Highway Program

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Memorandum

To: Tom Stevens
From: Karen Gross
Date: 6/18/2012
Subject: I-95 Frost Heave Mitigation
Dyer Brook, Island Falls

I have finished looking at all the available information at the frost heave locations on I-95 in Dyer Brook. I looked at six frost heave locations and the immediate adjacent areas. The locations as per as-built stations are 573+95, 689+15, 852+10, 885+37, 899+40, and 925+95. I looked at a minimum of 100 feet to the north and south of these locations because I am not positive if they are exact.

The following is a recap of the information I reviewed. This information includes as-builts plan views, cross sections and profile drawings, the pre-construction geotechnical reports, and a recent soils report written by Scott Hayden. Advantages and disadvantages of the various recommended frost mitigation options being discussed follows the summary of the existing information that I reviewed.

As-built Plans
As-built plans from 1978 and 1979 indicate that this section of roadway was originally constructed with 33" of select granular material, 13" of crushed base course gravel, 2 ¼ " of plant mix bituminous base course, and 6 ¾" of HMA (called hot bituminous pavement at that time). The crushed base course gravel is similar to the current base course specifications for Type A or Type B crushed aggregate. No specifications could be found for the select granular material, but it is reported by those that were working at the DOT during that time frame that this material typically was a clean Granular Borrow (# 703.19) similar to the current material for underwater backfill. The geotechnical reports for these projects indicate that the natural subgrade is glacial till, a mix of silt, sand, gravel, and cobbles. Glacial till is usually moderately to highly frost susceptible. Shallow groundwater, bedrock, and peat were encountered at many boring locations. Peat locations were mucked to the depth of the peat deposit, but it is unclear on the plans if and provisions were made for shallow groundwater or bedrock. The plans contain the transition detail for culverts and undercutting for ledge in frost susceptible soils, but the plans did not show that transitions were constructed.

The following is a summary of the subsurface conditions (subgrade and below) prior to and following construction at each frost heave location.

<u>Frost Heave 1 – Station 573+00 to 579+00 (Report Station 5120+25)</u>

- Cut Section
- Shallow bedrock sloping from right to left transversely (574+00 to 579+00)
- Longitudinal slope = +3.24%
- High groundwater table

<u>Frost Heave 2 – Station 688+00 to 690+00 (Report Station 5235+45)</u>

- 23' cut section
- Cut deepest on left side of roadway – ground slopes from left to right
- No shallow bedrock
- Longitudinal slope = +1.82%
- Many boulders

Frost Heave 3 – Station 851+00 to 855+00 (Report Station 5398+40)

- Transitions from fill to cut section
- Shallow bedrock at subgrade or just below
- Longitudinal slope = +2.8%

Frost Heave 4 – Station 885+00 to 886+00 (Report Station 5431+67)

- Fill section
- Waste areas at toe of slope – right and left
- Peat mucked out
- Longitudinal slope = +2.0%

Frost Heave 5 – Station 898+00 to 901+00 (Report Station 5445+70)

- Cut section
- Shallow bedrock - 5' to 13' below ground surface
- Longitudinal slope = +2.0%

Frost Heave 6 – Station 924+00 to 926+00 (Report Station 5472+25)

- Transitions transversely with cut and fill sections
- Left side toe of slope waste area
- Longitudinal slope = -2.78%

Soils Report No. 2010-115

The subsurface investigations from May 3, 2010 indicate that the natural subgrade consists of silty SANDS and sandy SILTS. Both of these soil types have a high fine content (% passing the #200 sieve) and are slightly to moderately frost susceptible. Most samples collected were wet which can indicate a shallow groundwater table or that the ground was in a state of thawing. Anticipated depth of frost penetration is expected to be between 72" and 104" below the ground surface.

The existing pavement structure aggregates are classified as SAND with varying amounts of gravel and silt. The differentiation between the base course gravel layer and the select granular material was not noted on the boring logs. Shallow refusal was encountered a Station 575+89 and 575+99 which is in the general vicinity of Frost Heave 1. Wet pavement structure aggregate and subgrade soils (3' to 7' below the ground surface) were encountered in most borings. The boring logs also state that the soils got drier with depth. I would expect a saturated zone at this depth and time of the year since ice lenses have probably just finished melting.

