Minimizing the Environmental and Economic Impact of Unpaved Road Maintenance

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Abstract

MINIMIZING THE ENVIRONMENTAL AND ECONOMIC IMPACT OF UNPAVED ROAD MAINTENANCE

Every year the total length of roads in Canada increases with the greatest amount of growth in non-paved roads for resource recovery and rural development. Accompanying this growth in road kilometers is a general decrease in the availability of aggregate resources for new construction and maintenance. In order to maximize the use of available aggregate and financial resources, this desktop study reviews the various methods and equipment available for non-paved road maintenance. This study uses case histories and conventional procedures as part of the review process.

Typical road maintenance techniques including grading and graveling as well as newer techniques such road reclaiming equipment are reviewed. The applicability of each technique for a number of common rural road concerns is reviewed. Road problems or defects include potholes, washboard, slippery surface, rutting, etc. The function or physical process for each maintenance technique is described with an emphasis on differentiating between the techniques. Finally, the paper attempts to quantify the complete applicability of each type of maintenance equipment. Additional considerations such as conservation of renewable resources and environmental impacts are reviewed. The paper's conclusions provide engineers, public works supervisors and anyone responsible for non-paved road maintenance an overall review of the applicability of various maintenance techniques, their pros and cons and the most appropriate occasion for their use.

1.0 Introduction

Every year the total length of unpaved roads in Canada and North America increases - currently over 2.6 million kilometres. A great number of these roads are unpaved and are being constructed to service the resource industry including oil, gas, mining and logging activities. These roads are being linked to existing road networks to carry raw materials to established central redistribution and processing points. Consolidation of the railway's grain transfer points has also placed additional burdens on rural roads. Many rural roads need to accommodate heavier loads and are generally required to support these loads regardless of weather conditions.

Counties, Municipalities and road authorities are charged with the task of carrying out the necessary maintenance activities on these roads from their limited budgets. The costs of road maintenance are escalating with the decreasing availability of aggregates used for road surfacing and the ongoing increases in equipment and labour costs.

For example, a study of unpaved road maintenance costs was carried out by the Rural Municipality of Eldon No. 471 in 1999. The Municipality is located in the heart of the Saskatchewan oil zone approximately 50 kilometres east of the Alberta border. The Municipality at the time had a gravel road network of approximately 456 kilometres (285 miles).

- The study established that over a five (5) year period road maintenance expenses as a percentage of the municipal taxes were as follows:

1998	95%
1997	103%
1996	73%
1995	73%
1994	90%

Over the five-year period the Municipality was using between 35,000 to 40,000 cubic metres of traffic gravel annually to maintain and preserve their municipal road surfaces. This illustrates the huge impact of unpaved road maintenance costs on the local authorities.

With such large costs implications, the efficiency of the maintenance procedures and the possible use of new procedures has been reviewed.

2.0 Road Surfacing Alternatives

The purpose of road surfaces is to provide a relatively smooth and uniform riding surface with sufficient traction for acceleration and stopping. The surface should be free of defects and function in all weather conditions. There are two different surfacing alternatives used in North America - hard, permanent pavements and short term or unpaved surfaces.

2.1 Paved Roads

Paved roads are used for primary highways and urban roads and are something that everyone is familiar with and takes for granted. These roads are paved with Hot Mix Asphalt or Concrete with sufficient depth to support the loads. They are designed to handle high traffic volumes, loads or speeds with minimal maintenance. The condition of these roads is expected to be near optimum at all times. These surfaces are very expensive to construct and repair and function best with regular traffic.

2.2 Unpaved Roads

Due to the high cost of paved roads a variety of unpaved road surface types are used. The common types are: gravel road surfaces, thin membrane bituminous surface treatments and bituminous cold mix surfaces. These roads require a much lower capital expenditure for construction but rely on ongoing regular maintenance to provide a functioning surface.

Gravel roads provide the lowest level of service as the surface is level but not smooth and the traction is fair. Gravel roads tend to be surface treated with 50 to 100 millimeters of aggregate placed and compacted onto a prepared subgrade. The maintenance is typically twofold with the addition of gravel frequently at the beginning and then every two to four years after the base has been established; and the regular repair of surface defects. Surface defects such as potholes, washboard, and the shifting of gravel away from the wheel path are typical.

Bituminous surface treatments are constructed by first applying a layer of asphaltic binder and then placing a lift of crushed graded aggregate on top the binder and then compacting the aggregate into the binder by use of pneumatic tired and/or steel drum rollers. These surfaces are generally referred to as Graded Aggregate Seal Coats or Thin Membrane Surfaces.

