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Vol. 1 No. 37 November 2000

Contents

Monitoring frost levels in thawing roadbeds to maximize the log hauling season

Abstract

When roadbeds on hauling routes begin to thaw in the spring, regulatory officials in B.C. impose load restrictions to avoid or restrict damage caused by high vehicle wheel loads. Until recently, the decision of when to impose these restrictions has been based on subjective criteria or traditional dates, which has tended to be conservative. Technology is available that can more accurately determine when to impose restrictions to protect the integrity of the road surface while maximizing the number of hauling days prior to the spring shutdown. This report documents the experience of the B.C. Ministry of Forests in applying this technology to two log hauling roads in northwestern B.C.

Keywords

Load restrictions, Thawing roads, Log hauling roads, Frost levels, British Columbia.

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Introduction

In much of western Canada, the forest industry relies heavily on frozen ground conditions to access timber resources (Figure 1). As daytime ambient temperatures rise in February and March, temperatures in the upper layers of a roadbed gradually rise above the freezing point. Surface and base materials lose strength as melt-water, from ice lenses formed in the roadbed and from accumulated snow and ice in roadside ditches, becomes mobile and saturates the roadbed. The resulting loss of load-bearing capacity of the road structure occurs very rapidly at the onset of thawing, often reaching its lowest level in a few days. Recovery is a much more gradual process, dependent on the rate of drying in the roadbase, and often stretches well into the summer (Blair 2000). If logging trucks and other heavy vehicles with high wheel loads are allowed to continue operating on thaw-weakened roads, extensive damage to the roadbase will occur.

Figure 1. Hauling on a frozen road surface.

Public road authorities restrict hauling activities or impose load restrictions during periods of low bearing capacity (spring thaw) to avoid or reduce high maintenance and repair costs. The decision of when to implement these restrictions may be based on observation of surface deterioration, on historical dates, or as in more recent years, on precise measurement of the roadbase temperature. Regional offices of the B.C. Ministry of Transportation and Highways (BCMOTH), principally in the interior of

the province, rely on the monitoring of subsurface frost levels in primary highway roadbeds to initiate load restrictions on local secondary roads. However, this practice does not take into account variations in roadbase design strength or geography that tend to maintain frozen roadbed conditions on specific log haul routes. In some cases, a low-strength secondary road, subject to early load restrictions, may act as a bottleneck between still-frozen forest roads and a primary highway, resulting in a log haul being shut down prematurely.

Premature imposition of load restrictions or hauling bans does not ensure that the road system operates at optimum efficiency, and can adversely impact the forest industry. Early shutdowns affect the profitability of hauling contractors and the stability of a reliable workforce. They may also result in mills having inadequate inventory of raw wood to sustain production through the spring and summer, or conversely, carrying larger than necessary inventories with ensuing additional carrying costs.

In 1998, the B.C. Ministry of Forests (BCMOF) first applied roadbase temperature monitoring technology on a Forest Service road used for hauling logs and copper ore concentrate, and in 1999, shared in the cost of instrumenting a second log hauling road that is administered by BCMOTH. Both of these roads are in the Smithers/Houston area of northwestern B.C. FERIC became aware of these activities, and with the cooperation of BCMOF, documented the results in the spring of 2000.

Figure 2. Measuring pavement deflection using Benkelman beam.

Objective

The objective of this report is to document the results, including an estimate of the costs and benefits, of monitoring frost levels in the roadbeds of specific log hauling roads. Greater awareness of the use of this technology to determine when to impose springtime load restrictions may lead to an increase in the number of hauling days available and/or to a minimizing of road maintenance costs.

Experience of BCMOTH

Traditionally, Benkelman beam measurements of pavement deflection (Figure 2) and/or visual observations of road surface deterioration have been used to determine when to implement load restrictions. However, over the past twenty years BCMOTH has been experimenting with a variety of temperature sensors to monitor frost levels in highway roadbeds, and has correlated the data obtained with pavement deflection measurements taken concurrently. It now has sufficient confidence in the subsurface temperature data that it is taking fewer deflection measurements and relying more on the temperature data to impose and rescind load restrictions on public roads under its jurisdiction.

Since 1990, geotechnical personnel of BCMOTH North West Region have progressively installed a network of temperature measuring stations along

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ISSN 1493-3381

Highway 16 between Terrace and Smithers.[1] Figure 3 illustrates a typical installation with details for monitoring either onsite with a portable readout instrument or remotely via the telephone system.