As per the report, it is believed that this water source is coming from surface water that is entering into wide cracks in the HMA. De-icing agents (salts) are also able to enter into the pavement structure through these cracks. Salts are hydrophilic substances that have the ability to attract and hold water to them. Since the existing pavement structure soils are not very well draining, the highest salt concentrations are probably very close to the surface, thus there can be a significant amount of surface water available to bond with these salts and then available to produce ice lenses close to the surface and adjacent to the cracks in the HMA.

Ice lenses near the surface will produce a distinct abrupt bump known as tenting and a highly irregular and uncomfortable riding surface develops. Tenting typically develops on roadways with longitudinal slopes that are near or exceed the transverse slope, and any transverse cracks in the HMA will intercept water, salts, and winter sand that flows longitudinally down the roadway. Tenting does not completely disappear after the thawing period like the heaving that is created by deeper ice lenses or differential materials. This is due to the accumulation of salt and sand at the crack location that does not allow the HMA to go back to a smooth condition.

Proposed Frost Heave Mitigation

Rich Crawford recommends rebuilding the existing pavement structure with 27” of free draining aggregates and 9” of new HMA (36” total). Using a rock cap construction method was mentioned, but after speaking with Rich, his intent was to use a permeable aggregate versus a railroad ballast type stone that is used in rock cap construction. The rock cap construction technique is used frequently by the Washington State DOT and the Idaho DOT as a treatment to allow four season travel on roads that typically require load restrictions during the spring thawing period. Ballast stone, with large particle sizes and many voids between them, is placed on top of the existing roadway aggregate as a new thick base course layer. By placing a new layer on top of the existing aggregate, the freezing depth elevation is higher and further away from any existing groundwater source. Because there are large amount of voids, it has excellent drainage capabilities and it acts as a capillary break, therefore ice lenses can not develop within the layer. To see a large project where Washington constructed a rock cap roadway, search for Colville, Washington in Google Earth and locate highway SR 20. Drop in the Street View Man and head east on State Route 20 (Northern Cascades Highway).You have to get a few miles out of town to see where the rock cap aggregate was placed. This highway is the northern most route in the State of Washington and definitely is subjected to harsh winter weather.

One of the primary distresses caused by thaw weakening is rutting in the HMA, base aggregate, and subgrade soils. Rutting occurs due to the weakening of the subgrade and base aggregate when the ice lenses melt and these soils become super saturated. The load supporting capabilities of the base and subgrade will be greatly reduced when wet. Ice lenses will typically melt from the surface downward in pavements that are exposed to direct sunlight. At first, this can create a situation where water gets trapped between the underlying frozen layers and frozen shoulders. High water pressures develop when a heavy load is applied and these pressures are exerted on the confining HMA surface layer. This is particularly detrimental to the HMA if there are many freeze-thaw cycles and over time, cracking will develop. As melting progresses downward, the water content of the base aggregate and the subgrade increases and the bearing strength of the soils increases. It is in this phase of the thawing process that permanent damage is done to the subgrade and base aggregate (permanent deformation) and when subsequent rutting develops in the HMA layer. Pavement management data indicates that the existing rut depths are 0.6” to 0.8”.

Removing the existing aggregate and replacing it with a more drainable material will help eliminate near surface ice lens formation as will sealing the surface with a new HMA layer. However, the cracks that are there now had to form originally either due to deeper ice lens development, due to differential heaving, thaw weakening, or simply from the expansion and contraction of the HMA material. In my opinion and based on the as-built construction plans , cross sections and the existing wet soils, I would conclude that the existing cracks in the HMA formed due to deep ice lens formation and from differential heaving (depending on location). Once these cracks formed, water and deicing agents were allowed to enter into the pavement structure, and near surface ice lenses developed.

