EFFECT OF COLD IN-PLACE RECYCLING ON THE HEAVYWEIGHT TRUCKING INDUSTRY

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Presented at:

6th International Conference on Heavy Vehicle Weights and Dimension Proceedings
Saskatoon,
Pp 447-457
2000

ABSTRACT

The province of Saskatchewan is very dependent upon the heavyweight trucking industry whose continued growth ties in directly to the Province's economic well being. Consequently, the condition of the Province's road network is directly linked to its use by the trucking industry. It is to the Province's advantage to research and develop long term preservation strategies with a high benefit to cost ratio to keep the road network in the best state possible.

Cold in-place recycling or "CIR" is an attractive alternative for highway rehabilitation because of its economic and structural strengthening advantages. The top of the road surface is milled, recycled with an emulsion and reapplied to the roadbed with an overlay to create a new driving surface. This mixture continues to cure and strengthen structurally as cohesion increases. CIR mixtures have larger modulus values and significantly greater fatigue lives than standard hot bituminous mixtures and are able to withstand heavier loadings.

Other jurisdictions have found that CIR is a cost effective rehabilitation method because no aggregate material needs to be transported; it conserves aggregate resources and eliminates all types of paving distresses. It is an environmentally friendly process that is a minor inconvenience to the trucking industry when being conducted. The original crown and cross slope of the roadway can also be restored while engineering costs such as design and surveying are reduced.

The public will benefit through reduced preservation costs, while also enjoying the economic growth that is tied to the Province's trucking industry. The department's use of this technology is still in the infancy stage and we are continuing to examine its viability and applicability to Saskatchewan's transportation network.

1.0 INTRODUCTION

The province of Saskatchewan is very dependent upon the heavyweight trucking industry whose continued growth ties directly to the Province's economy. Consequently, the condition of the Province's road network is directly linked to its use by the trucking industry. Saskatchewan Highways and Transportation is responsible for managing approximately 26 100 km of two lane equivalent roads, with an estimated capital asset value of $4.1 billion. Given the enormous capital asset value of the Saskatchewan road network and the direct link it has to the Saskatchewan economy, balancing preservation of Saskatchewan roads while promoting transportation efficiency is important to Saskatchewan.

It is to the Province's advantage to research and develop long term preservation strategies with a high benefit to cost ratio to keep the road network in the best state possible. Cold in-place recycling (CIR) is an attractive alternative for highway rehabilitation because of its economic and structural strengthening advantages.

Other jurisdictions have found that CIR is a cost effective rehabilitation method because limited amounts of or no aggregate material needs to be transported; it conserves aggregate resources and eliminates many types of paving distresses. It is an environmentally friendly process that is a minor inconvenience to the trucking industry when being conducted. The original crown and cross slope of the roadway can also be restored while engineering costs such as design and surveying are reduced.

The public benefits through reduced preservation costs, while also enjoying the economic growth that is tied to the Province's trucking industry. The department's use of this technology is still in the infancy stage. Saskatchewan Highways and Transportation will continue to examine CIR's viability for preserving the Saskatchewan's transportation network.

2.0 IMPACT OF THE TRUCKING INDUSTRY ON SASKATCHEWAN'S SECONDARY HIGHWAY NETWORK

Changing transportation policies over recent years have increased commercial trucking on many Saskatchewan roads. Of particular concern has been the recent removal of the Crow Rate for the transportation of export grain and economic diversification and value added initiatives within the Saskatchewan economy. Abolishment of the Crow Rate has led to rapid rationalization of the provincial grain handling system. This has resulted in rail companies abandoning branch lines and elevator companies replacing hundreds of country grain elevators along rail branch lines with fewer, but substantially larger inland terminals along the rail mainlines. As a result, farm to market delivery of grain has shifted from multiple short trips in two and three axle farm trucks to larger, more efficient commercial trucks.

In addition to grain transportation rationalization, the government of Saskatchewan has encouraged both economic diversification and value added activities within the Saskatchewan economy. Examples include the development of the Province's' oil and gas reserves, expansion of the hog industry, and development of the province's mining sector. The combined impact of grain transportation rationalization and proactive economic diversification has, and will continue to, increase truck volumes by several orders of magnitude on many Saskatchewan roads. Truck weights and dimensions have also increased to larger, more cost-effective configurations as shown in Figure 1 and Figure 2.

