LTPP Data Analysis

Task Order #03

"Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost"

Quarterly Progress Report

July, August, September 2005

Prepared for:

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Federal Highway Administration
400 Seventh Street, S.W.
Washington, D.C. 20590

Detailed Technical Summary of NCE Task Order #03 “Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost”

In this quarter, NCE has continued work on Task 8 and 9 and started Task 10 of Task Order #03.

Task 8

Conduct detailed analysis of the effects of multiple freeze-thaw cycles verses deep frost penetration on pavement performance

Work under this task is nearing completion. Multiple regression models, using various performance-age relationships (i.e. natural logarithm of age), have been developed for each performance measure. The best regression alternative was selected through an evaluation of scatter plots as well as R-squared and root mean squared error statistics to determine the model that most accurately predicted the observed data set.

Using the selected models, performance curves for the various environmental regions were plotted for purposes of comparison. Table 1 and 2 provide summaries on the five climatic scenarios for flexible and rigid pavements, respectively. Details on the process used to select the environmental values in each climatic region can be found in Table 3. With the exception of FTC, the values selected for all environmental variables were the median value present within the region. For example, the median FI of test sections in the no freeze region (i.e. 0<FI<50) was found to be 10 degree Celsius days. Similarly, the CI value of 205 degree Celsius days was determined to be the median CI value present for test sections in the Deep Freeze region (FI>400).

Table 1. Overview of climatic scenarios for flexible pavements.

SCENARIOS	ACTHICK	BASE	SG	LESN	EXP	FI	FTC	PRECIP	CI
Deep Freeze Wet Region (low FTC)	6.5	DGAB	FINE	1.02	G1	688	80	1140	205
Moderate Freeze Wet Region (high FTC)	6.5	DGAB	FINE	1.02	G1	137	130	1140	645
No Freeze Wet Region	6.5	DGAB	FINE	1.02	G1	10	10	1140	1300
Deep Freeze Dry Region (low FTC)	6.5	DGAB	FINE	1.02	G1	688	80	380	205
Moderate Freeze Dry Region (high FTC)	6.5	DGAB	FINE	1.02	G1	137	130	380	645

Table 2. Overview of climatic scenarios for rigid pavements.

SCENARIOS	FC	D	BASE	SG	LEDT	EXP	FI	FTC	PRECIP	CI
Deep Freeze Wet Region (low FTC)	2	9.5	DGAB	FINE	0.59	S2	688	80	1140	205
Moderate Freeze Wet Region (high FTC)	2	9.5	DGAB	FINE	0.59	S2	137	130	1140	645
No Freeze Wet Region	2	9.5	DGAB	FINE	0.59	S2	10	10	1140	1300
Deep Freeze Dry Region (low FTC)	2	9.5	DGAB	FINE	0.59	S2	688	80	380	205
Moderate Freeze Dry Region (high FTC)	2	9.5	DGAB	FINE	0.59	S2	137	130	380	645

Table 3. Details on selection of environmental variables.

Variable	Criteria	Value
Deep Freeze (FI)	50th percentile of deep freeze (>400 FI)	688
Moderate Freeze (FI)	50th percentile of moderate freeze (50<FI<400)	137
No Freeze (FI)	50th percentile of no freeze (<50 FI)	10
Low FTC	10th percentile of FTC values in deep freeze (>400 FI)	80
High FTC	90th percentile of FTC values in mod freeze (50<FI<400)	130
No Freeze FTC	50th percentile of FTC values in no freeze (<50 FI)	10
Dry (PRECIP)	50th percentile of dry region (<508mm)	380
Wet (PRECIP)	50th percentile of wet region (>508mm)	1140
Deep Freeze (CI)	50th percentile of deep freeze (>400 FI)	205
Moderate Freeze (CI)	50th percentile of moderate freeze (50<FI<400)	645
No Freeze (CI)	50th percentile of no freeze (<50 FI)	1300

Because the aim of the study is to compare the trade-off in pavement deterioration between deep frost and multiple freeze-thaw cycles, the percentile used to select FTC values was different for each region. In the deep freeze region, one of the lowest FTC values present (10th percentile) was selected while one of the highest values was identified for the moderate freeze region (90th percentile). This approach was utilized to isolate the contribution of FI from FTC in the deep freeze region and allow the contribution of FTC to be investigated in the moderate freeze region. As a caveat, it is apparent that pavements do exist in areas with both deep frost penetration and multiple freeze-thaw cycles as can be seen in Figure 1.

