MATERIALS AND ROAD RESEARCH SECTION *RESEARCH PROJECT WORK PLAN*	INV. No. 828

TITLE OF PROJECT: Local Road Material Properties and Calibration for MnPAVE

IS THIS A RESPONSE TO A PROBLEM STATEMENT? ☐ NO ☒ YES
IF YES, STATE NAME OF CONTACT PERSON. Bruce Tanquist

PRINCIPAL INVESTIGATOR (LAST, FIRST, MIDDLE). Tanquist, Bruce Allen

POSITION TITLE/DEGREES Research Project Engineer, MS, PE

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TOTAL BUDGET: FUNDING SOURCE AMOUNT LRRB 55995	TOTAL BUDGET PERIOD: START DATE: 7/1/2005 END DATE: 6/1/2008 PROJECT LENGTH (MONTHS): 20

KEY PERSONNEL OTHER THAN PRINCIPAL INVESTIGATOR.

NAME	NAME
POSITION TITLE	POSITION TITLE
ORGANIZATION	ORGANIZATION
DEGREE(S)	DEGREE(S) B
ROLE ON THE PROJECT	ROLE ON THE PROJECT

PROJECT LIAISONS

TECHNICAL LIAISON: NAME Jerry Geib ORGANIZATION Mn/DOT	ADMINISTRATIVE LIAISON: NAME Dan Warzala ORGANIZATION Mn/DOT ADDRESS 395 John Ireland Blvd., St. Paul, MN 55155

KEY WORDS
Mechanistic Empirical design, M-E design, MnPAVE, asphalt, local roads, low volume roads, calibration

RESEARCH PROJECT WORK PLAN

ABSTRACT

The existing version of MnPAVE was calibrated to match the existing R-Value design procedure and typical state highway pavement structures. Estimates of the seasonal variation in soil and aggregate base material properties were based primarily on studies done at a single location. This study will produce a version of MnPAVE that focuses on local road structures and seasonal variations in material properties, specifically during the Spring Thaw period. MnPAVE will also be calibrated to local road performance data. The results of this research can also be implemented in the Mechanistic-Empirical Pavement Design Guide developed for NCHRP.

IMPLEMENTATION *What methods, procedures, products, and/or standards should change as a result of this research project?*

A new design procedure will be proposed for implementation in local road and State Aid pavement design specifications.

What are the specific benefits of this change(s), why would this change(s) be important, and how can these benefits be measured?

Money savings due to improved reliability of pavement designs and a user-friendly mechanistic-empirical pavement design program calibrated for local roads.

DETAILED BUDGET FOR ENTIRE PROJECT

SALARY: 54924	DOLLAR AMOUNT (OMIT CENTS)		
NAME/ROLE	YEAR 1	YEAR 2	TOTALS
Bruce Tanquist	26409	13414	39823
Student Worker	6746	3426	10172
TOTAL SALARIES	**33155**	**16840**	**49995**
DIRECT COSTS:			
CONSULTANT/CONTRACTOR COSTS (See Note(1))			
EQUIPMENT (ITEMIZE)			
SUPPLIES	2000	1000	3000
TRAVEL (In-state only)	2000	1000	3000
OTHER EXPENSES (i.e., testing)			
TOTAL DIRECT COSTS	**4000**	**2000**	**6000**
TOTAL PROJECT COSTS	**37155**	**18840**	**55995**

Note(1): Contracts for consultants/contractors will be processed by P.I. through Consultant Services and encumbered directly from LRRB accounts. Requisition for contract is sent through Research Services for coding of accounting information

IF PROJECT EXTENDS BEYOND TWO YEARS, DUPLICATE BUDGET PAGE AND PROVIDE PROJECT TOTAL AT THE END OF ADDITIONAL YEARS.

