FULL DEPTH COLD IN-PLACE RECYCLING/STABILIZATION FOR LOW VOLUME ROAD STRENGTHENING: A CASE STUDY ON HWY 19-06

Prepared By:

Curtis Berthelot Ph.D., P.Eng.
Dept. of Civil Engineering
University of Saskatchewan

Ron Gerbrandt, P. Eng.
Preservation Engineer, Central Region

Derek Baker M.Sc.
Dept. of Civil Engineering
University of Saskatchewan

Paper prepared for presentation:
at the “Innovative Pavement Design and Evaluation Techniques” Session
of the 2000 Annual Conference of the
Transportation Association of Canada
Edmonton, Alberta

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of the Saskatchewan Department of Highways Keneston Section Crew and the contractor on this project, Road Warrior from Swift Current. In addition, we would like to acknowledge manufactures and suppliers: LaFarge Canada, SaskPower International, CBRPlus and Pounder Emulsions for their support and materials used in the project.
ABSTRACT

Grain transportation rationalization, economic diversification and value added initiatives within the Saskatchewan economy has increased commercial truck traffic on many Saskatchewan roads and will continue to do so in the foreseeable future. These increases in commercial truck traffic hold significant and often-immediate implications for Saskatchewan secondary roads (roads traditionally with ESALs of between 100 and 1000) because many of these roads were not designed to accommodate significant numbers of heavily loaded commercial trucks. Of particular concern, is the approximately 8600 km of thin membrane surfaced (TMS) roads of which many are experiencing accelerated and at times, catastrophic damage. TMS roads are of particular concern because they are expensive to repair once surface breaks occur and TMS roads can be particularly sensitive to truck loading when subgrades are thaw-weakened. As a result, increasing commercial truck traffic has translated into a clear need to strengthen many Saskatchewan TMS and other secondary highways.

Although preserving the Saskatchewan secondary road network using conventional methods is both technically feasible and economically tenable in some situations, conventional methods are not economically feasible for many low volume roads in the time frame required to provide an sustainable level of service that serves the immediate needs of the commercial road transport industry across the entire secondary road network. As a result, alternative and innovative road strengthening solutions are required. This paper presents the technical and economic case study of pilot test sections constructed by the Preservation and Operations Branch of Saskatchewan Highways and Transportation to evaluate alternative full-depth cold in-place recycling and strengthening techniques on Control Section 19-06.
1.0 BACKGROUND

The Saskatchewan road infrastructure is comprised of approximately 198,700 kilometers of two lane equivalent roads with an estimated capital asset value of seven billion dollars (SHT, 1996). A primary function of the Saskatchewan road infrastructure is to facilitate the assembly and export of bulk resources such as grain, timber, petroleum, building products, and mined minerals. Since the export of bulk resources comprises two thirds of Saskatchewan’s gross domestic product, efficient road transportation has a direct and profound impact on the Saskatchewan economy. Grain transportation rationalization and economic diversification including value-added initiatives within the Saskatchewan economy has significantly increased commercial truck traffic on many Saskatchewan roads.

1.1 Pressures on Saskatchewan Highway Network

Given the significant capital asset value of the Saskatchewan road network and the direct link roads have to the Saskatchewan economy, preserving Saskatchewan roads while promoting transportation efficiency is of paramount importance to Saskatchewan. Changing transportation policies in recent years has increased commercial trucking on many Saskatchewan roads by orders of magnitude. Policy changes such as removal of the Crow Rate for the transportation of export grain, which resulted in rationalization of the provincial grain transportation system. In particular, rail companies abandoned branch lines and elevator companies replaced thousands of country grain elevators along rail branch lines with a mere handful of large 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, the government of Saskatchewan has encouraged both diversification and value added activities within the Saskatchewan economy, particularly rural Saskatchewan. 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 increased road transport tonne-kilometers by orders of magnitude on many Saskatchewan roads, as well as encouraged the use of larger more cost-effective commercial trucks as shown in Figure 1.

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 and therefore experience only marginal increases in preservation costs over their design lives. However, these increases in commercial truck traffic hold significant and often-immediate implications for many Saskatchewan secondary roads, of which many were not initially designed or constructed to accommodate significant numbers of heavily loaded commercial vehicles. As a result, increasing commercial truck traffic has translated into the need to strengthen many Saskatchewan secondary roads. Of particular concern is the approximately 8600 km of Saskatchewan non-structural thin membrane surface (TMS) roads of which many are experiencing accelerated damage. TMS roads are of particular concern because they are expensive to repair once surface breaks occur and these types of roads are particularly sensitive to truck loading when subgrades are thaw-weakened.
1.2 Thin Membrane Surface Roads

Over the past several decades Saskatchewan Highways and Transportation designed and constructed approximately 8600 km of thin membrane surface roadways. TMS roads were a relatively inexpensive method of providing oil treated surfaces for low volume roads.

