Sensitive sites, poor soils and heavy loads: Meeting traditional low-volume road challenges in Canada with 21\textsuperscript{st} Century solutions

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Content

- FPInnovations
- Context of resource roads in Canada
- Challenges building roads over wetlands and with poor quality materials
- Road design solutions
- Road friendly trucks
- Conclusions
FPInnovations

Canada’s Forest Innovative Hub

- One of the world’s largest private, not-for-profit, member based forest research and innovation centres
- Unique Industry/Government Partnership
  - 80-year history
  - >250 members
- World-scale Forest Sector Research
  - 550 specialized staff
  - Annual budget: $CA90M
- A track record of developing and deploying innovations needed by the industry
FPInnovations

From ideas to market value

FPInnovations’ unique value chain capacity includes innovative approaches to enhance economic returns in:

- Forest fibre
- Forest Operations
- Wood Products
- Pulp & Paper
- Bio-products
Forest Operations in Canada

Highlights

- Annual harvest around 140 million m³
- 90% harvest on public land and 10% on private land
- 95% contractor operations employed by forest companies
- Contractors can own a single machine or a small fleet (large size range)
- Roads typically built and maintained by contractors/forest company
- Some roads maintained by provincial government
Forest Operations in Canada

Challenges

- Long transportation distances between the forest and the mills
- Operating season (harvesting, trucking) can vary from 6 to 11 months
- High transport costs
- Environmental concerns and increased pressure to develop resources
- Lack of forest workers – especially log hauling truck drivers
Canadian Resource Roads

- Are they really low-volume roads??
- Traffic volume can range from 50 to >1000 ADT
- Loads can range from 57 t to >150 t

Source: R. Douglas 1988
Canadian Resource Roads (unpaved)

Primary
- Life >25 years
- 8 to 10 m wide
- Crushed aggregate as running surface
- Dust control often used

Secondary
- All-season road
- Life 5 to 15 years
- 7 to 9 m wide
- Good quality pit-run or screened material as running surface

Tertiary
- Seasonal use only
- Life 1 month to 2 years
- 5 to 7 m wide
- *In situ* material or near-by pit-run as running surface

Winter roads
- Frozen months only
- 5 to 6 m wide
- *In situ* material and snow
Pavement design challenges

A working “system”

Creating Connections

Axle loading

Thickness design

In-situ subgrade soils
For every *in situ* soil challenge..
..there is a road design solutions!
Roads and wetlands

A new reality

- Accessing fiber through sensitive sites
- Environmental bar has been raised
- Working closely with NGO’s such as Ducks Unlimited Canada
- Maintaining hydrologic function, quality in wetlands and ecosystem function
- Social licence
Roads and wetlands

- Drainage and bearing capacity
- Mitigating the environmental impact
- Maintaining the hydrological function (efficient drainage, water quality)
- Long-term structure performance
- Bearing capacity and foundation improvement

Challenges
Design solutions with geosynthetics

Four functions of a geosynthetic

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<th>Non-woven</th>
<th>Woven</th>
<th>Geogrid</th>
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<td>Separation</td>
<td>✔ ✔</td>
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<td>Reinforcement</td>
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<td>Filtration</td>
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<td>Drainage</td>
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- Non-woven
- Woven
- Geogrid
Roads and wetlands - Drainage

Log bundles to provide water passage

- Culvert surrounded by bundle of logs (corduroy) placed on the harvested stumps in the right-of-way in drainage channels or wet areas. Rootmat is not cut or disturbed.

- Geotextile separates the logs from the granular base course and provides some load sharing to protect the culvert.

- Logs extend across entire road width and aligned with butts and tops mixed.
Roads and wetlands - Drainage

Log bundles to provide water passage

- Currently monitoring the performance of several installations
Design solutions with geosynthetics

Separation function

- Prevents the aggregate from punching down into the subgrade, and fines pumping upwards to contaminate the base course.