BUDGET BY TASK:

(List Task number and dollar value for each task in work plan. If project includes consultant/contractor, provide breakdown of task budget for Materials and consultant/contractor)

Task No.	Description	Lab	Contractor
1	Survey of Local Road Officials	18000	
2	Model Selection	8000	
3	MnPAVE Programming	10000	
4	Calibration	10000	
5	Expand MnPAVE Help Files	5000	
6	Five-page summary, User's Guide and MnPAVE CD	5000	

COMMENTS/JUSTIFICATION

TECHNICAL LIAISON: (Check one)

Work Plan Approved ☐

Work Plan Approved with Changes Noted ☐

Work Plan Not Approved ☐

PRINT NAME:

DATE:

PRINCIPAL INVESTIGATOR:
I agree to accept responsibility for the scientific conduct of this project and to provide the required progress reports.

SIGNATURE OF
PRINCIPAL INVESTIGATOR:

DATE:

MANAGER, ROAD RESEARCH SECTION :

I hereby certify sufficient staff time will be scheduled for the Principal Investigator to complete the research as outlined in the attached work plan.

SIGNATURE OF
MANAGER ROAD RESEARCH
SECTION:

DATE:

PROJECT INFORMATION

PLEASE ATTACH SEPARATE SHEETS THAT PROVIDE ALL OF THE INFORMATION LISTED BELOW:

BACKGROUND: Include any background information pertinent to the research including any previous related work performed for/by Mn/DOT. Maximum length = 300 words.

OBJECTIVE: Concisely describe the goals or objectives of the project. Maximum length = 200 words.

SCOPE: Briefly describe the range or scope of work encompassed by this project. Maximum length = 200 words.

TASKS: In chronological order list each major task or milestone necessary to complete the project. The work on each task will be reviewed to track progress of the project and to determine when payment should be made.

Deliverable:	For EACH TASK list all deliverables that result from work on this task such as reports, test results, maps, software etc. The MININUM deliverable for ANY task is a 1-2 paragraph write-up describing the outcome of the task.
Duration:	For EACH TASK indicate the amount of time needed to complete the task. List the time in NUMBER of months, not Jan-Mar, etc.

PROJECT SCHEDULE: Include a project schedule such as the one shown here: Note: *<u>This is a Sample!</u>*
ADD ONE MONTH BEYOND YOUR WORK SCHEDULE FOR TECHNICAL REVIEW.

TASK	MONTH												
	1	2	3	4	5	6	7	8	9	10	11	12	13…
Title of task 1	xxxxxxxx												
Title of task 2			xxxxxxxxxxxxxxxxxxxxx										
Title of task 3									xxxxxxxxxx				
Title of task N – Draft Final Report(2)										xxxxxxxx			
Title of task N – Final Report (2)												xxxxxxx	

NOTE(2): The final report MUST be listed as the final two tasks as shown above to provide for technical review. Each task will have a dollar value in the Budget by Task.

Because the start of a project is sometimes delayed due to processing of the contract, the months in the schedule should be listed by NUMBER from the time the contract is approved, not Jan, Feb, Mar, etc.

LITERATURE SEARCH: Include your findings related to this project from a literature search. A literature search is required before any contract negotiations begin.

RESEARCH PROJECT WORK PLAN

Background:

Minnesota's M-E design program began as a Mn/DOT-funded research project at the University of Minnesota in the mid 1990's. The outcome of that research was a computer programs called "ROADENT". In 2000, Mn/DOT expanded the ROADENT software into a new design program called "MnPAVE". This software was calibrated using existing R-Value and Soil Factor designs, and validated using MnROAD test sections. A statewide MnPAVE training program was conducted in 2002.

Resilient modulus testing of aggregate base and soil materials has been conducted for decades. Mn/DOT is developing a database of resilient modulus test results conducted on Minnesota materials. The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has performed freezing and thawing tests on several materials from MnROAD to determine the effects of Spring thaw on the resilient modulus of these materials.

The University of Minnesota's Department of Soil, Water & Climate recently completed a study on the moisture retention characteristics of base and subbase materials. This data will be useful in developing models that relate moisture content to material properties needed for pavement design.