A typical temperature probe used in this region consists of a series of 17 electronic temperature sensors, or thermistors, spaced at 75–300-mm intervals. Overall, the assembly is approximately 25 mm in diameter and 2.3 m in length. It is inserted into a protective plastic sleeve and dropped into a hole drilled in the roadbed, with the highest sensor located 15–100 mm below the asphalt road surface. On primary highways, the probe is located in the outside vehicle wheel path to ensure that the surface will be free of the insulating effect of snow cover for the majority of time.

The thermistor output leads are run in conduit to a datalogger buried in a water-tight enclosure at the side of the road. Temperature readings are collected every six hours by the datalogger and downloaded by BCMOTH personnel in Terrace as required, via the telephone system. The series of sensors provide a temperature profile from depth to surface, which changes as the thaw progresses. Technicians can correlate this with weather forecasts and determine when to implement load restrictions.

Experience here has shown that when the temperature in the top 200–300 mm rises to -0.5°C, the strength of the roadbed will be at a critical point. Then, depending on the design strength of the particular roadbed, load restrictions may have to be imposed. Major highways, such as Highway 16, are designed to accommodate full highway-legal loads even through the spring thaw. However, secondary roads may be designed to a lower standard and hence, subject to load restrictions.

The Babine Lake Road is a public access road administered by BCMOTH but with numerous Forest Service roads feeding into it. It runs northeast from Highway 16 at Smithers. The 16 km of road immediately north of the highway had been a bottleneck for log haulers for many years. Although this section was paved, it was not designed to carry full, highway-legal axle loads through the spring thaw period. Its low elevation, combined with the thermal properties of the asphalt surface, resulted in an earlier thaw relative to the road sections at higher elevations. This led BCMOTH to impose early load restrictions. Thus, although the gravel-surfaced portion of the road extending to the higher elevations remained frozen and still capable of carrying full highway-legal weights, as was Highway 16, the log haul was forced to shut down.

Responding to this problem, BCMOTH rebuilt and repaved this 16-km section during the 1998 and 1999 construction seasons, and it is now rated to handle 100% highway-legal loads in its weakest condition.

[1] Highway 16 is a major East-West connector crossing the centre of the western provinces and providing a link to the west coast port of Prince Rupert.

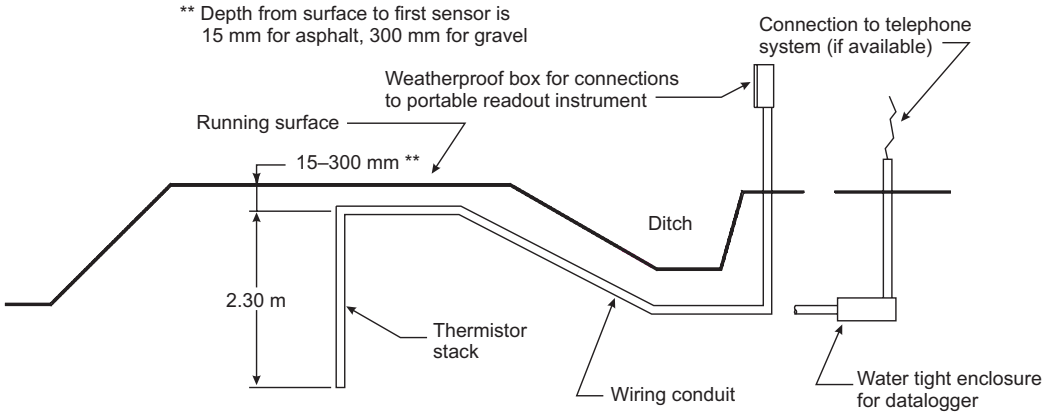

Figure 3. Road cross-section with thermistor station.

A thermistor station was installed at the 14.5-km mark and connected to the telephone system. In the years prior to this upgrading, decisions relating to imposition of load limits on Babine Lake Road were based on a combination of pavement deflection measurements on a control section close to Highway 16, and frost level data from the nearest thermistor station located about 15 km to the east on Highway 16 near Round Lake.