Bituminous cold mix surfaces are also used which consist of a premixed asphalt product that relies on water or solvents to keep the product workable. The bituminous products are placed on the subgrade or are part of a structure that may consist of granular base course material. These surface types produce a smooth driving surface with good traction and drainage. It should be noted that these surfaces have very limited strength and they rely on the subsurface soils to carry traffic loading. Maintenance for these roads consists of patching and crack sealing similar to paved roads until the base fails when reconstruction is required.

3.0 Conventional Maintenance Procedures

3.1 Gravel Surfaced Roads

Following construction of a new unpaved road base an application of traffic gravel is applied to the road surface to aid in stabilizing the insitu material, to add strength to the subgrade material and to provide traction. Gravel application rates vary due to differences in soil conditions and constructed top widths. Average application rates generally start at approximately 200 m^3/km for 7.0 m top widths. The cost of producing crushed aggregate for traffic gravel, hauling, placing and spreading it on the roadway can vary greatly depending on availability. These costs can be substantial in areas with limited aggregate availability.

Through normal road usage, traffic displaces the surface gravel and rows of loose material collect between the regularly traveled wheel paths and along the shoulders. Higher speed traffic also tends to kick gravel from the road surface onto the sideslopes and into the ditches. Snow removal during winter maintenance also causes traffic gravel loss as a percentage of loose aggregate is removed from the road along with the snow.

Conventional maintenance procedures for defect repair consist of blading of the road surface with a motor grader. A **motor grader** is a self-propelled piece of road construction and maintenance equipment primarily designed to move loose material with its blade. A motor grader is used to eliminate or reduce surface deficiencies or failures such as potholes, washboards and ruts. The motor grader tends to correct these deficiencies by moving gravel along the length of the road from localized high areas to localized low areas or defects. The grader is generally very effective at restoration of shallow defects but defects that are more severe are covered over but tend to reappear sooner. The motor grading is able to move aggregate laterally across the road to adjust the crown or slope.

The standard operating blade of a motor grader is not designed to break into hard surface roads.

Blade attachments can be mounted on the motor grader blade to break into road surfaces. Use of these blade attachments on hard road surfaces can fracture the road surface material or lift it in slabs making the material difficult to work with. Ripper bar attachments can be mounted on the back of motor graders to aid in facilitating the breaking into hard road surfaces. Ripper teeth break the road surface into large pieces, which then need to be reduced in size by other means. Ripper bars lack precise depth control, which can sometimes cause additional maintenance concerns such as contact and unwanted intermixing of subsurface materials.

Normal motor grader operating costs (including operator) are in the $100 to $200 per hour range depending on the size of the machine. Generally one motor grader is required for every 100 to 150 kilometres of road to be maintained annually.

3.2 BITUMINOUS SURFACED ROADS

Maintenance of these road surfaces consists of a crack filling and patching program. Over time and traffic loading these road surfaces degrade to the point that they can be very expensive to maintain and exhibit a very poor ride quality. When this point is reached the bituminous surface is in a state that it is no longer maintainable and the only alternative has been to remove the surface and reconstruct.

4.0 Innovative Equipment

Through the years many types of new and innovative equipment have been developed and refined for use in road maintenance. Some of these are the windrow pulverizer, shouldering disks, grader mounted dozer blade, grader mounted roller compactor, rock rakes, reclaimer/pulverizer, etc.

Two of the latest types of equipment that have been developed are the reclaimer/pulverizer and a piece of equipment that restores the road surface called the Road Badger.

The **reclaimer/pulverizer** is a piece road reconstruction equipment which pulverizes existing road surface and base materials ultimately ending up with a homogenized mix of both to establish a new base layer. Reclaimers were originally designed for the breaking down of concrete and hot mix asphalt surfaces and are now also being used for cold mix and gravel road applications. The newest models of this equipment are generally mounted on a front-end loader platform and are powered from an additional source most often a high horsepower diesel engine. As a general rule after the break up of the original surface has been completed additional materials are added to complete the resurfacing operations. The reclaimer is effective in all types of unpaved roads when the base has deteriorated to such a degree that it cannot support the traffic loads. This equipment will mix the surface and base to depths of 300 to 500 mm to provide a uniform base for placement of additional traffic gravel.

The **road restoration equipment** reviewed was developed specifically to provide maintenance of gravel and bituminous surface treatment surfaced roadways. This equipment has a frame mounted ripper bar for ripping the road surface to a controlled depth which is followed by a separator system for separating coarse and fine material in the road surface such that the coarse material is deposited on the fine material. The ripper bar has teeth in rows on both sides of the ripper and is rotatable so that either set of teeth, which may be at different heights, rip the road surface. The separator is formed of ground turning disks mounted on angled shafts. The depth of the rippers and separators is precisely controlled to a maximum depth of 150 millimetres so as not to penetrate the sub-surface material.

