RESEARCH ANNUAL REPORTS
FY 2000 - FY 2001
FY 2002 - FY 2003
FY 2004

MDOT
Michigan Department of Transportation

CONSTRUCTION AND TECHNOLOGY DIVISION

TESTING AND RESEARCH SECTION
CONSTRUCTION AND TECHNOLOGY DIVISION
RESEARCH REPORT NO. R-1458

MDOT
Michigan Department of Transportation

RESEARCH ANNUAL REPORTS
FY 2000 – FY 2004

Management
Construction
Pavement Design
Pavement Performance
Bridges
Materials
Traffic

Projects Developed and Managed by:

Testing and Research Section
Construction and Technology

December 31, 2004

FOREWARD

This report has been compiled by Sudhakar Kulkarni and Nancy Crider. The report is a summary of five years of the Michigan Department of Transportation (MDOT)'s research program, which includes 75 completed projects at a cost of approximately $6,501,753.87. Thanks are due to the project managers for providing this information. Thanks are also due to Chris Helmer for her assistance in managing the SPR Part II program. Special thanks to Nancy Crider for typing this report.

FOR Jon W. Reincke
Engineer of Testing and Research

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Research Program Highlights
FY 2000

During fiscal year 2000, the Testing and Research Section of MDOT completed 10 projects at a cost of $649,132.11. The projects can be broadly classified into the following areas:

TYPE	NUMBER OF PROJECTS/ CONTRACTS	TOTAL EXPENDITURES FOR PROJECT/ CONTRACTS	TOTAL EXPENDITURES IN PERCENT
Management	3	$80,685.53	12.43%
Construction	1	$39,092.39	6.02%
Pavement Design	1	$125,068.43	19.27%
Pavement Performance	4	$362,055.78	55.78%
Bridges	1	$42,229.98	6.51%
Materials	0	$-	0.00%
TOTALS	**10**	**$649,132.11**	**100.00%**

Research Program Highlights
FY 2001

During fiscal year 2001, the Testing and Research Section of the MDOT completed 13 research projects at a cost of $1,004.251.83. The projects are classified as follows:

TYPE	NUMBER OF PROJECTS/ CONTRACTS	TOTAL EXPENDITURES FOR PROJECT/ CONTRACTS	TOTAL EXPENDITURES IN PERCENT
Management	3	$65,855.07	6.56%
Construction	0	$-	0.00%
Pavement Design	3	$45,976.96	4.58%
Pavement Performance	1	$59,652.64	5.94%
Bridges	5	$771,397.16	76.81%
Materials	1	$61,370.00	6.11%
TOTALS	**13**	**$1,004,251.83**	**100.00%**

Research Program Highlights
FY 2002

During the fiscal year 2002, the Testing and Research Section of the MDOT completed 27 research projects at a cost of $2,152,248.13. The projects can be broadly classified into the following areas:

TYPE	NUMBER OF PROJECTS/ CONTRACTS	TOTAL EXPENDITURES FOR PROJECT/ CONTRACTS	TOTAL EXPENDITURES IN PERCENT
Management	4	$161,965.98	7.53%
Construction	2	$154,801.37	7.19%
Construction (Non-SPR funds)	1	$101,119.96	4.70%
Pavement Design	3	$375,027.01	17.42%
Pavement Performance	4	$581,853.23	27.03%
Bridges	6	$397,629.59	18.48%
Materials	4	$379,850.99	17.65%
TOTALS	**24**	**$2,152,248.13**	**100.00%**

Research Program Highlights
FY 2003

During fiscal year 2003, the Testing and Research Section of MDOT completed 19 projects at a cost of $1,273,709.95. The projects can be broadly classified into the following areas:

TYPE	NUMBER OF PROJECTS/ CONTRACTS	TOTAL EXPENDITURES FOR PROJECT/ CONTRACTS	TOTAL EXPENDITURES IN PERCENT
Management	5	$191,329.75	13.18%
Construction	3	$151,544.41	10.44%
Construction (Non-SPR funds)	1	$177,687.00	12.24%
Pavement Design	0	$-	0.00%
Pavement Performance	7	$525,926.82	36.24%
Bridges	2	$212,777.24	14.66%
Materials	1	$192,131.73	13.24%
TOTALS	**19**	**$1,451,396.95**	**100.00%**

Research Program Highlights FY 2004			
During fiscal year 2004, the Testing and Research Section of MDOT completed 9 projects at a cost of $1,244,724.55. The projects can be broadly classified into the following areas:			
TYPE	**NUMBER OF PROJECTS/ CONTRACTS**	**TOTAL EXPENDITURES FOR PROJECT/ CONTRACTS**	**TOTAL EXPENDITURES IN PERCENT**
Management	0	$-	0.00%
Construction	1	$158,313.00	12.72%
Construction (Non-SPR funds)	0	$-	0.00%
Pavement Design	1	$136,056.98	10.93%
Pavement Performance	1	$182,237.00	14.64%
Bridges	4	$540,969.60	43.46%
Materials	1	$145,000.00	11.65%
Traffic	1	$82,147.97	6.60%
TOTALS	**9**	**$1,244,724.55**	**100.00%**

The implemented items or products received are in the Summaries Section for each area in bold letters for your quick review. Benefits of these items or products must be documented for future reference.