Objective:

The lack of a Mechanistic-Empirical design alternative for local roads will be addressed by this research. A version of MnPAVE that has more detailed material properties and calibrated for local roads will provide a more accurate pavement design alternative for local officials.

Scope:

A survey of local road officials will be conducted to collect pavement condition data for calibrating MnPAVE. Local road performance data will be collected by e-mail and telephone interviews. An incentive for local road officials to participate will be the availability of FWD and GPR testing (performed by Mn/DOT) to fill in missing structural information and access to statewide performance data. This information will be used to calibrate a new transfer function to predict pavement performance of local roads in Minnesota.

Models will be selected to predict the resilient modulus of several Minnesota aggregate base and soil materials during freezing, thawing and other times of the year. The models will be validated using resilient modulus test data queried from the Mn/DOT resilient modulus database. Climate models will be used to predict moisture content and freezing and thawing depths around the state. The models will be programmed into a new version of MnPAVE, and the results of the pavement condition survey will be used to calibrate the existing damage models and/or develop new damage models for the design of local roads.

Tasks:

Task 1: Survey of Local Road Officials ($18,000)
Submit and e-mail survey through the State Aid office to solicit information that will be useful in the calibration of MnPAVE for local roads. This will include structural, traffic, and pavement condition data. FWD and GPR testing will be offered for pavements that look promising for calibration purposes but have incomplete structural data. An important distinction in the performance of the pavement is whether the subgrade soil was compacted according to specified density or quality compaction. Comments and suggestions for improving the user interface of MnPAVE will also be requested in the survey.

Deliverable: Letter report, presentation

Task 2: Model Selection ($8,000)
Select appropriate aggregate base and soil resilient modulus models to compare in MnPAVE. Models will focus on the effects of moisture, freezing, and thawing on the resilient modulus, shear strength and bearing capacity of the materials. The Mn/DOT resilient modulus database will be queried for test results to use in selecting the appropriate models. A climate model will also be selected to predict the moisture content and freezing and thawing depths around the state. Seasonal moduli will be compared to the default values in the Mechanistic Empirical Pavement Design Guide (MEPDG).

Deliverable: Letter report, presentation

Task 3: MnPAVE Programming ($10,000)
Program the selected models in MnPAVE. Include the option of modeling weekly material property changes during the Spring thaw and recovery periods. Streamline the user interface so that only features needed for local road design are visible. Implement suggestions from the survey to make the design process as streamlined as possible.

Deliverable: Letter report, presentation

Task 4: Calibration ($10,000)
Use the survey results to refine the existing damage models (fatigue and rutting) and/or develop new models to predict the life of local roads. Possible new models to consider include performance prediction models based on pavement condition indices such as Present Serviceability Index (PSI), Pavement Distress Index (PDI), Pavement Quality

Index (PQI), or International Ride Index (IRI). These indices may be useful in classifying pavements that do not fail in fatigue or rutting.

Deliverable: Letter report, presentation

Task 5: Expand MnPAVE Help Files ($5,000)
Expand the Help files in MnPAVE and with a focus on the local road designer.

Deliverable: Letter report, presentation

Task 6: User's Guide and MnPAVE CD. ($2,000)

Deliverable: Five-page summary.

Timeline

Task	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Survey	■	■	■	■	■	■	■	■	■											
2	Model Selection	■	■	■	■	■															
3	Programming						■	■	■	■	■	■	■								
4	Calibration													■	■	■	■				
5	Expand Help Files																	■	■		
6	User's Guide																			■	■

Literature Search:

Materials Characterization
Several research projects have focused on Minnesota paving materials. Ovik et al (1) characterized the environmental conditions and the effects of Spring thaw on low volume roads in order to determine the best time to place Spring load restrictions. This study concluded that M-E pavement design is best accomplished using a 5-season year (Fall, Winter, Early Spring, Late Spring, Summer) to characterize seasonal changes in material properties.