In the Thompson-Okanagan Region, BCMOTH has 15 frost probes located on major highways and another 6 stations on secondary roads.[2] The main differences between data gathered in this region and in the North West Region are the depth of frost penetration and the duration of the frozen condition. For example, four probes in the south Okanagan have an average frost penetration of one metre for six to eight weeks, compared to the 14.5-km station on Babine Lake Road which has penetration up to 1.8 m for over 15 weeks.

Experience of BCMOF

BCMOF Engineering Section in Smithers has undertaken two initiatives to obtain roadbed thawing information on specific log hauling routes. These are slightly different in the types of road surface involved, composition of the user group, maximum gross combined vehicle weights involved, and jurisdictional authority.

Morice River Road

The Morice River Road is a low-gradient, gravel-surfaced road running south from Highway 16 at Houston. Its use is regulated by BCMOF through road use contracts. There are many branch roads, but the main road of interest extends to an open pit copper mining operation. A major bulk hauling company hauls copper ore concentrate from the mine to Stewart, B.C. In addition, there are two forestry companies with operations along this road system, both with sawmills located in Houston. The log hauling operations using this road to feed the mills are entirely off-highway, and therefore the maximum vehicle loads, as specified in the road use contracts, can be 42–55% greater than highway-legal load limits. In contrast, the ore concentrate hauling vehicles carry only highway-legal loads, since their route continues west on Highway 16 after reaching Houston. The mining company and the two forest products companies constitute the road users group, and their contracts with BCMOF include a requirement to maintain the road.

Being aware of BCMOTH's experience in monitoring frost levels in thawing roadbeds, BCMOF decided to apply this technology in the management of the Morice River Road. Over the length of 122 km, the road rises from an elevation of approximately 600 m to approximately 1375 m. In 1998, BCMOF established four roadbed temperature monitoring stations to determine the rate of thaw over the elevation range. The conditions at the low elevation zones would dictate when load restrictions should be imposed, while conditions at the high elevation zones would determine the overall duration of the restrictions.

Starting at the 6.5-km mark, the stations were spaced at roughly 26-km intervals. The instrumentation at each station consisted of a stack of 10 thermistors installed in the centre of the roadbed in a manner similar to that used by BCMOTH. The top sensor is located approximately 300 mm below the road surface to ensure that it will not be disturbed by grading. Lead wires run from the thermistor stack to a weatherproof box at the side of the road where connections can be made to a portable readout instrument.

Prior to this installation, the decision of when to implement load restrictions was based strictly on visual evaluation of changing road surface conditions and the anticipated effect of forecasted weather. With a better understanding of the roadbase condition, as indicated by the temperature readings, and using the same criteria as developed by

[2] Jim Mader, Regional Roadway Design Technician, BCMOTH, Thompson-Okanagan Region, Kamloops, B.C., personal communication, August 2000.

BCMOTH, BCMOF can now decide, with greater confidence, how long to allow the winter log haul to continue before imposing load restrictions. This provides the optimum balance between maximizing the number of available hauling days and minimizing damage to the road.

On March 14, 2000, FERIC accompanied BCMOF engineers to collect data from the thermistor stations. A high temperature of -0.6°C was measured by the top sensor at the 6.5-km station, while corresponding readings at the other stations were 0.2–1.0°C colder. FERIC noticed that at the higher elevations the road maintenance crew was clearing accumulated snow and ice from the ditches to expedite drainage of water from the thawing roadbed. The thermistor readings recorded on this date were the first to raise concern for the continuation of the log haul. Based on this information and weather forecasts for the next several days, BCMOF made a tentative decision to impose load restrictions four days later. However, several nights of subfreezing temperature over the following days allowed them to delay implementation of restrictions to March 23. At this point, a maximum load limit (based on past experience) of 80% of highway-legal loads was imposed and the forest companies elected to discontinue the winter log haul. Only the mine haul continued, but with reduced payloads.

Babine Lake Road

Unlike the Morice River Road, the Babine Lake Road rises in elevation quite steeply as it leaves Highway 16. From an elevation of approximately 500 m it rises to approximately 1160 m at 53 km. The primary industrial usage of the road is for log hauling, but there is considerable recreational usage, particularly during the summer months. Log hauling vehicles using this road are limited to highway-legal load limits since they use Highway 16 to travel to their destination. In November 1999, at the instigation of BCMOF, two thermistor stations were installed at approximately 26 and 50 km to supplement the existing BCMOTH station at 14.5 km.