While these changes in Saskatchewan's commercial trucking profile have long-term implications for the primary highway system, these major routes are designed to accommodate significant volumes of heavily loaded trucks. Consequently, they experience only marginal increases in preservation costs over their design lives. On the other hand, these increases in commercial truck traffic have significant and often; immediate implications for Saskatchewan's local roads. Many of these secondary roads were not initially designed to accommodate significant numbers of heavily loaded commercial trucks. Increasing commercial truck traffic has translated into the need to strengthen many Saskatchewan secondary roads.

Of particular concern in this regard is the approximately 8 600 kms of Saskatchewan non-structural thin membrane surfaced (TMS) roads. Originally, TMS roads were not intended to add structural capacity to the road structure, but were a cost effective means to provide dust, mud, and stone free roads to local rural residents where truck traffic was minimal. Under minimal truck traffic, TMS roads were found to be a very cost effective and relatively easily maintained road surface. Given recent increases in commercial truck traffic, there is little question that road preservation/strengthening efforts will have to be increased in order to provide a sustainable level of service on many Saskatchewan TMS roads.

3.0 COLD IN-PLACE RECYCLING

3.1 What is Cold In-Place Recycling?

Cold in-place recycling involves rehabilitation of the existing asphalt or granular road surface. The existing surface is pulvarized, using specialized machines, normally to a depth of 50 mm to 150 mm. The pulvarized material is then mixed on site with an asphalt emulsion or emulsified recycling agent. The mixed material is then spread and recompacted to a specified density and improved road cross-section. The CIR surface is then covered with a new asphalt concrete mat or a graded seal aggregate and emulsified surface. The final surface type depends on traffic volumes and other unique factors.

CIR is an attractive alternative for highway rehabilitation operations because of its economic and environmental advantages. Major economic advantages involve the recycling of existing road surface aggregates and reduced haul requirements for incorporating new aggregate. In Saskatchewan there are many regions where aggregate resources are or will be depleted in the near future. Aggregate haul in these regions is expensive given the extensive haul distances and the corresponding increase in haul costs. The annual demand for aggregate in the province is approximately four million cubic metres per year and accounts for approximately 80% of the Province's consumption. By recycling existing in-place road materials and providing additional strength with the mixing of different emulsions or strengthening agents, new aggregate and asphalt material requirements are reduced. In addition, impacts on adjacent haul roads are minimized or eliminated because of reduced new aggregate requirements. Major environmental advantages involve the use of cold in-place recycling and no requirement for heat during construction work. CIR is an energy efficient process that does not produce harmful emissions and does not require the asphalt mixture to be transported to an off-site plant. In addition, transportation of large amounts of aggregate are reduced; therefore, less diesel fuel is burned to provide road-building materials.

3.2 Saskatchewan Highways and Transportation Experience

Although preserving the Saskatchewan road network using conventional methods is tenable and technically feasible, other more economical techniques are required to provide a long-term sustainable road network. Alternate methods, like CIR, are required to address existing and future pressures on the provincial road system.

CIR has been successfully used since 1989 in other jurisdictions in Canada. Saskatchewan Highways and Transportation is in the infancy stage of using CIR for recycling existing roads. To date, the department has completed a number of small pilot projects on a number of different highways under different road conditions. By examining the results of these test sections, the department will be better prepared to identify and take advantage of the savings that this new technology can bring to preserving the highway network.

In 1999, a CIR contract was completed on four different Saskatchewan highways to determine its effectiveness on different surface types, road characteristics and user requirements. Surface types included TMS, granular and asphalt concrete pavements. The four test sections were: Highway #2 south of Watrous (granular pavement), Highway #6 north of Raymore (asphalt concrete pavement), Highways #21 north of Kerrobert (granular pavement) and Highway #51 east of Kerrobert (TMS). Department objectives, construction procedures, and department expectations are outlined as follows.