Berg et al (2, 3, 4, 5) tested materials from MnROAD in order to develop freezing and thawing models for use in the CRREL M-E design procedure. The materials tested cover a wide range of aggregates and soils found in Minnesota.

Jong et al (6) used FWD tests in Wisconsin to determine the effects of freezing and thawing on aggregate base and subgrade soil moduli. Three flexible pavement structures were instrumented and monitored for 18 months. FWD tests were conducted weekly during the spring and monthly during summer and fall. The spring thaw period resulted in saturated base and subgrade layers and significantly lower modulus values. The return to pre-freezing modulus values took about four months.

Cole et al (7) used layered elastic analysis (LEA) to relate field and laboratory testing of freezing and thawing effects on aggregate base and soil modulus. Laboratory-determined resilient modulus values were entered into a pavement simulation program to predict deflection basins from FWD testing. The authors determined that simulated and measured deflection basins showed fairly good agreement for materials in the frozen, thawed, and recovered states.

Chamberlain et al (8) determined the frozen and thawed resilient moduli for clay and silt materials. A new method was also developed for measuring Poisson's ratio. Frozen samples were obtained undisturbed, then tested in frozen, thawed and recovering conditions. For silt specimens, frozen resilient moduli ranged from 100,000 to 6,000,000 psi (0.7 to 42 GPa), thawed values dropped as low as 600 psi (4 MPa), and recovered values ranged from 4,000 to 44,000 psi (28 to 300 MPa). Results for clay specimens were slightly lower.

Johnson et al (9) provide an overview of a six-year research program that developed laboratory tests and computer models to predict the effect of freezing and thawing on the resilient modulus of granular soils and base materials. Field sites included six test sections at the Winchendon, Massachusetts test site and two test sections at the Albany County Airport in New York State. Numerous measurements were taken during freeze-thaw-recovery seasons between 1979 and 1983. Three existing frost susceptibility index tests were evaluated. A new simplified index test was recommended. A laboratory test was developed to measure moisture and density changes during freezing and thawing. A mathematical model for predicting thaw settlement was evaluated. The authors stated that the frost heave results from the model can be related to roughness criteria for pavement design. A model was proposed to characterize seasonal changes in resilient modulus based on changes in moisture.

Lee et al (10) and Simonson et al (11) conducted closed-system freeze-thaw resilient modulus testing on subgrade soils. Lee et al tested cohesive soils, and found that the first freeze-thaw cycle resulted in a 30 to 50% reduction in resilient modulus. Equations were developed to model the resilient modulus of thawed soils. Simonson et al conducted tests on coarse and fine grained soils and found thaw-induced reductions in resilient modulus of 20 to 60%.

Gupta et al (12) characterized soil water retention for 25 materials used in Minnesota pavement construction. The models developed in this study can be adapted to predict design modulus from material index and moisture properties for aggregate base and granular subbase for M-E pavement design.

Performance Models

Baladi (13) describes the development of a pavement design program for the Michigan Department of Transportation (MDOT) that addresses both functional and structural issues. The goal was to consolidate the various flexible pavement design procedures used by MDOT into a unified process that optimizes performance while minimizing life cycle costs. Emphasis was placed on characterizing the engineering properties of roadbed soils and paving materials. The author recommends using existing M-E design tools (MICHPAVE and MICHBACK), which are based on layered-elastic analysis and fatigue and rutting performance models.

Pierce et al (14) describe pavement index prediction models used by the South Carolina Department of Transportation (SCDOT). The authors used pavement condition data to calibrate models that predict Present Serviceability Index (PSI), Pavement Distress Index (PDI), and Pavement Quality Index (PQI) based on pavement type and applied Equivalent Single Axle Loads (ESALs).