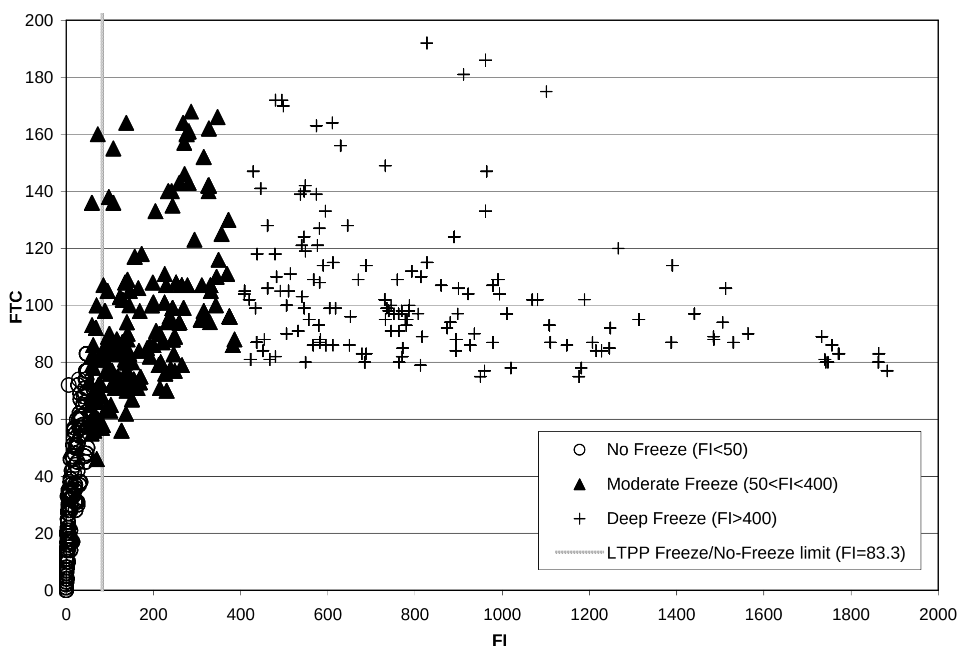

Figure 1. Relationship between freezing index and freeze thaw cycles.

Mean prediction values were plotted as a function of pavement age for each scenario. As an example, mean flexible pavement transverse cracking predictions are provided in Figure 2. As can be seen in the figure, there are differences in the accumulation of transverse cracking at a pavement age of 20 years. However, when making comparisons, a determination must be made as to whether performance differences in the prediction of each scenario are statistically significant. The relatively small differences in performance can be confounded by the error inherent in the models. These differences cannot be attributed solely to the contribution of climatic setting. Rather, it is likely that the variability within the model is the source of the differences. Confidence intervals were utilized to determine if differences in performance were statistically significant. A confidence interval of 95 percent was selected for this study. Confidence intervals for the transverse cracking example can be found in Figure 3.

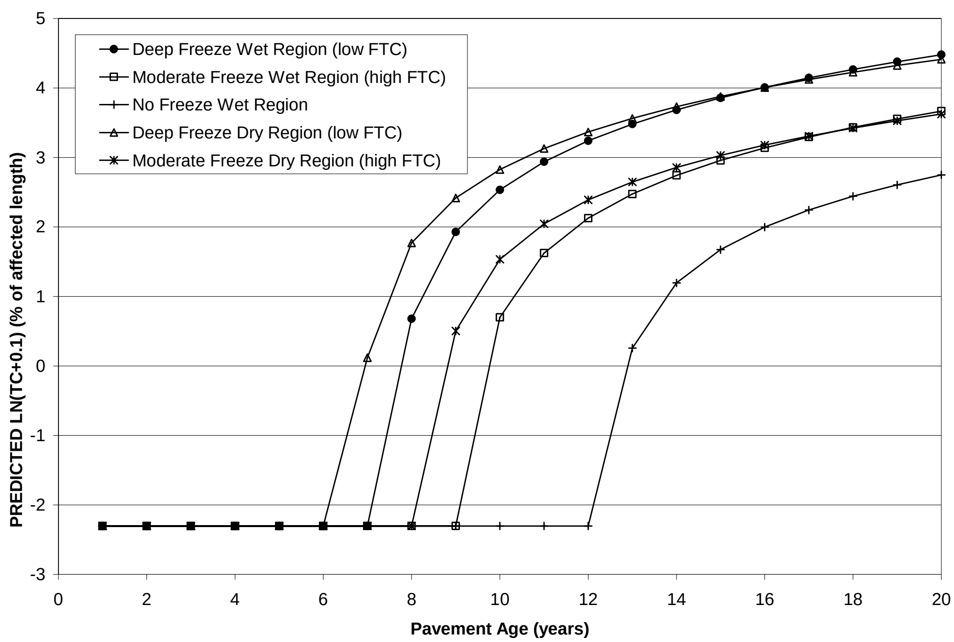

Figure 2. Mean predicted flexible pavement TC values for each climatic region (BASE=DGAB/SG=FINE).