TMS roads were not intended to provide added structural capacity, but were a cost effective means to provide dust, mud, and stone free roads to local rural residents where truck traffic was minimal (ESAL’s <1000/day). Under minimal truck traffic, TMS roads were found to be a cost...
effective and an easily maintainable road surface. However, in recent years, increased truck traffic associated with changing road transportation policies, Saskatchewan TMS roads have experienced considerable increased haul pressure resulting in extensive damage to much of the TMS system.

1.3 Conventional Preservation of Thin Membrane Surface Roads

Conventional TMS preservation/management solutions currently employed by Saskatchewan Highways and Transportation (SHT) include:

- Maintain existing TMS roads in spite of increasing maintenance costs.
- Make the capital investment required to upgrade TMS roads to paved structural roads.
- Revert TMS roads to gravel surfaced roads.
- Regulate and/or restrict commercial traffic and/or limit truck weights.
- Enter into partnerships with local Rural Municipalities to have commercial trucks operate on the RM gravel system instead of the TMS system.
- Enter into partnership haul agreements with commercial carriers whom employ road friendly vehicle technologies such as central tire inflation and air-spring suspension systems.
- Implement some combination of a) through f).

Although preserving the Saskatchewan TMS road network using conventional methods is tenable in some situations, conventional methods are not economically feasible in the time frame required to provide an adequate and sustainable level of service across the entire TMS road network.

1.4 Cold In-Place Recycling Road Strengthening Alternatives

Given the pressures facing Saskatchewan’s secondary road network, new innovative TMS road strengthening solutions are required for a significant portion of the TMS road network. Recent advances in stabilization engineering and in-place recycling construction techniques can potentially provide several advantages for managing the TMS road network using a “build down” approach. Several full depth stabilization systems are currently available on the market, including granular soil, cement, lime, flyash, geotextiles, natural and manufactured fibers, emulsified bitumen, tall oil, lignin, foamed bitumen and synthetic ionic chemicals. However, there is considerable uncertainty associated with these stabilized road systems because of their inherent complex physiochemical and micro mechanical behavior. The high degree of uncertainty is primarily related to the fact that, until very recently, only phenomenological laboratory tests and/or experience based methods have been available for the design, specification, quality control/quality assurance, and performance prediction of stabilized road systems. These traditional phenomenological-empirical methods are limited because they are, in effect, trial and error methods. As a result, public road agencies have been reluctant to use stabilization in anything other than small trial applications, even though the potential economic and environmental benefits of stabilized road systems can be quite compelling.

Recent developments in thermomechanistic and physiochemical characterization and mechanistic modeling of roads have the potential to overcome the limited predictive capabilities
associated with traditional phenomenological-empirical methods and provide road engineers with a rational framework to defensibly evaluate stabilized road systems. A mechanistic framework will reduce the uncertainty associated with the performance of stabilized road systems in diverse applications.

2.0 HIGHWAY 19-06 COLD IN-PLACE RECYLING/STRENGTHENING PILOT PROJECT

2.1 Goal and Objectives of Highway 19-06 Pilot Project

Given recent increases in commercial truck traffic, SHT needs to research and implement alternative preservation/strengthening procedures in order to provide a timely and sustainable level of service on many Saskatchewan TMS roads. Although conventional TMS preservation strategies are effective in most situations, it is apparent there will be significant benefits associated with more cost-effective ways to strengthen existing TMS roads, increasing their load carrying capacity and reducing their moisture and freeze/thaw sensitivity. As a result, Saskatchewan Highways and Transportation are investigating cold in-place recycling (CIR) as an alternative TMS preservation treatment.