On February 23, 2000, when the temperature indicated by the top sensor at the 14.5-km thermistor station had risen to -1.8°C, BCMOTH imposed a load limit of 100% of highway-legal loads effective February 28, to avoid damage to the lower 16-km paved section. This meant that no overload permits would be issued after this date and any heavy equipment still in the harvesting areas could not be brought out until load restrictions were lifted, possibly as late as June. This load restriction did not directly affect the log haulers. At this time, although daytime ambient temperatures were on the rise, the roadbed temperatures at the 26- and 50-km sites remained below freezing, with the thermistor closest to the surface registering in the -2 to -3°C range.

In the first week of March 2000, daytime ambient temperatures were rising above the freezing point on a regular basis, so a more frequent monitoring of the thermistors at the 26- and 50-km stations was started. Depending on daily weather and ambient temperature variations, monitoring at these stations continued through March at one- to three-day intervals (Figure 4). Readings from the sensors closest to the surface gradually approached the critical -0.5°C level. On March 31, BCMOTH imposed a 70% highway-legal load limit effective April 2. This would have effectively forced the hauling contractors to shut down the log haul, had it still been operating, due to the poor economics of hauling partial loads. BCMOTH is reported to have commented that had the paved section not been upgraded,

Figure 4. Recording thermistor readings at 50 km, Babine Lake Road, March 13, 2000.

they would have had to impose reduced load limits on March 2 based on spring 2000's conditions.[3] Therefore, between the upgrading of the lower paved section and the monitoring of frost levels in the higher elevation sections, there was the potential for an additional 21 days of hauling prior to the spring shutdown. Of this number, 12 days can be attributed to more accurately determining when the thawing road was about to lose its load bearing capacity. Without this information, the log haul would have been planned to close on the traditional date of March 15.

Road user economics

Figures supplied by BCMOTH and BCMOF showed the cost of purchasing and installing the two manually read instrument stations on the Babine Lake Road was approximately $6300. BCMOTH supplied the thermistor assemblies at a value of $2900, leaving the balance of $3400 as a one-time cost to be split between the road users and BCMOF. Although BCMOF assumed the job of monitoring the instruments, in future years it may want to share these costs with the other road users. Such costs would probably be subject to negotiation and could be quite variable, depending on the time required to collect and disseminate the data.

Actual benefits accruing from this investment and the resulting additional hauling days experienced in 2000 are difficult to express in dollar terms at this time, since the extra days were not factored into the scheduling of the 1999–2000 winter haul. However, one indication of savings can be obtained by using FERIC's Log Transportation Cost Model to calculate just the haul cost savings resulting from an increase of 21 hauling days in a year.

Based on a fleet of 16 vehicles of various configurations hauling an annual volume of 221 000 m^3 over a 125-km route using the Babine Lake Road, a savings of $0.80/$m^3$ could be realized as a result of the extended spring hauling period. However, one mill actually stopped hauling on March 24, 2000 as a result of filling its logyard. Theoretically, if the haul had continued to the April 1 cut-off date and the mill had continued to consume a portion of that intake, the inventory volume required to carry the operations through the balance of the spring and early summer would be less, and hence the total dollar value of the inventory at the end of the haul would be lower. The lower inventory volume would result in shorter storage time for the earliest delivered wood. Therefore, the inventory would, on average, be fresher at the time it was processed by the mill, resulting in higher quality end products. Other benefits of a longer log haul period include lower dollars/hour ownership costs for trucks and harvesting machinery, a more even flow of logs coming into the millyard, and the possibility of attracting and retaining a more stable workforce.

Results and discussion

Traditionally, mills in the Smithers area, whose hauling contractors use the Babine Lake Road, plan their winter log haul to end during March 10–15, subject to BCMOTH load restrictions based on the low-strength paved section at the lower end. With the upgrading of this section, the focus for determining when to impose load restrictions that will affect log hauling has shifted to the higher elevation gravelled portion of the route. Data from the 26- and 50-km thermistor stations will allow BCMOTH to decide how long to allow the winter log haul to continue before having to impose load restrictions to protect the upper gravelled portion of the road. In March 2000, an additional 12 hauling days were available as a direct result of monitoring roadbed frost levels specific to this haul route. It is important to note, however, that the 1999–2000 winter had been exceptionally mild and resulted in higher than expected roadbase temperatures.