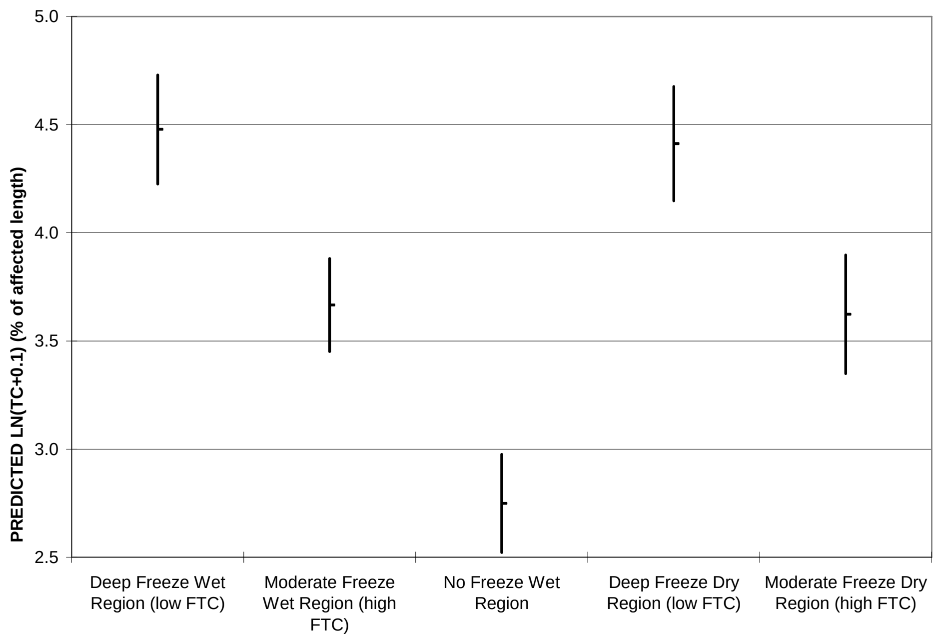

Figure 3. Predicted flexible pavement TC values at 20 years for each climatic region (BASE=DGAB/SG=FINE).

In Figure 2, transverse cracking initiation ranges between 6 and 12 years, initiating earlier in the deep freeze regions which experience colder minimum temperatures in the winter months. Conversely, pavements in the no freeze regions, with mild winter temperatures, initiate transverse cracking much later.

As can be seen in Figure 3, pavements exposed to deep sustained frost penetration exhibit quantities of transverse cracking that are significantly larger than in pavements in the multiple freeze-thaw cycle climate, at a 95 percent confidence interval. This holds true for both relatively wet and dry climate. Additionally, pavements exposed to climatic conditions that are representative of the southern reaches of the no freeze region accumulate less transverse cracking (at 95 percent confidence) compared to areas with both deep sustained frost and multiple freeze thaw cycles.

Comparisons for the other performance measures were made in a similar fashion. Additional comparisons were made for the various combinations of base and subgrade types as well as for different pavement structures (i.e. flexible overlay, flexible non-overlay, and rigid pavements).

Predicted performance was also plotted for representative climates (and a standard pavement section) in each of the pooled fund states to gain an understanding of the relative performance between the agencies. Rutting predictions are provided as an example in Figure 4.

Considerable climatic variation does exist within each agency. As such, state maps were generated for each of the pooled fund states that contain the geographic location of each test section used in the study. These maps can be used with the known climatic information of each test section to evaluate environmental variation across a state.