The Highway No. 19 project involved SHT, the University of Saskatchewan and three materials suppliers; Lafarge Canada, SaskPower International and CBRPlus-Pounder Emulsions. The overall goal of the project was to evaluate and implement more cost-effective and efficient strengthening methods for low volume thin membrane surfaces. Each participant has individual goals and objectives:

➢ Saskatchewan Highways and Transportation
  • Provide more cost-effective road strengthening solutions for Saskatchewan taxpayers.
➢ The University of Saskatchewan
  • To develop and prove out a mechanistic based engineering framework to evaluate, specify and control in-place recycling and strengthening systems for Saskatchewan TMS roads.
➢ Materials Suppliers
  • Benefits to the environment include employing co-products for use as blending into a viable road subgrade soil stabilization material. Achieving this reduces the need for disposing high concentrations of co-products in environmentally controlled landfills.
  • Benefits to the road building industry include helping to facilitate the growth of in-place recycling and stabilization of existing roads.
  • In addition, if markets could be developed or improved for specific products this would be a further benefit.

In regards to the Highway 19-06 project the concentrated and cooperative effort of the parties involved was very successful. At various stages throughout the project, innovative solutions and teamwork was required to solve current challenges in providing a sustainable low volume road network in Saskatchewan.
2.2 Construction Goals and Methods

CIR involves breaking down the old pavement structure using rotomixing equipment as shown in Figure 3. The objective of rotomixing is to reclaim the insitu material and produce a homogeneous material that provides optimal engineering-strengthening value of the reclaimed material as shown in Figure 4.

![Figure 3: Cold In-Place Recycling/Strengthening](image)

With the development of modern reclaimer/stabilizer equipment, addition of stabilizers has become more precise and reliable and allows stabilizers to be thoroughly mixed into the recycled soil providing a uniformly mixed material. These recent advances in stabilization engineering and in-place recycling/stabilization construction equipment can now potentially provide a new solution for managing the TMS road network using a “build down” approach, including the following:

a) Reclaim, reshape, and reconstruct the existing road structure with a more uniform and higher quality material than that obtained through conventional ripping, scarifying, and disking methods.

b) Strengthen the road subgrade in-place by blending soil stabilizers into the subgrade enhancing its mechanical behavior and environmental durability with little additional cost.
c) Significantly reduce aggregate requirements, thereby reducing costly aggregate hauls and road damage while preserving scarce aggregate resources.
d) Optimal use of existing materials already in-place and paid for by the taxpayer.
e) Strengthen narrow TMS roads by “building down” where the geometry of the existing road is not sufficient to “build up” with conventional full pavement structures.
f) Integrate the “build down” strengthening alternative in an overall strategic road management framework, incorporating strategic haul agreement partnerships and staged construction to mitigate road deterioration over the next decade, resulting in time to implement more permanent conventional road strengthening solutions.

![Figure 4: Cold In-Place Recycle Material](image)

### 2.3 Highway 19-06 Pilot Test Site Construction

During the summer of 1999, SHT initiated a pilot project using cold in-place recycling and subgrade strengthening. Road Warrior Inc., from Swift Current, Saskatchewan, provided rotomixing services and SHT crews provided all support equipment to construct test sites on Highway 19-06 in the Loreburn area. Approximately 12.6 kilometers were strengthened using combinations of SHT conventional strengthening and cold in-place recycled systems. The goal of this research effort was to develop more cost-effective strengthening systems for Saskatchewan TMS roads. The specific objectives of the Highway 19-06 project were to:

a) Investigate alternative types of soil stabilizers that may be used in conjunction with cold in-place recycling to improve the load carrying capacity and environmental durability of typical Saskatchewan TMS road subgrades.
b) Identify and select soil stabilization systems that pose the most promise, in terms of technical soundness, economic benefits, and impact on environmental sustainability.

c) Characterize the mechanical behavior and environmental durability of the alternative soil stabilizers across typical Saskatchewan TMS road subgrades.

d) Begin to develop a rational mechanistic framework to reliably characterize the mechanical behavior and environmental durability of alternative soil stabilizers that is reliable and pragmatic for the road building industry.

e) Begin to develop a stabilized road modeling methodology that employs mechanistic material constitutive relations to accurately predict the performance of typical Saskatchewan recycled/strengthened TMS roads.

f) Design, construct, monitor, and document the performance of conventional and stabilized TMS strengthening test sections built as part of this research.

g) Develop a performance based life cycle costing framework with the ability to evaluate the cost effectiveness of in-place recycled and strengthened Saskatchewan TMS systems.

h) Leverage the engineering methods developed within this research to other applications.