- Maintains a consistent thickness of the as-designed granular specification.
Design solutions with geosynthetics

Reinforcement (Membrane support)

- Mobilizes at very low strains if a thin aggregate layer is used and rutting of subgrade occurs.
- Anchoring is important to develop support.
Design solutions with geosynthetics

Reinforcement (Bearing capacity increase)

- “Snow-shoe” effect with Geogrid
- Wider distribution of vertical pressure on subgrade
Design solutions with geosynthetics

Reinforcement (Lateral restraint)

- Geogrid interlock: Interlocks with aggregate at its subgrade interface preventing lateral movement of the aggregate
- Geogrid confinement: Provides a uniform confinement plane below the aggregate and limits the amount of rutting and upheaval of the subgrade
- Woven geosynthetic: Friction
Case study – Upgrading a road for all season use with geosynthetic

Typical surface distress before construction

- Significant rutting
- Structural failure of the underlying base layers and subgrade
- Deep depressions perpendicular to traffic
Geogrid reinforcement

Design approach

100 mm wearing course “metal”

200 mm base course
Geogrid

Clay Subgrade
Geogrid reinforcement

- Compacted subgrade
- Overlapped geogrid and tie-wraps

- Crushed aggregate base and wearing course
- Compacted

- Dust control/surface stabilization
- Rejuvenation several times per season

- Minimal-to-no grading needed between applications
- Reliable all-season road
Geogrid reinforcement

Performance

- Surface CBR values >150
- Surface Modulus >160 MPa
- Modulus approached values of thin asphalt surface treatments
- Approx. 7000 heavy trucks per summer (100,000 ESALs)
- GCVW 60 to 68 tonnes (5 to 7 axles)
Geotextile separator

Separation of fine-grained soils

- Placed during the winter on frozen subgrade
  - Easier to install
  - Access with heavy vehicles
  - Reduced rutting during construction

- Surfaced with well-graded aggregate
GRS – Geotextile Reinforced Soil

- Multiple layers of closely spaced geotextile and compacted granular fill. Faced with wire forms.
- Geotextile confines granular materials creating a composite, reinforced block of fill.
- GRS structures are very strong, resistant to water and vibration. Very long lasting with no or minimal maintenance required.
- Granular fill is usually from site. Other materials are inexpensive, light and easy to transport.
**GRS – Geotextile Reinforced Soil**

**Stream crossing applications**

- GRS arch concept for open-bottomed culverts:
  - Load is transmitted through soil arch to foundation areas – no footings needed; steel arch only for construction form and erosion protection.
  - Erosion resistant design and wide foundation areas are less susceptible to undercutting.
  - Vertical-faced road embankments minimize culvert length.
  - Versatile design allows founding on weaker soils
  - Reduces crossing costs by up to 30%
Mitigating the impact of heavy vehicle traffic

“Road friendly” technologies

- Reduces the impact of the load on the road structure
- Effectively “spreads the load” over a greater surface area

- Solutions for:
  - Construction equipment
  - Heavy vehicles on unpaved roads
  - Heavy vehicles on paved road
Road construction solutions

High flotation tyres

- High flotation and traction capabilities
- 750/45R22.5
- 45 psi (5800 kg)
Road construction solutions

High flotation tyres

- Reduced contact pressure and rutting
- Lowered road construction and maintenance costs
Tyre Pressure Control Systems (TPCS)

- Also known as Central Tyre Inflation (CTI)
- Widely used in Canada for the past 15-20 years
- Southern hemisphere has been implementing TPCS for a while now (Argentina, Brazil, NZ, Australia and South Africa)
Over 1000 TPCS in use in Canada

- Vacuum trucks
- Bed trucks
- Other oil & gas specialty trucks
- Low beds (floats)
- Log trucks
- Transit mixers
- Transport trucks (wood chips, petroleum, potatoes, etc.)
- Gravel trucks
Tire & Rim Association Load–Speed–Inflation for 11R24.5 tires

Industry Norm

900 1400 1900 2400 2900

Cold Tire Inflation (psi)

900 1400 1900 2400 2900

Tire Load (kg)

56 kph

105 kph

2250 kg

80 kph

Design

Footprints

Industry Norm
Reducing Inflation Pressure Causes Fundamental Changes to Tyre-Road Impacts

- Stiffness and Spring Rate
  - 90 PSI
  - 25 PSI

- Contact Area
  - Contact stress distribution

- Lighter footprint, more tread
- Less impact energy
Key USFS findings on variable tire pressures & resource roads