Kher and Phang (15) describe an M-E design program called OPAC (Ontario Pavement Analysis of Costs). Layered elastic theory and an environmental model are combined to predict pavement life. Life cycle cost analysis is then used to determine the most cost-effective design. The life of the pavement is determined by the Riding Comfort Index (RCI), a number between 1 and 10 (10 represents the smoothest ride).

References

1. Ovik, J.M., Siekmeier, J.A., and Van Deusen, D.A., “Improved Spring Load Restriction Guidelines Using Mechanistic Analysis,” Final Report MN/RC-2000/18, Minnesota Department of Transportation, 2000.
2. Berg, R.L., Bigl, S.R., Stark, J., and Durell, G., “Resilient Modulus Testing of Materials from Mn/ROAD, Phase 1”, Final Report MN/RC-96/21 (CRREL Special Report No. 96-19), Minnesota Department of Transportation, 1996.
3. Bigl, S.R. and Berg, R.L., “Modeling of Mn/ROAD Test Sections with the CRREL Mechanistic Pavement Design Procedure”, Final Report MN/RC-96/22 (CRREL Special Report No. 96-21), Minnesota Department of Transportation, 1996.
4. Bigl, S.R. and Berg, R.L., “Material Testing and Initial Pavement Design Modeling: Minnesota Road Research Project”, Final Report MN/RC-96/23 (CRREL Special Report No. 96-14), Minnesota Department of Transportation, 1996.
5. Bigl, S.R. and Berg, R.L., “Testing of Materials from the Minnesota Cold Regions Pavement Research Test Facility”, Final Report MN/RC-96/24 (CRREL Special Report No. 96-20), Minnesota Department of Transportation, 1996.
6. Jong, D., Bosscher, P.J., and Benson, C.H., “Field Assessment of Changes in Pavement Moduli Caused by Freezing and Thawing,” Transportation Research Record, No. 1615, Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 41-48.
7. Cole, DM; Irwin, LH; Johnson, TC , “Effect of Freezing and Thawing on Resilient Modulus of a Granular Soil Exhibiting Nonlinear Behavior,” Transportation Research Record, No. 809, Transportation Research Board, National Research Council, Washington, D.C., 1981, pp. 19-26.
8. Chamberlain, EJ; Johnson, TC; Cole, DM , “Resilient Response of Two Frozen and Thawed Soils,” ASCE Journal of the Geotechnical Engineering Div, Vol. 105, Issue GT2, 1979, pp. 257-271.
9. Johnson, T.C., Berg, R.L., and DiMillio, A., "Frost Action Predictive Techniques: An Overview of Research Results," Transportation Research Record, No. 1089, Transportation Research Board, National Research Council, Washington, D.C., 1986.
10. Lee, W., Bohra, N.C., Altschaeffl, A.G., and White, T.D., "Resilient Modulus of Cohesive Soils and the Effect of Freeze-Thaw," Canadian Geotechnical Journal, Vol. 32, 1995, pp. 559-568.
11. Simonsen, E., Janoo, V.C., and Isacsson, U., "Resilient Properties of Unbound Road Materials During Seasonal Frost Conditions," Journal of Cold Regions Engineering, Vol. 16, No. 1, March 2002, pp. 28-50.
12. Gupta, S., Singh, A., and Ranaivoson, A., "Moisture Retention Characteristics of Base and Sub-base Materials," Final Report No. MN/RC-2005-06, Minnesota Department of Transportation,
13. Baladi, Gilbert Y., "Mechanistic Design Implementation Plan for Flexible Pavements and Overlays," Final Report No. MDOT-PRCE-MSU-1997-102, Michigan Deparment of Transportation, November 26, 1997.
14. Pierce, C.E., Baus, R.L., and Wang, D., "Calibrating Pavement Performance Prediction Models for Interstate and Primary Highway Systems in South Carolina," Final Report No. FHWA-SC-02-07, South Carolina Department of Transportaion, June 2002.
15. Kher, R., and Phang, W.A., "OPAC Design System," Ontario Ministry of Transportation and Communications, 1976.