The following scope employed in this study:

a) Highway 19-06 is comprised of a design 40 mm of cold mix mat placed over a prepared clay-till subgrade.

b) Three test sites within Highway 19-06 located between kilometers 12.96 and 32.46. Typical failed sections along Highway19-06 prior to construction of the test sections are shown in Figure 5 and Figure 6.

c) Stabilizers or strengthening agents considered in this study included blends of high lime flyash, cement kiln dust, and CBRPlus.

d) Subgrades were stabilized to a depth of 150 mm and 300 mm.

e) Different base overlay thicknesses consisted of depths of 0mm, 100mm and 150 mm.

f) HF-250 and HF-250P double seal was placed on specific sections throughout the test sites.

g) A Caterpillar RR-250 reclaimer/stabilizer performed the in-place recycling and injection of the stabilizers.

h) SHT crews and equipment provided all construction support including shaping, packing, trucking, safety, signing, and other miscellaneous tasks.

The structure of each segment was chosen based on the objective to analyze the performance of each stabilizer and compare them to conventional SHT preservation/strengthening treatments. Each segment was based on stabilizer type, stabilizer depth, depth of rotomixing, thickness of base overlay and type of asphalt emulsion used in the double seal coat. These variables were modified across each segment based on the construction plan, equipment requirements, material requirements, quality control/quality assurance testing, budget and schedule for the project.
Figure 5: Typical Highway 19-06 Surface Breaks

Figure 6: Typical Highway 19-06 Fatigue Cracking and Rutting
Three materials were selected to strengthen the subgrade of Highway 19-06 for this pilot study: a blend of cementitious materials, class C high-lime-flyash, and CBRPlus anionic stabilizer. Cementitious materials such as cement, lime and flyash have been used for stabilizing soils for several decades. Flyash is the fine ash collected in the smokestacks of coal combustion energy producing power plants. During the burning process of coal at the Shand Power station located in Estevan Saskatchewan, SaskPower injects limestone into the furnace to improve the combustion ratio and reduce expelled particulates during the burning process. As a result, Shand power generation station produces flyash with a higher than normal lime content. CBRPlus is a synthetic anionic surfactant soil stabilizer used to modify the clay component present in soils by converting its water-adsorbing characteristic to one of a hydrophobic nature. CBRPlus was developed in South Africa as a construction aid for all-weather roads using in-situ soils containing expansive clays. CBRPlus may benefit the Saskatchewan road network if it could be properly applied and proven in the Saskatchewan environment.

In all, three test sites were constructed as part of the Highway 19-06 pilot project. The specifics of each test site and the segments within each test section are summarized below.

### 2.3.1 Highway 19-06 Test Site #1 Sections

Table 1 summarizes the test sections contained within Test Site #1. As seen in Table 1, two stabilizers were employed in Test Site #: CBRPlus and flyash. In addition to subgrade strengthening, Test Site #1 used polymer-modified asphalt emulsion HF-250P to construct portions of the double seal for the wearing coarse. Table 1 summarizes the test sections constructed as part of Test Site #1.

- **Segment 71** comprised of rotomixing flyash into 150mm of the existing grade with 100mm base overlay added. Surfacing included 250m of double seal wearing coarse using HF-250 asphalt emulsion and 250m using HF-250P asphalt emulsion.

- **Segment 72** comprised of rotomixing flyash into 150mm of the existing grade with 150mm base overlay added. Surfacing included 250m of double seal wearing coarse using HF-250P asphalt emulsion and 250m using HF-250 asphalt emulsion.

- **Segment 73** comprised of rotomixing the existing TMS mat into 150mm of the existing grade with 100mm base overlay added. Surfacing included double seal wearing coarse using HF-250 asphalt emulsion.

- **Segment 74** comprised of rotomixing CBRPlus into 150mm of the existing grade with 100mm base overlay added. Surfacing included 250m of double seal wearing coarse using HF-250P asphalt emulsion and 250m using HF-250P asphalt emulsion.

- **Segment 75** comprised of rotomixing CBRPlus into 150mm of the existing grade with 150mm base overlay added. Surfacing included 250m of double seal wearing coarse using HF-250P asphalt emulsion and 250m using HF-250 asphalt emulsion.

- **Segment 76** comprised of placing 150mm base overlay onto the existing TMS surface. Surfacing included 750m of double seal wearing coarse using HF-250 asphalt emulsion and 750m using HF-250P asphalt emulsion.