3.2.1 Cold In-Place on Thin Membrane Surfaces

Saskatchewan Highways and Transportation manages approximately 8 600 km of non-structural TMS roads. TMS roads were originally intended to provide a dust free surface for light vehicle traffic and minimal loading. Typical construction procedures involve the preparation of a subgrade using existing apparent materials with the final surface consisting of a thin lift (50 mm to 100 mm) of cold mix asphalt aggregate. The structural capacity of the apparent subgrade material determines the ability of the TMS road to carry heavier vehicular traffic. In the past, under minimal loading conditions, maintenance treatments were sufficient to provide an acceptable level of service to the public and the trucking industry. This is no longer the case on many TMS roads. TMS roads with weak subgrade material, limited or no surfacing structure and heavy vehicle loading are failing at an increased rate.

The department's primary objectives for implementing CIR on TMS roads is to provide adequate strength on existing weak roads and at the same time restore a good cross section to existing distorted or poor riding surfaces. The economic and technical feasibility of using CIR is dependant upon the existing road characteristics and the apparent subgrade material.

The potential benefits of in-place road recycling and stabilization for Saskatchewan Highways and Transportation on TMS roads is best illustrated by the following example. In west central Saskatchewan (i.e. north of Kindersley), there are significant kilometers of TMS roads in need of strengthening to support increased truck traffic associated with oil development and rationalization of grain transportation. Gravel sources in the area have been depleted resulting in 80 to 100 km gravel hauls with longer hauls projected in the near future. Under these circumstances strengthening TMS roads using conventional re-grading methods would cost approximately $150,000 to $250,000/km. Given the insitu soil profiles and predicted commercial truck traffic, preliminary analysis indicates that TMS roads could potentially be strengthened using in-place recycling and stabilization for significantly less investment than conventional methods. Since Saskatchewan has approximately 4 000 km of TMS roads requiring structural strengthening, the potential cost savings of developing and successfully implementing in-place recycling and full-depth stabilization could be in excess of one hundred million dollars.

3.2.2 Cold in Place on Granular Pavements

Saskatchewan Highways and Transportation manages approximately 3 400 km of granular paved highways. Granular pavements are designed to provide adequate strength to carry pre-determined loads over a specified period of years. Granular pavements are typically constructed on highways with an average annual daily traffic (AADT) of 1200 vehicles or less. The constructed surface normally consists of sub-base, base and a double graded seal aggregate with emulsion. Granular pavements are typically applied over a prepared subgrade or an existing TMS or paved structure. Deterioration over the life of the granular pavement involves de-compaction of the base layer, increased rutting, shear failures in the base, sub-base and possibly the subgrade layers. In addition, the sealed surface deteriorates requiring additional sealing or other more extensive repairs. Towards the end of a pavement's service life, road users may experience a poor ride and hazardous driving conditions.

Conventional rehabilitation work on granular pavements typically consists of overlaying the existing surface with 100 mm to 150 mm of new base material finished with a double seal. This type of rehabilitation is very cost-effective and technically proven. Typical problems involve limited aggregate resources or trapped moisture in the new base layer. When moisture penetrates the top seal layer it is trapped in the base layer above the old seal coat. Moisture in the base layer causes premature failures and reduces the life of the structure.

The department's primary objective for implementing CIR on granular pavements is to rehabilitate deteriorated granular surfaces using more cost-effective solutions. Throughout Saskatchewan there are many regions where aggregate sources have been depleted causing increased haul distances and rehabilitation costs. CIR allows the department to add emulsion to existing pulvarized base material to increase the strength of the base. Research has shown adding emulsion to base aggregate increases the strength of the base by a factor of at least 1.4 and may increase it to above 1.8. Increasing the structural capacity of the base layer allows the department to reduce or eliminate the amount of new aggregate needed to rehabilitate and strengthen existing granular pavements. In addition, CIR eliminates the existing impermeable seal coat layer that traps moisture. For granular pavements, depending on haul distances to aggregate resources, there is the potential for the department to save considerable funding in aggregate scarce regions.