- Slower rutting rate – especially on very weak roads and for low traffic volumes. Wider, shallow ruts.
- Less gravel loss (less dust control & re-gravelling)
- Less gravel needed for structural requirements
- Reduced pot holing and corrugations
- Healed existing damage (ruts and corrugations)
- Reduced (or eliminated) maintenance grading
- Enhanced traction and mobility under steep or slippery conditions
Key findings from operations using TPCS on resource roads in Canada

- Trucks must vary their wheel paths to slow rutting
- Don’t mix high/low pressure traffic - TPCS trucks create a packed surface crust allowing them to work on soft roads
- TPCS on drive and trailer tyres needed - to get traction and mobility gains on soft wet roads
- Grading savings - if graders can be redirected to other work
- Self-loading log trucks able to forward loads from very weak block roads
- TPCS allows trucks to resume hauling after wet weather
- TPCS can extend operating season into traditional shutdown periods with large savings in inventory and mill yard handling losses
Vertical stress distribution in a low standard road

Largest stress reductions occur in surfacing and base layers

Vertical stress, psi

Depth, mm

-1500

-1250

-1000

-750

-500

-250

0

2045 kg tire load

100 psi inflation

65 psi inflation

35 psi inflation
Effect of tyre pressure on pavement strains and cracking

- Thin A/C experience higher strains at the bottom of the mat than thick A/C.
- Thin A/C pavements rut from high base and subgrade vertical strains so TPCS helps this. Especially beneficial in wet road conditions and on roads where base is contaminated with lots of fines.
- Transverse strains are more sensitive to low tire pressure than longitudinal strains but both respond.
- Steering tires create larger transverse strains than longitudinal strains; the reverse is true for dual-tired assemblies.
- Smaller numbers of steering tires have less pavement impact than dual-tired assemblies, however, their impacts become more comparable at low pressure.
- Impacts of heavily loaded single tires could be reduced with lower pressures.
TPCS impact on thin A/C pavement rutting and distortions

- Truck dynamic axle loadings = 2 to 14x static loadings at rough spots on A/C depending on suspension, speed, bump size, load, etc.

- TPCS tire generated 1/6 vertical energy of high pressure tires at bumps (NATC test).
**TPCS and public policy**

**TPCS compensates for heaving truck payloads**

- Saskatchewan trucking policy allows TPCS trucks at Primary Highway weights to haul on Secondary Highways (assuming no net increase in damage)

- FPInnovations evaluation for Nova Scotia indicates that TPCS-equipped B-Trains could operate on weak secondary pavements with no net increase in damage

- These changes shorten many routes and cycle times, improve on truck efficiency and utilization, lower hauling costs and GHG emissions, reduce number of drivers needed
TPCS and public policy

Operating during spring-load restriction periods

- Implemented in Saskatchewan, British Columbia, Ontario, Manitoba
- Policies require on-board computers to monitor tire pressure, speed, routes and load
- Effectively extend haul season by 1 to 4 weeks – more flexibility, more revenue
- Potential to reduce mill inventories or risk associated with running smaller inventories
Operational benefits from TPCS

- Improved traction
  - Fewer & shorter delays from getting stuck
  - Fewer assists so shorter cycle times and lower repair costs
  - Fewer assists saves on cost of redirecting harvesting machines to make assist trucks

- Improved tire performance
  - Longer tire life and fewer flats
  - Reduced maintenance costs

- Reduced vehicle maintenance
  - Reduced vibrations on chassis and suspension
  - Improved fuel consumption

- Improved operator comfort!
Conclusions

▪ Innovative road design and construction solutions combined with “road friendly” truck technologies provide opportunities for more reliable transportation

▪ Today’s technologies allow access to difficult sites and construction with weak and sensitive soils while minimizing the environmental impact:
  • Improved drainage designs
  • Tighter running surfaces to shed water and slow deterioration
  • Geosynthetics for strengthening weak subgrades
  • Road friendly vehicles for construction and transport
Upcoming event of interest!

**11th International Conference on Low-Volume Roads**

- July 12 to 15, 2015
- Pittsburgh, PA, USA
- Hosted by the Transportation Research Board (TRB)
- Conference held every 4 years, will feature the latest about low-volume road management, design, construction, safety, maintenance, and many other related topics.

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<td>December 2013 – March 2014</td>
<td>Website open for submission of draft manuscripts</td>
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Questions and answers
Thank you!

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