- **Segment 76** comprised of rotomixing 150mm of the existing TMS surface with 150mm base overlay added. Surfacing included 1000m of double seal wearing coarse using HF-250P asphalt emulsion and 1000m using HF-250P asphalt emulsion.
Table 1: Highway 19-06 Test Site #1

<table>
<thead>
<tr>
<th>Segment</th>
<th>Kilometer</th>
<th>Base Added Prior to Rotomixing (mm)</th>
<th>Subgrade Preparation/ Depth of Rotomixing (mm)</th>
<th>Stabilizer and Depth (mm)</th>
<th>Base Overlay Thickness (mm)</th>
<th>Double Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>13.00</td>
<td>13.25</td>
<td>0</td>
<td>LFA – 150</td>
<td>100</td>
<td>HF-250</td>
</tr>
<tr>
<td>71P</td>
<td>13.25</td>
<td>13.50</td>
<td>0</td>
<td>LFA – 150</td>
<td>100</td>
<td>HF-250P</td>
</tr>
<tr>
<td>72P</td>
<td>13.50</td>
<td>13.75</td>
<td>0</td>
<td>LFA – 150</td>
<td>150</td>
<td>HF-250P</td>
</tr>
<tr>
<td>72</td>
<td>13.75</td>
<td>14.00</td>
<td>0</td>
<td>LFA – 150</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>73</td>
<td>14.00</td>
<td>14.50</td>
<td>0</td>
<td>N/A</td>
<td>100</td>
<td>HF-250</td>
</tr>
<tr>
<td>74</td>
<td>14.50</td>
<td>14.75</td>
<td>0</td>
<td>CBR – 150</td>
<td>100</td>
<td>HF-250</td>
</tr>
<tr>
<td>74P</td>
<td>14.75</td>
<td>15.00</td>
<td>0</td>
<td>CBR – 150</td>
<td>100</td>
<td>HF-250P</td>
</tr>
<tr>
<td>75P</td>
<td>15.00</td>
<td>15.25</td>
<td>0</td>
<td>CBR – 150</td>
<td>150</td>
<td>HF-250P</td>
</tr>
<tr>
<td>75</td>
<td>15.25</td>
<td>15.50</td>
<td>0</td>
<td>CBR – 150</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>76</td>
<td>15.50</td>
<td>16.25</td>
<td>0</td>
<td>N/A</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>76P</td>
<td>16.25</td>
<td>17.00</td>
<td>0</td>
<td>N/A</td>
<td>150</td>
<td>HF-250P</td>
</tr>
<tr>
<td>77P</td>
<td>17.00</td>
<td>18.00</td>
<td>0</td>
<td>N/A</td>
<td>150</td>
<td>HF-250P</td>
</tr>
<tr>
<td>77</td>
<td>18.00</td>
<td>19.00</td>
<td>0</td>
<td>N/A</td>
<td>150</td>
<td>HF-250</td>
</tr>
</tbody>
</table>

2.3.2 Highway 19-06 Test Site #2 Sections

Table 2 summarizes the test section contained in Test Site #2. As seen in Table 2, Test Site #2 contains segment 78 that is comprised of 75 mm of base aggregate rotomixed into the existing double seal and 75 mm of based overlay placed on 40 mm of cold mix asphalt concrete from two years previous. Once the aggregate was mixed with the existing structure, the roadway was shaped and compacted. A 25 mm base overlay was placed over the grade to level the road surface prior to the double seal.

Table 2: Highway 19-06 Test Site #2

<table>
<thead>
<tr>
<th>Segment</th>
<th>Kilometer</th>
<th>Base Added Prior to Rotomixing (mm)</th>
<th>Subgrade Preparation/ Depth of Rotomixing (mm)</th>
<th>Stabilizer and Depth (mm)</th>
<th>Base Overlay Thickness (mm)</th>
<th>Double Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>78</td>
<td>21.3</td>
<td>22.5</td>
<td>75</td>
<td>Mat depth</td>
<td>N/A</td>
<td>0</td>
</tr>
</tbody>
</table>

2.3.3 Highway 19-06 Test Site #3 Sections

Table 3 summarizes the test sections contained within Test Site #3. As seen in Table 3, three stabilizers were employed in Test Site #3: CBRPlus, flyash, and a blend of cementitious materials. Each stabilizer was constructed in four segments of 400-meter length with varied structural composition.

- Segment 79 comprised of rotomixing CBRPlus into 300 mm of the existing grade with no base overlay added. Surfacing included approximately 25 mm of gravel to properly shape the finished grade with a double seal wearing coarse using HF-250 asphalt emulsion.
Segment 80 employed CBRPlus rotomixed into 150mm of the existing mat. Surfacing included approximately 25 mm of gravel to properly shape the finished grade with a double seal wearing coarse using HF-250 asphalt emulsion.