3.2.3 Cold In-Place on Asphalt Concrete Pavements

Saskatchewan Highways and Transportation manages approximately 8 900 km of asphalt concrete (AC) paved highways. AC pavements are the primary highway system in Saskatchewan, carrying the majority of the traffic. They are normally constructed on highways carrying AADT greater than 1200 vehicles per day.

Deterioration over the life of an AC pavement involves increased cracking, rutting, shear failures, decreased rider comfort, plus other distresses. Major rehabilitation work typically consists of overlaying the existing surface with either a thin lift of 40 mm to 80 mm of new asphalt concrete or a structural overlay of 80 mm to 180 mm of new asphalt concrete. Other minor or lower cost maintenance treatments are completed when needed to extend the life of the pavement. Overlaying the existing surface with new asphalt concrete is a very effective rehabilitation treatment. The one major problem is reflective cracking from the underlying old existing AC surface. Reflective cracking is caused by the propagation of existing cracks in underlying layers through an asphalt concrete overlay. Reflective cracking can originate from low temperature transverse cracks and fatigue cracks in the underlying asphalt concrete, and shrinkage cracks in the underlying soil cement structures. Normally, depending on the thickness of the new asphalt concrete layer, reflective cracking will occur within a one to two year period. Cracks that exist in the old mat will crack the new mat in the same location. Reflective cracking allows moisture to penetrate to underlying layers causing deterioration at both the crack and underlying surface layers. Over time, increased moisture will impact structural layers and continue to increase crack depressions effecting ride.

The department's primary objective for implementing CIR on AC pavements is to rehabilitate deteriorated AC surfaces and reduce or defer reflective cracking through new pavement layers. CIR allows the department to rejuvenate existing AC surfaces and at the same time provide a layer that mitigates reflective cracking. The best candidates for CIR are cracked pavements with structurally sound, well-drained bases and subgrades. CIR can be used on poor or marginal base, sub-base and subgrade conditions, when a stabilising agent is added. A stabilising agent, such as Lime or fly ash, can be added to provide early strength to the mixture and allow it time to develop the necessary strength without failure.

CIR has the capability to rehabilitate existing deteriorated AC surfaces by reusing existing roadway materials. The preservation of aggregates and bitumen allows CIR to be a cost-effective process. Deferring or reducing reflective cracking will reduce maintenance requirements and extend pavement life. This will result in substantial cost savings for the province.

4.0 SUMMARY AND CONCLUSIONS

Saskatchewan Highways and Transportation is in the infancy stage of incorporating cold in-place recycling into their preservation program. To date, pilot project work has been completed to determine the viability of different preservation treatments on various surface types and under different circumstances and conditions.

4.1 Advantages of Cold In-Place Recycling

Saskatchewan Highways and Transportation anticipates substantial cost savings and efficiencies associated with the following:

1. Conservation of existing aggregate resources by utilizing existing roadway materials. There is the potential for major cost savings by reducing department aggregate requirements, especially in aggregate scare regions in the province.

2. Reduce dependence for asphalt cements through conservation. Residual asphalt in existing roadways can be rejuvenated and reused by cold recycling methods, thus reducing the department requirements for large amounts of asphalt cements.

3. CIR restores the original crown and cross slope to the existing distorted roadway. This is important for proper drainage, snow removal and the overall ride comfort for the road users, specifically the trucking industry.

4. CIR conserves energy and does not require heating during the construction process. Canada has committed to reduce harmful emissions under the Kyoto Agreement. CIR is more environmentally friendly than hot in-place recycling or conventional paving operations.

5. CIR has been proven to reduce reflective cracking on asphalt concrete pavements. By deferring or reducing the amount of reflective cracking on AC pavements the pavement life and the overall ride is improved.

6. Reduce fuel dependencies and requirements by reducing aggregate hauls on CIR projects.

7. Recycling existing roadway materials reduces surfacing costs on all surface types under certain circumstances. CIR will provide additional treatments that are more cost-effective for rehabilitating or strengthening roadways.

8. CIR will reduce impacts on adjacent roadways by reducing aggregate hauls. Under most cases new aggregate is reduced or eliminated, thus reducing the impact of increased loading on adjacent haul roads.