If the underlying cause of the heaving is indeed due to frost issues at deeper depths, removing and replacing the top 36” of the existing pavement will not change the depth of frost penetration from where it is now and heaving will still be an issue. In order to change the freezing front elevation, the roadway surface elevation needs to change. I would recommend placing the new 36” structure on the existing aggregate base gravel, much like the rock cap construction treatment, however raising the roadway grade this much will have significant impacts to the in-slopes and ditches.

Reducing the amount of available water that can feed ice lens development will greatly reduce or even eliminate frost issues. This can be economically accomplished by installing longitudinal underdrains along both sides of the road at a depth deep enough to lower the groundwater table. Installing deep longitudinal underdrains and replacing the top 36” of the pavement structure with highly drainable aggregate should reduce both subsurface and surface frost issues. I did not see any drainage information on the as-built plans that would indicate underdrain, french drains, or weepers were provided in the original construction of this project. Since the geotechnical and as-built construction information indicates that high groundwater and muck areas (usually water is present) were present and water removal was not addressed during construction, I would anticipate that groundwater is still available for ice formation.

The issue with rebuilding the pavement structure and installing underdrain is that it is a high cost solution if the frost heaving issue is due to surface ice lens formation only. If this is the case, removing all the distressed HMA and some of the salt contaminated base course and placing new base course HMA would be an appropriate treatment. Timely crack sealing will help prevent the intrusion of water and salts and future near surface ice lens formation.

The following is a summary of some of the advantages and disadvantages of each of the above mitigation strategies.

REBUILD WITH 27” DRAINABLE BASE, 9” HMA

Advantages	Disadvantages
• Drainable base aggregate will prevent the formation of ice lenses within the pavement granular base course layer. • New HMA will improve the ride quality and prevent water and salt from entering into the pavement structure.	• Depth of frost penetration unchanged from existing condition. • Will require excavation and long term lane closures. • High cost to construct if the heaves are produced by near surface ice lenses. • With deep underdrain, deeper frost issues (subgrade to freezing front) will be reduced or eliminated since the water supply will be limited

REMOVING AND REPLACING HMA AND SALT CONTAMINATED GRAVEL

Advantages	Disadvantages
• New HMA will improve ride and prevent water and salt from entering into the pavement structure. • Much lower cost than rebuilding pavement structure. • Shorter construction time than rebuilding pavement structure.	• Will not correct deep frost issues. • Will not improve drainage capabilities of the pavement aggregate.

Conclusions

Frost action is a very complex process and unfortunately it is difficult to determine the actual cause of the heaving with the current condition of the pavement. The existing transverse cracks are so wide that I would expect that a significant amount of surface water enters into them resulting in the development of near surface ice lenses.

One way to determine if the underlying cause is due to near surface or deep ice lens development would be to repair some of the existing crack locations. This can be done by removing the existing HMA and some of the contaminated base gravel and replacing it with new HMA and gravel. The width of the repair should be at least a width that a paver and vibratory roller can place and compact. Since this method will not correct deep frost issues caused by groundwater or differential materials, any heaving that occurs during the winter following this repair would indicate that it is not a near surface ice formation issue and that tenting is occurring as a side effect of the cracks formed by deep frost action and subsequent water and de-icing salt intrusion. I recommend that each repair section is monitored regularly and surface elevations should be recorded to determine if differential heave is occurring. Once the actual cause of heaving is determined, the appropriate treatment can then be selected and constructed.

Another concern I have is that the pavement is experiencing thaw weakening. This is based on the high water contents of the base aggregate and subgrade soils (3’ to 7’ below the ground surface) as reported on the borings and as per lab testing data. The depth of the wet soils corresponds to about the location were ice lenses would form with the anticipated frost depths for this area. To determine if the rutting is due to thaw weakening, a trench can be cut across the roadway and the rutting can be observed in the HMA layer. If the rutting is confined to the upper layers, the cause is load related. If the entire HMA layer is deformed, it can indicate that the subgrade soils are experiencing thaw weakening and that there is a significant loss of support during the thawing period.

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