Segment 81 and 82, CBRPlus was rotomixed into 150 mm of the existing grade. For additional structural support, 150 mm and 100 mm base overlays were added to segments 81 and 82, respectively both with a double seal wearing coarse using HF-250 asphalt emulsion.

Segment 83 was designed as a control section with a specified rotomixed depth of 150 mm with no stabilizers added. For additional structural support, 150 mm base overlay was added and a double seal wearing coarse using HF-250 asphalt emulsion was applied.

Segments 84 through 87 were constructed using identical construction procedures as segments 79 through 82, with the exception that flyash was the stabilizer instead of CBRPlus.

Segments 88 through 91 were constructed using identical construction procedures as segments 79 through 82, with the exception that a blend of cements was the stabilizer instead of CBRPlus.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Kilometer</th>
<th>Base Added Prior to Rotomixing (mm)</th>
<th>Subgrade Preparation/Depth of Rotomixing (mm)</th>
<th>Stabilizer and Depth (mm)</th>
<th>Base Overlay Thickness (mm)</th>
<th>Double Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>27.1</td>
<td>NA</td>
<td>300</td>
<td>CBR – 300</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>80</td>
<td>27.5</td>
<td>NA</td>
<td>150</td>
<td>CBR – 150</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>81</td>
<td>27.9</td>
<td>NA</td>
<td>150</td>
<td>CBR – 150</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>82</td>
<td>28.3</td>
<td>NA</td>
<td>150</td>
<td>CBR – 150</td>
<td>100</td>
<td>HF-250</td>
</tr>
<tr>
<td>83</td>
<td>28.7</td>
<td>NA</td>
<td>150</td>
<td>N/A</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>84</td>
<td>29.1</td>
<td>NA</td>
<td>300</td>
<td>FA – 300</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>85</td>
<td>29.5</td>
<td>NA</td>
<td>150</td>
<td>FA – 150</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>86</td>
<td>29.9</td>
<td>NA</td>
<td>150</td>
<td>FA – 150</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>87</td>
<td>30.3</td>
<td>NA</td>
<td>150</td>
<td>FA – 150</td>
<td>100</td>
<td>HF-250</td>
</tr>
<tr>
<td>88</td>
<td>30.7</td>
<td>NA</td>
<td>300</td>
<td>CEM – 300</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>89</td>
<td>31.1</td>
<td>NA</td>
<td>150</td>
<td>CEM – 150</td>
<td>0</td>
<td>HF-250</td>
</tr>
<tr>
<td>90</td>
<td>31.5</td>
<td>NA</td>
<td>150</td>
<td>CEM – 150</td>
<td>150</td>
<td>HF-250</td>
</tr>
<tr>
<td>91</td>
<td>31.9</td>
<td>NA</td>
<td>150</td>
<td>CEM – 150</td>
<td>100</td>
<td>HF-250</td>
</tr>
</tbody>
</table>

### 3.0 HIGHWAY 19-06 CONSTRUCTION COSTS

Construction costs for each test section were recorded to evaluate the economics and viability of each segment. Costs were separated into each element of construction:

- **Grade reconstruction** – all costs associated with rotomixing, shaping, addition of stabilizers and compaction of the subgrade soil.
- **Base overlay and double seal construction** – all costs associated with base overlay and double seal using SHT base overlay construction procedures.
Table 4 and Figure 7 summarize the grading costs incurred during construction of the 19-06 test sections. As seen in Table 4 and Figure 7, grading costs on Highway 19-06 range from $9,500/km to $82,700/km, depending on the specified treatment. Costs affecting each segment include stabilizer, stabilizer depth, rotomixing, SHT labor, and equipment costs (i.e. tractors, wobbles, vibrator sheep's foot compactors, grader, trucks, water trucks). Caution needs to be exercised when extrapolating these costs to actual implementation costs because this was the first in-place recycling project undertaken by SHT. As a result, some of the costs presented are higher due to the inexperience and logistics of constructing short test sections. For example, when grading segment 88, construction crews were too large and not well organized. As a result, the labor costs for segment 88 was considerably higher than expected. As construction progressed production rates increased; therefore, reducing the relative costs of subsequent sections. To further illustrate, poor weather during construction played a major factor in the incurred costs. For example, rain increased the cost of grading on segment 79. Also, the costs associated with flyash construction are low because only the transport cost of the flyash was incurred; SaskPower incurred all in-house costs in the spirit of the evaluation pilot project.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Stabilizer Treatment And Rotomix Depth (mm)</th>
<th>Total ($/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>FLYASH – 150</td>
<td>26,000</td>
</tr>
<tr>
<td>72</td>
<td>FLYASH – 150</td>
<td>28,900</td>
</tr>
<tr>
<td>73</td>
<td>NONE - 150</td>
<td>11,000</td>
</tr>
<tr>
<td>74</td>
<td>CBRPLUS – 150</td>
<td>26,700</td>
</tr>
<tr>
<td>75</td>
<td>CBRPLUS – 150</td>
<td>29,500</td>
</tr>
<tr>
<td>76</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>77</td>
<td>NONE - 150</td>
<td>9,500</td>
</tr>
<tr>
<td>78</td>
<td>NONE - 150</td>
<td>18,000</td>
</tr>
<tr>
<td>79</td>
<td>CBRPLUS – 300</td>
<td>82,700</td>
</tr>
<tr>
<td>80</td>
<td>CBRPLUS – 150</td>
<td>35,900</td>
</tr>
<tr>
<td>81</td>
<td>CBRPLUS – 150</td>
<td>38,600</td>
</tr>
<tr>
<td>82</td>
<td>CBRPLUS – 150</td>
<td>31,500</td>
</tr>
<tr>
<td>83</td>
<td>NONE - 0</td>
<td>13,400</td>
</tr>
<tr>
<td>84</td>
<td>FLYASH – 300</td>
<td>45,100</td>
</tr>
<tr>
<td>85</td>
<td>FLYASH – 150</td>
<td>27,100</td>
</tr>
<tr>
<td>86</td>
<td>FLYASH – 150</td>
<td>25,700</td>
</tr>
<tr>
<td>87</td>
<td>FLYASH – 150</td>
<td>23,700</td>
</tr>
<tr>
<td>88</td>
<td>CEM – 300</td>
<td>72,400</td>
</tr>
<tr>
<td>89</td>
<td>CEM – 150</td>
<td>44,800</td>
</tr>
<tr>
<td>90</td>
<td>CEM – 150</td>
<td>44,400</td>
</tr>
<tr>
<td>91</td>
<td>CEM – 150</td>
<td>31,700</td>
</tr>
</tbody>
</table>
4.0 HIGHWAY 19-06 INITIAL RESULTS

Post construction quality assurance testing included visual inspection, ground penetrating radar (GPR) survey, dynamic cone penetrometer (DCP) tests. Visual inspections were performed periodically since construction. Visual inspection of the subgrade two months after construction just prior to the base overlay and double seal showed the cementitious and high lime flyash sections showed minimal consolidation rutting, but the exposed subgrades produced traffic dust. The exposed subgrades of the CBRPlus test sections were found to slightly more consolidation rutting compared to the cementitious and flyash sections due to the inherent delayed cure time of CBRPlus. However, the subgrade surface was found to be less dusty. Based on these observations, it was concluded that the cementitious and flyash stabilizers provide higher early strength and are more forgiving in adverse weather conditions. It was found that the CBRPlus takes much longer to cure (manufacturer recommends leaving the grade open for a period of one year prior to sealing, however, CBRPlus was found to significantly reduce dust under light traffic. CBRPlus was also found to extremely sensitive to moisture content during construction. Therefore, the potential for higher than expected construction costs will be incurred if rainfall occurs during construction because of the CBRPlus nature to not shed moisture initially when curing. In the case of Segment 79, the section required rotomixing and drying one year later.

GPR surveys were conducted to ensure proper layer thicknesses were constructed as planned within allowable tolerances. The GPR survey results found that all test section structural cross sections had been constructed within the allowable set tolerance of ±25 mm.
To compare relative insitu subgrade strength across the test sections, DCP tests were performed approximately six weeks after construction. Figure 8 illustrates the mean DCP results obtained from the 150mm stabilized grades prior to base overlay and sealing. As can be seen in Figure 8, the blend of cementitious materials showed the highest increase in subgrade DCP values, followed by the flyash, CBRPlus, and the control section. It is interesting to note that the cementitious blend and to a certain degree, the flyash increased the DCP values below the stabilized thickness. This is most likely due to the induced drying of the lower subgrade during initial hydration. The CBRPlus was found not to provide significant early strength relative to the control section after six weeks of curing.