[3] Gordon Gunson, Woods Manager, West Fraser Mills Limited, Pacific Inland Resources Division, personal communication, May 2000.

Haul cost savings of $0.80/m^3 were calculated using FERIC's Log Transportation Cost Model. Other anticipated benefits include:

- reduced mill log inventories with attendant lower total dollar value
- higher quality end products resulting from having fresher wood for processing
- more even hauling schedules throughout the year resulting in increased employment for drivers, loader operators and harvesting crews
- lower hourly ownership costs for vehicle and machine owners and the possibility of attracting and maintaining a more stable workforce

On the Morice River Road, it has been traditional for mill operators to aim to haul until the end of the third week in March. The actual shutdown date varied from year to year but was dependent on BCMOF engineers' visual evaluation of road surface conditions. In March 2000, the mills' planned hauling shutdown date coincided almost exactly with the imposition of load restrictions by BCMOF. The mills did not realize any additional hauling days as a result of the frost level monitoring. However, they did have reassurance, in the temperature data reported by BCMOF, that they would not be causing excessive damage to the road and incurring large maintenance costs as they approached their inventory targets. Observation of this road in the springs of 1999 and 2000 has shown that the monitoring of frost levels in the roadbed is a valuable tool in managing the road system for maximizing the winter log haul opportunity while minimizing damage due to heavy vehicle traffic.

Relying on visual observation of road surface deterioration to determine when to reduce allowable vehicle loads is dependent on subjective evaluation and is frequently conservative. This may result in a loss of hauling opportunity. In addition, while some visible deterioration may be acceptable on a gravelled surface (since it can be corrected by grading), on a paved surface, the degree of damage is much greater when it has progressed to the point of being readily visible.

The use of -0.5°C as the trigger point for imposition of load restrictions (per BCMOTH North West Region practice on asphalt surfaced highways) may not be entirely appropriate for gravelled roads, given the difference in heat absorption between asphalt and gravel. However, it is probably conservative and allows for some flexibility in establishing a specific date for implementing load restrictions. Blair (2000) indicates that once the roadbed is completely thawed, temperature alone may not be an adequate indicator of when hauling may be resumed. Other factors, such as the rate at which the moisture content decreases over time, vehicle configuration, number of axles, and use of optimized tire pressures, have a strong influence on this decision.

Conclusions

Roadbase temperature monitoring offers a quantitative method for determining the onset of thawing and associated loss of load bearing capacity. Applying this technology to a particular log-hauling road provides site-specific data for effectively managing the road network. It ensures that the maximum number of haul days are achieved before having to restrict hauling to avoid incurring excessive road maintenance costs.

The one-time cost of installing one or more thermistor stations on a log hauling route is a relatively small investment for most mills to make in return for the potential benefits accruing from the additional hauling days obtained. If several mills share the initial cost, the net benefits to each are even greater.

Based on data obtained in the spring of 2000, planning for the winter 2001 haul on the Babine Lake Road will be able to include, with some certainty, the extra days experienced this year. It may then be possible to track the actual benefits from various perspectives.

Implementation

- On critical log hauling roads, where location or structure suggests that thawing occurs later than the date when load restrictions are usually imposed, the installation of thermistor stations should be considered in conjunction with the respective regulatory authority.
- Thermistor readings should be gathered on an annual basis and analyzed in conjunction with annual weather variations to determine the latest date for the spring shutdown of the log haul in future years.
- Industry and BCMOTH should cooperate in the identification and upgrading of secondary public roads that become bottlenecks to log hauling in the spring, as a means of extending the winter log hauling season.
- To further increase the number of available hauling days, continued study should be made of factors affecting the earliest date when hauling can be resumed as the roadbed strength recovers.
- Once the spring thaw begins in earnest, ditches should be cleared of accumulated ice and snow to speed the drainage of water trapped in the upper roadbed.
- Consideration should be given as to whether, or to what extent, the techniques discussed in this report are applicable in the southern parts of the province or other regions where the depth of frost penetration is less than 1.8 m.

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Acknowledgements

The authors would like to express their appreciation for assistance and comments provided by Thomas Bosch, Engineering Assistant, Morice Forest District, Ministry of Forests, Houston, B.C. and Brent Andrews, Roadway Design Technician, North West Region, Ministry of Transportation and Highways, Terrace, B.C.