The unit is self contained, powered by a four cylinder air cooled diesel engine and may be pulled by a wide variety of equipment including motor graders, tractors, loaders, packers or trucks. This equipment is well suited for restoration of road defects to a depth of 125 mm. The advantage of this equipment is that it brings the coarse gravel to the surface without moving the materials horizontally. This provides a restored roadway surface that is uniform and has good traction properties. Operating costs range from $3 to 8 per hour plus the cost of the vehicle that is pulling it ($80 - $200).

5.0 Comparison of Maintenance Procedures

There are three methods of maintenance that this paper will look at in depth; Conventional Motor Grader; Reclaimer/Pulverizer and Road Restoration Equipment.

Conventional maintenance consists of passes with a **motor grader**. The grader will typically make two to four passes over every lane, one to three passes to loosen and move and another to move and tamp. Problem areas will commonly require more passes of the motor grader. This maintenance method is very good at maintaining or re-establishing the road crown and slopes. It also removes the shallow surface defects, however it is not as effective at deeper defects as it moves gravel to fill in low areas thereby reducing the gravel thickness in other areas. One motor grader will be required to complete the maintenance of 100 to 150 kilometres per season. It is expected that maintenance with a motor grader alone would be required every 4 to 8 weeks.

The **reclaimer/pulverizer** is well suited to severely deteriorated roads, and with the addition of surfacing gravel it provides an improved road base for a rejuvenated road surface and structure. This equipment is not well suited to regular maintenance and additional compaction equipment is required. This equipment is best suited for the reconstruction of paved and unpaved roads that are past their design life and require more than surface improvements. It is expected that reconstruction with a reclaimer/pulverizer may be required after 5 to 20 years.

The **road restoration** equipment, the Road Badger uses the existing road gravel to provide a better road surface. By loosening and sorting the gravel in place, the equipment is able to repair roadway defects without reducing gravel thicknesses around the defect. The equipment is not self propelled and requires a tight blade pass from a motor grader to complete the maintenance. Advantages of this equipment are that it utilizes the existing road gravel without disturbing the subgrade soils and thereby lengthens the time between regravelling. One road badger unit can restore about 400 to 500 kilometres of road each season. It is expected that maintenance with a road restorer would be required once or twice per year.

Table 1.0: Equipment Comparison

Rating	Motor Grader	Reclaimer/ Pulverizer	Road Badger
Maintenance Rating			
Pothole Repairs - Shallow	E	F	E
Pothole Repairs - Deep	G	G	E
Washboard Repairs - Shallow	E	F	E
Washboard Repairs - Deep	G	G	E
Crown / Slope Restoration	E	F	F
Efficiency / Production			
Lane - km/Day	12	10	20
Maintenance Occasions	3 – 5 per year	Every 8+ years	1 - 2 per year
Re-Gravel Frequency	2 - 4 years	2 - 3 years	3 - 7 years
Ease of Operation	G	F	E
Suitability for Maintenance	E	F	E

Legend: E - Excellent
G - Good
F - Fair

In a 2002 a case study was undertaken on 117 kilometres of resource roads in Northern Alberta. The use of the Road Badger for road restoration was credited with saving over 45,000 m^3 of gravel over one construction season.

6.0 Conclusion

Based on the information gathered and provided in this report conventional road maintenance procedures are not efficient and are not maximizing the limited resources of most road authorities. There are savings in the efficiency of the maintenance and in the annual cost of aggregates by utilizing new road maintenance equipment. The reclaimer/ pulverizer is not considered to be viable for maintenance purposes but may be valuable for reconstruction activities.

The use of road restoration equipment such as the Road Badger provides better maintenance of deeper road defects meaning a longer return period until those defects appear again thereby reducing the frequency (and cost) of annual maintenance. The road restoration equipment provides a surface that is free of defects and provides good traction without the addition of gravel. The use of this type of equipment is expected to lengthen the time between applications of additional aggregate.

An unpaved road maintenance program that incorporates motor graders for the light maintenance and road restoration equipment for moderate to severe maintenance is considered the most efficient. The reduction in maintenance frequency and the application of additional aggregate has significant cost and environmental resource impacts. The costs of aggregate are climbing as the costs of fuel, the haul distances and the cost of the aggregate supply increase. Less operating hours for trucks hauling aggregate and maintenance equipment as well as the increased fuel efficiency of vehicles traveling better maintained roads results in a large positive environmental impact. The 2002 case study in Northern Alberta which saved an estimated 45,000 m^3 of gravel resulted in a reduction in fuel consumption of just under one million litres of diesel fuel.

A combination of conventional and innovative maintenance methods should be implemented to balance the rising costs of road maintenance. Economic benefits, preservation of non-renewable aggregate resources and reduction in fuel consumption can be achieved by integrating innovative technologies with conventional procedures.