9. CIR reduces inconveniences to the travelling public and the trucking industry. CIR construction procedures are less disruptive to vehicles and traffic accommodation.

10. CIR eliminates all types of pavement or surface distress by re-working the existing surface. Transverse and longitudinal cracks, potholes, wheel ruts, and other irregularities are removed during the process.

11. CIR reduces overall engineering costs by reducing the amount of time required for pavement design and surveying activities.

4.2 Challenges of Cold In-Place Recycling

To date, the department has identified a number of challenges or limitations using cold in-place recycling. The following are some of the issues that need to be improved or understood:

1. CIR is a relatively new rehabilitating technique with limited mix design procedures. Currently, there are many jurisdictions working in conjunction with various universities and companies to create better mix design procedures.

2. Quality assurance and quality control using CIR is not as reliable as a central plant operation because the process uses existing surface material. The existing surface material determines the consistency of the final mix properties. If the existing surface material is relatively homogenous in nature then the final surface properties will be relatively consistent. If the existing surface material is inconsistent, then CIR operations must be continuously altered to achieve a consistent product. The consistency of the final surface is dependant on the experience and the ability of the process to adapt to changing material conditions.

3. CIR is limited to summer months because of the warm, dry conditions required to complete the process.

4. CIR is susceptible to moisture intrusion and abrasion. Therefore, it requires a wearing surface such as a seal coat or hot mix asphalt overlay.

5. A curing period of two weeks is normally required in order to achieve adequate strength associated with emulsions and curing time.

6. Typical milling depths on AC pavements are 100 mm to 150 mm. This allows for the removal of reflective cracking. Due to irregularities in the depth of the existing AC materials, the CIR procedure may intrude into the underlying granular structure making it very difficult to keep consistent mix properties in the relayed surface. Ground penetrating radar or other technology may prove to be helpful in determining the AC and other layer depths.

7. CIR is still relatively unproven in Saskatchewan. Other jurisdictions such as Ontario have found that granular base equivalencies for CIR mixes are between 1.4 and 1.8. However, their application is mainly on AC pavements. It is unclear how these equivalencies will apply to granular structures in Saskatchewan given our different climate and soil conditions.

4.3 Conclusions

The province of Saskatchewan is very dependent upon the heavy vehicle trucking industry whose continued viability ties directly to the province's economic well being. Saskatchewan Highways and Transportation's strategic management framework is intended to provide a sustainable transportation system for its users and stakeholders. The condition of the transportation system asset has a direct impact on economic stability of the province. It is to the province's advantage to research and develop long term preservation strategies with a high benefit to cost ratio to keep the road network in the best state possible.

When the provincial highway network was first established, grain was the most commonly transported commodity. It was first moved by horse and wagon, and then by one to two tonne trucks. Today, large trucks are capable of transporting considerable payloads of grain and other materials across the province. With the closure of many small town elevators, more trucking is occurring each year. It has been estimated that the tonnage hauled on the Saskatchewan road system will double within four years. This will place even more stress on the road system and the raw materials, such as aggregate, needed to maintain the infrastructure.

The department has conducted an aggregate management strategy review that stressed how important managing our existing aggregate supply is and will continue to be in the future. However, future demand is based upon traditional preservation methods and marginal increases in budget levels and truck traffic.

Although conventional rehabilitation methods are proven, more economical techniques are required in order to provide a long-term sustainable transportation system. Saskatchewan Highways and Transportation continues to research, develop and implement new methods for preserving the provincial roadway network. Cold in-place recycling is one of these new methods that has the potential to provide a more cost-effective approach for preserving this network. CIR will have a profound effect on aggregate needs in the future by greatly reducing the amount of aggregate required for road rehabilitation.

The department is still in the infancy stage of implementing and improving CIR procedures. Advantages have already been identified and challenges and limitations need to be overcome to improve the success of CIR. Cold in-place recycling has the potential to provide cost-effective methods for preserving the road network. The long-term department objective is to provide a substantial transportation system for the province of Saskatchewan that supports its users and the trucking industry.

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FIGURES

Figure 1: 9-Axle B-train Grain Truck

Figure 2: 9-Axle B-Train Mine Truck