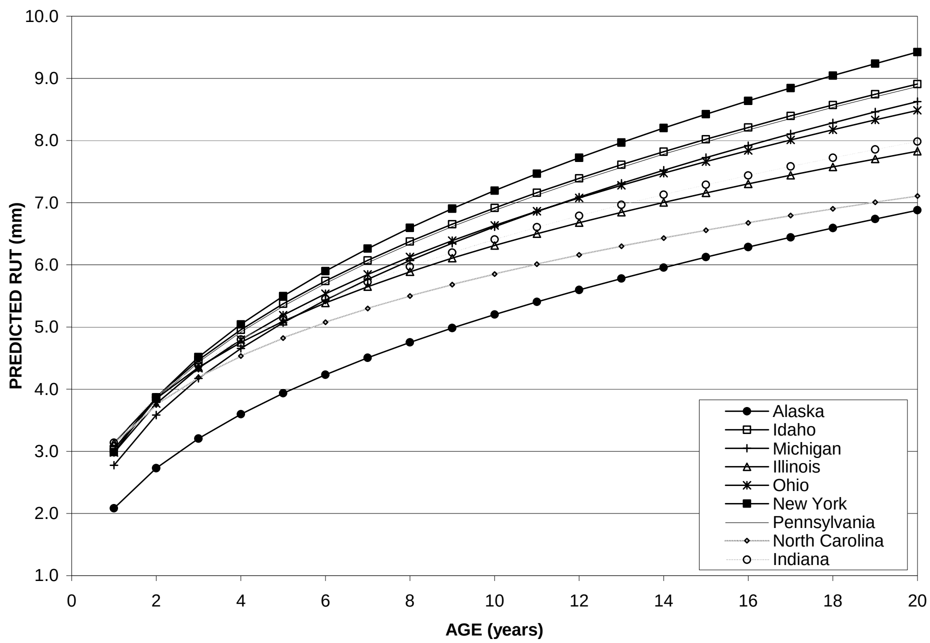

Figure 4. Flexible pavement RUT for selected sites in each agency.

Work will continue on finalizing the observations and key findings from this task in the next quarter. Analysis performed under this task will also be used to make life cycle cost comparisons between the established regions.

Task 9

Conduct detailed analysis of the extent to which local adaptations of materials standards and empirical pavement design practices have been effective at reducing the rate of pavement deterioration

NCE has received all of the states' responses to the questionnaire sent out in March, 2004. A summary of the data from the states was presented at the pooled fund panel meeting at the Annual TRB Meeting. The summary indicates a large variation in the typical pavement sections provided by the different states to the design criteria stated in the questionnaire. The variation is not necessarily consistent with trends in frost depth or freeze-thaw cycles. This information was returned to the pooled fund panel members for review and comments as well as a request to provide any known information on bordering states' unique approaches to mitigate frost effects and possible contacts. To date, four of the eight states have responded to that request. NCE is also compiling the information on materials and specifications that was submitted in response to the questionnaire. Most of the responses regarding material and standard specifications directed NCE to each department's website.

NCE has downloaded and compiled all of the relevant materials and construction specifications to supplement information supplied by the states. NCE has not fully analyzed the data or made any conclusions at this time. However, it has been observed that the nationwide adoption of Superpave binder specifications specifically address environmental issues such as rutting and thermal cracking. Unfortunately the performance information available in the LTPP database is largely related to binder specifications that predate the binder and mix design that is currently included in the states' specifications. Additionally, the current Superpave mix design procedures tend to treat all environmental areas the same whereas state specifications in place before the adoption of Superpave may have more specifically addressed the environment in which they were used. The performance data will only indicate the trends based on the prior material and construction specifications.

A couple of basic approaches to treating frost susceptible soils have been noted. Several of the more northern states sub-excavate frost susceptible soils to a depth as great as three feet to minimize the effects of frost heave and thaw weakening due to the presence of these soils. One of the states has been using a deep rock base, which is referred to as a rock cap, to minimize the effect of the frost action on the roadway section. It might be possible to quantify these effects in the models that have been developed.

In one case, information not included in the specifications might provide some insight into the difference between specifications in response to frost effects. One state uses a modified Lottman procedure to determine moisture sensitivity in their mix design procedure. The modification eliminates the freezing stage incorporated in the original Lottman procedure. Because this procedure was developed based on experience from a northern state with significant freeze-thaw cycles, it may be cost effective to eliminate that part of the procedure in more southern states.

Task 10

Conduct detailed analysis of the costs associated with building and maintaining similar pavements to provide equal performance trends in the various freeze to no-freeze climatic regions.

NCE has begun to assemble the data needed to conduct the detailed analysis of the costs associated with the building and maintaining of similar pavements in different environments.

Resources Used

Figure B.1 in Appendix B shows the current work schedule for Task Order #03 through September 2005.

A six month no-cost time extension was requested and granted on this project. This provides more time to complete the project while allowing the final meeting to be held in Washington, DC during the Annual Transportation Research Board Meeting.