![Figure 8: Highway 19-06 Post Construction Mean DCP Results](image)

Ongoing DCP, ground penetrating radar and deflection monitoring of the Highway 19-06 test sections is planned to continue over a number of years to evaluate long-term results and show possible effects caused by environmental conditions.
4.0 BENEFITS OF “BUILD DOWN” APPROACH TO STRENGTHENING TMS ROADS

4.1 Benefits to Public Road Agencies

It is estimated that Saskatchewan has approximately 4000 km of TMS roads province wide that will be in need of structural strengthening in the foreseeable future. The potential economic benefits of developing and successfully implementing in-place recycling and full-depth stabilization could be in excess of a hundred million dollars in Saskatchewan. Therefore, a rational, scientific based methodology for engineering cold in-place recycled and stabilized road systems would greatly improve SHT’s ability to cost effectively meet future road strengthening objectives and will also demonstrate to the taxpaying public that they are providing optimal and competent solutions that satisfy Saskatchewan’s road infrastructure needs.

The potential benefits of in-place road recycling and stabilization for SHT and potentially other Saskatchewan public road agencies can be illustrated by example. In west central Saskatchewan (i.e. north of Kindersley) there are significant kilometers of TMS roads in need of strengthening to support the increased truck traffic associated with oil development and rationalization of grain transportation. Gravel sources in the area are becoming depleted currently resulting in 80-100 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 in these types of scenarios could potentially be strengthened using in-place recycling and stabilization for significantly less investment than conventional methods. In addition, in-place recycling and strengthening can be used in a staged upgrading approach to provide a seal on subgrade that will provide load carrying capacity for a few years prior to full upgrading.

4.2 Benefits to the Material Suppliers and the Environment

A major component of this research is specifically directed at testing and evaluating lower cost waste co-products for use as blending into a viable road subgrade soil stabilization materials. The successful use of co-products in road construction would help solve environmental problems associated with the disposal of these co-products. The potential productive use of these co-products would mitigate the need for expansion of landfill facilities and turning a traditional wasted material into a marketable product.

4.3 Benefits to State of Practice in Stabilization

A longer-term benefit of this research is to advance the state of knowledge and practice in cold in-place recycling and subgrade-strengthening using advanced stabilization materials. Improved engineering methods are needed because of the inherent complex physiochemical and micro mechanical behavior of these road systems. These inherent complexities induce a high degree of uncertainty primarily related to the fact that, until very recently, only phenomenological laboratory tests and/or experience based methods have been available for the design, specification, quality control/quality assurance, and performance prediction of stabilized road systems. These traditional phenomenological-empirical methods are limited because they are, in
effect, trial and error methods. As a result, public road agencies have been reluctant to use stabilization in anything other than small trial applications, even though the potential economic and environmental benefits of stabilized road systems can be quite compelling. Recent developments in thermomechanistic and physiochemical characterization and mechanistic road modeling of roads have the potential to overcome the limited predictive capabilities associated with traditional phenomenological-empirical methods and provide road engineers with a rational framework to defensibly evaluate stabilized road systems. A mechanistic framework will reduce the uncertainty associated with the performance of stabilized road systems in diverse applications.

5.0 SUMMARY AND CONCLUSIONS

Saskatchewan Highways and Transportation (SHT) is responsible for maintaining approximately 8600 kilometers of thin membrane surface (TMS) roads. Many of these TMS roads are experiencing added pressures from the recent rationalization of the provincial grain handling transportation system plus other heavy haul dependent industries. Unfortunately, the Saskatchewan TMS system was never designed to handle the increased loads and traffic. As a result, the TMS system is deteriorating with limited resources to improve or maintain existing conditions in an expected timely fashion. To increase timely repair or structural strengthening these roads require new and innovative measures resulting in more cost-effective and efficient treatments. The work on Highway No. 19 is a step towards fulfilling this goal.

The economic viability for the province of Saskatchewan is dependent upon its transportation system. The condition of the transportation network has a direct impact on the economic stability of the province. SHT intends to provide a sustainable transportation system for its users and stakeholders. Current changes in grain handling and other major industries like oil and forestry have placed considerable pressure on the highway network, particularly the secondary road system. Although conventional rehabilitation methods are proven, more economical techniques are required in order to provided timely repair or rehabilitation of the secondary highway network.

Based on the findings of this study, cold in-place recycling in conjunction with stabilization systems may prove to be a viable treatment alternative for the province. If savings can be realized due to reduced aggregate usage, while at the same time, providing a strengthened subgrade that can carry more tones over a few years prior to full upgrading. The pilot project on Highway 19-06 will continue to be monitored to quantify the long-term performance for each test site. Other projects will be completed and other products evaluated to identify other possible treatment options. SHT will continue to research, develop, and implement new methods for preserving the provincial roadway network.
REFERENCES

