strength, soil moisture content during the trafficking trials, and the soil particle size distribution were not collected. Assessment of the relative performance of the roads surfaced with mulched wood was achieved by including one soil road section in each of the test roads.

The amount of mulched wood produced was estimated as both the mass and volume of mulched wood in a road section. For each road section that was surfaced with mulched wood the surface profile was measured and the depth of the mulched wood was estimated at cross sections located at 10m intervals along the road. At each cross section the depth of the mulched wood was estimated at 1m intervals along the cross section. For each 10m section the areas of the cross sections at the beginning and end of the section,
were averaged and multiplied by the section length to estimate the volume of the section. The volume of a road section was the sum of the section estimates for that section.

To estimate the mass of mulched wood in a road section it was necessary to estimate the density of the mulched wood. Three estimates of density were made for each road section that was surfaced with mulched wood, and these were on the road centerline at 5m, 25m and 45m along the section. At each sampling point a column of mulched wood, with a cross section of approximately 0.25m$^2$, was excavated to the base of the surface material. The density of the sample was the mass of the excavated material divided by the volume of the column. The density samples were taken between one and three days after the material was mulched. Some of the waste material in the windrows consisted of dead trees, mostly pine or cedar, and thus some density measurements could contain a significant amount of dry wood. The density estimates for a road section were averaged and this, multiplied by the section volume, produced the mulched wood mass estimate for the road section.

The distance between the centers of the gravel truck drive axle dual wheel assemblies used in this study was 1.9m. Allowing for some drift either side of the centerline, the portion of the road surface used by the gravel truck was contained within 1.5m either side of the centerline. The amount of mulched wood at a particular location was a function of the depth of the mulched wood, and whether there were voids in the column (average density of the column). It was not possible to measure the average density at every point where the depth was estimated. The best measure available in this study of the amount of mulched wood at points along the traveled portion of the road was the depth of the surface material. Thus, in this study the minimum depth is defined as the
Rut depth was defined as the vertical distance between the road surface under the wheels and the highest point of the road surface between the wheels. This definition was selected since it was a serviceability limit that was being considered not a bearing capacity limit. The number of gravel truck passes was recorded and rut measurements were taken at 20m and 30m along each 50m road section.

3.0 RESULTS

The results of the field trial are summarized in Table 2. In the trafficking trial the gravel truck could not complete one pass on any of the soil road sections, which indicates the local soil was very weak under the conditions when the trafficking trials were conducted. This is a dramatic contrast to dry conditions when soil roads in this region typically support multiple passes of log trucks. Thus, the performance of the road sections surfaced with mulched wood is being compared to the soil road sections under the most adverse conditions. Comparing these roads under adverse conditions is appropriate since these are the conditions when a surfaced road is required.

The number of truck passes at failure data in Table 2 indicates the road sections surfaced with mulched wood consistently outperformed the soil road sections for all the test roads, and the road sections surfaced with mulched wood from a 40m RW outperformed the 20m RW. As expected the volume and mass of mulched wood for the 40m RW section was greater than the 20m RW section of a given road; however, the magnitudes of these values varied dramatically between test roads. It is important to note
the mulched wood roads did not fail because of a uniform increase in rut depth; instead they failed because of excessive rut depth at particular points along the road. The localized failure zones were between 1 and 3 meters long. In the trafficking trials we constrained the truck to run repeatedly over the same path and no action was taken to fill in ruts as they formed. In an operational application the small local ruts could be filled with a skidder or even a hand shovel, and this would have extended the life of the sections indefinitely.

Given that failure resulted from excessive localized rutting, the frequency of low volume spots is more important than the total volume of mulched wood in a section, provided there is a minimum amount of material. The available data that best describes the frequency of low volume spots is the minimum depth of mulched material in the portion of the road subject to vehicle loading (Figure 3). Figure 3 indicates there is a strong correlation between the minimum depth of the mulched material in the portion of the road subject to vehicle loading and the number of vehicle passes that caused failure. There is more variation in the data for the 40m RW sections than for the 20m RW sections. In the 20m RW sections the wheels quickly cut through the mulched wood in small localized regions, and once the wheels were into the subgrade failure quickly followed. Shallow continuous ruts formed quickly in the 40m RW sections; however, the continuous ruts stabilized at about 0.2m (Figure 4). Failure in the 40m RW sections appeared to be the result of a more complicated process.

In the Road 1 40m RW section the failure location originally had a deeper layer of mulched material with more voids. The failure location was only on one side of the road, which caused the gravel truck to lean as the mulched wood was compacted. With the
greater lean of the gravel truck more of the load was transferred to the wheels going over the failure location, and this aggravated the compaction and lateral displacement of the mulched wood. Eventually rut depth and the lean of the truck required an end to the tests on this section.

The Road 2 40m RW section never failed completely. As with the other road sections shallow continuous ruts formed and stabilized. At some locations deeper ruts began to form; however, they also stabilized before becoming too deep to allow the gravel truck to pass. Thus, the trafficking trial on this section was eventually terminated because of time constraints.

The Road 3 40m RW section failed sooner than expected. The total volume and mass data for this section indicates there was significantly more mulched wood in this section; however, the minimum depth value was only slightly greater than for the 40m RW sections in Roads 1 and 2. The Road 3 40m RW section had a number of large dead cedar logs in the waste pile, and these logs generated a large volume of mulched material. The localized rut that caused failure of the Road 3 40m RW section was located where there was a high concentration of mulched wood from a dead cedar log. As the number of gravel truck passes over the failure location increased the mulched wood from the dead cedar logs began to degrade, and eventually the wheels cut through to the subgrade with failure following soon after.
5.0 CONCLUSIONS

In this field trial the road sections surfaced with mulched wood outperformed the soil surfaced sections, and the 40m RW sections performed better than the 20m RW sections under the test conditions. We do not believe this is a result of the average depth of the mulched wood, since the roads failed due to excessive rut depth at particular points along the road. For both the 40m RW and the 20m RW, the sections between the localized failures developed ruts that stabilized at about 0.2 m depth. Instead we believe there is a critical depth of mulched wood below which the wheels quickly cut through to the subgrade, and the probability of having the depth of mulched wood below this critical depth is greater when the total volume of mulched wood is less. The goal of the field trial was to fail the roads; however, in an operational application the localized ruts could be filled by a skidder blade or hand shovel and this would greatly extend the performance of the roads.

In this project we windrowed the waste wood from the defined right-of-way and then ran the mulchers over the windrow as a separate phase. This process was efficient; however, it resulted in variability in the distribution of the mulched wood. If we accept there will have to be some repair of localized failures, then the procedures used in this project work well. Operationally we believe this will be more efficient than having feller processors, excavators, and mulchers working at the same to time to produce a more uniform distribution of the mulched wood.
REFERENCES


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Table 2, Field trial results

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Notes:
- NA: Not applicable

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