A meeting room has been requested for Saturday January 21, 2006 between 7:00 p.m. and 10:00 p.m. at the Marriott Hotel. NCE will notify the panel members when TRB confirms the final meeting time and place.

The expenditures have continued to be about 30 percent below planned expenditures as a carryover from the earlier delay. Figure B.2 in Appendix B shows the planned costs versus actual costs for Task Order #03 through September 2005. With the six month extension, the current expenditure rate is more in line with the budget rate through the time extension.

Appendix B

Task Order #03

Work and Costs Summaries

Through September 2005

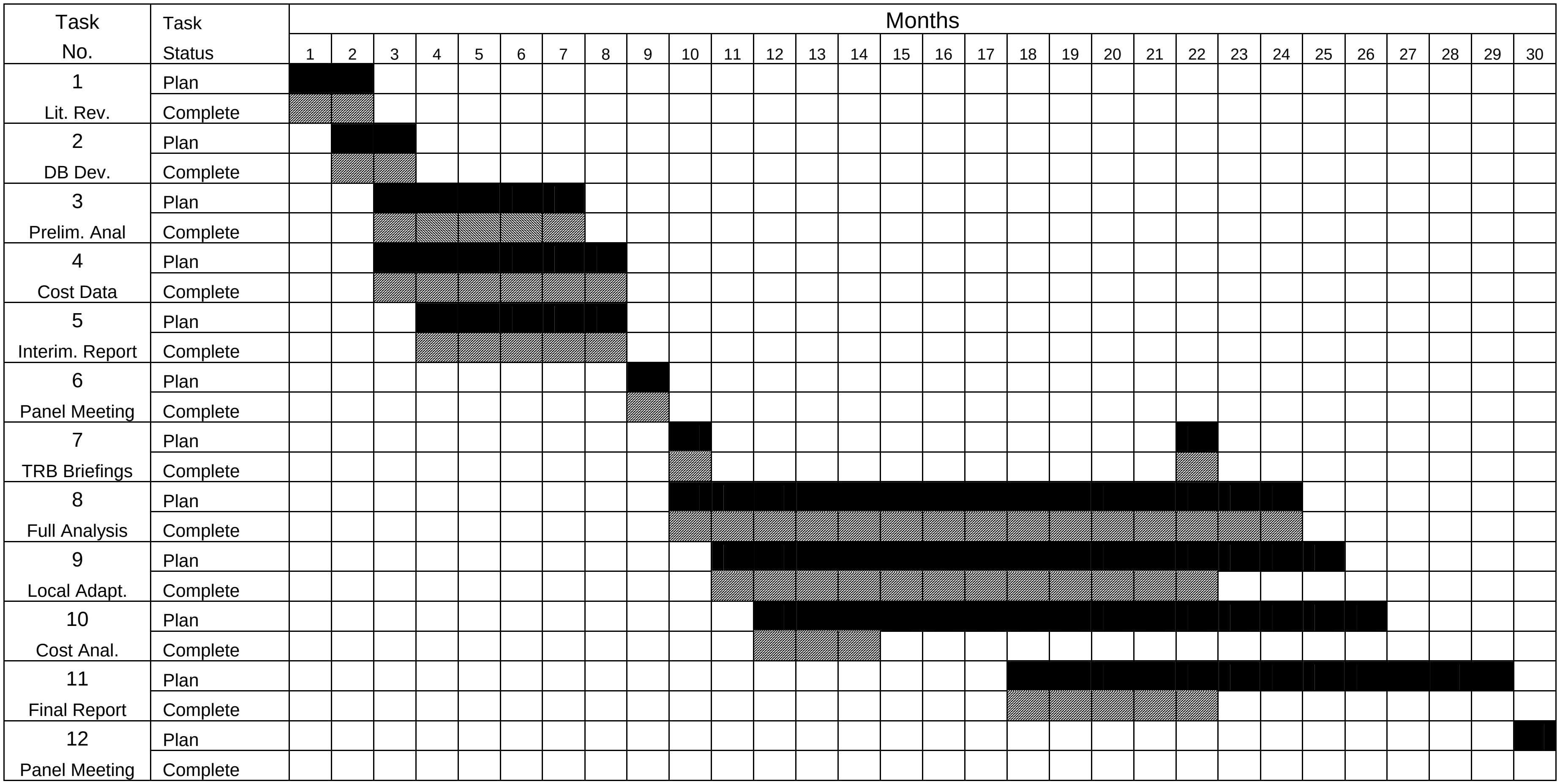

Figure B.1. Work Schedule for Task Order #03 through September 2005.