PROJECTS/CONTRACTS CLOSED FY 2000

PROJECT/CONTRACT NUMBER	MANAGER	TITLE	TOTAL EXPENDITURES	CLOSED DATE	TYPE
00-MTU-1	Jon Reincke	Publication of Research Record	$30,998.79	9/30/00	Management
00-MTU-2	Jon Reincke	Operation & Coordination of the Transportation Materials Research Center (TMRC)	$33,130.08	9/30/00	Management
MSU 00-6-2	Jon Reincke	Coordination & Management of the Pavement Research Center of Excellence	$16,556.66	9/30/00	Management
99-MTU-5	John LaVoy	Construction Project Scheduling at MDOT	$39,092.39	8/23/00	Construction
MSU 96-1-0	Tom Hynes	Improvement of MichPave & MichBack	$125,068.43	9/20/00	Pavement Design
MSU 97-7-1	John Staton	Factors Affecting Shear Capacity of Tansverse Cracks in Jointed Pavement	$128,021.28	6/19/00	Pavement Performance
MSU 98-2-1	Mike Frankhouse	Detecting & Quantifying Segregation in Bituminous Pavements & Relating Its Effect to Condition	$141,980.27	7/13/00	Pavement Performance
MSU 99-3-3	Dave Smiley	Comparison of Concrete Pavement Performance Utilizing Different Types of Coarse Aggregate	$7,835.77	6/30/01	Pavement Performance
MSU 99-4-3	Vern Barnhart	Identify Causes for Under-Performing Rubbilized Concrete Pavement Projects Phase I	$84,218.46	9/5/00	Pavement Performance
UM 98-1219	Roger Till	Development of a Guide for the Evaluation of Existing Bridges Phase II	$42,229.98	11/15/99	Bridge
		TOTAL	**$649,132.11**		

PROJECTS/CONTRACTS CLOSED FY 2001

PROJECT/CONTRACT NUMBER	MANAGER	TITLE	TOTAL EXPENDITURES	CLOSED DATE	TYPE
01-MTU-2	Jon Reincke	Operation & Coordination of the Transportation Materials Research Center (TMRC)	$31,619.93	10/31/01	Management
01-MTU-4	Roger Till	Administrative Operations for the Center for Structural Durability (CSD) at WSU/MTU	$20,000.00	10/31/01	Management
01-MTU-7	Jon Reincke	Publication of the Research Record	$14,235.14	10/31/01	Management
98-MTU-1	Dave Smiley	Modernization of the Illi-Slab Finite Element Analysis Program for Concrete Pavements	$40,012.00	12/14/00	Pavement Design
00-MTU-8	Dave Smiley	Feasibility Evaluation for Enchancing Michigan's Procedures for Pavement Design & Selection	$679.44	9/21/01	Pavement Design
MSU 00-5-1	Dave Smiley	Feasibility Evaluation for Enchancing Michigan's Procedures for Pavement Design & Selection	$5,285.52	7/2/01	Pavement Design
MSU 00-2-1	Mike Eacker	Evaluation of Alignment Tolerances for Dowel Bars & Their Effects on Joint Performance	$59,652.64	7/16/01	Pavement Performance
UM 96-1067	Roger Till	Repair & Strengthening of Reinforced & Prestressed Concrete Beams Using CFRP Glued-On Plates	$149,670.00	1/25/01	Bridge
MSU 96-1068	Dave Juntunen	Non-Metallic Reinforcement of Concrete Bridge Decks	$262,221.03	3/21/01	Bridge
MSU 96-1069	Roger Till	Polymer Composite Jackets for Column Repair	$194,497.03	1/25/01	Bridge
UM 98-1303	Dave Juntunen	Research Study to Determine Procedures for Efficient Evaluation of Bridge Decks	$61,359.10	6/26/01	Bridge
UM 00-0341	Roger Till	Verification of Girder Distribution Factors for Steel Girder Bridges	$103,650.00	7/9/01	Bridge
00-MTU-3	John Staton	Aggregate Absorption as Related to Anti-Icing for Elastomeric Concrete Bridge Deck Overlays	$61,370.00	4/12/01	Bridge
		TOTAL	**$1,004,251.83**		

PROJECTS/CONTRACTS CLOSED FY 2002

PROJECT/CONTRACT NUMBER	MANAGER	TITLE	TOTAL EXPENDITURES	CLOSED DATE	TYPE
02-MTU-1	Jon Reincke	Operation & Coordination of the Transportation Materials Research Center (TMRC)	$103,223.00	9/30/02	Management
02-MTU-2	Roger Till	Administrative Operations for the Center for Structural Durability (CSD) at WSU/MTU	$20,340.00	9/30/02	Management
02-MTU-3	Jon Reincke	Publication of the Research Record	$24,740.98	9/30/02	Management
26	Jon Reincke	Coordination & Management of the Pavement Research Center of Excellence (PRCE)	$13,662.00	9/30/02	Management
01-MTU-5	John LaVoy	Work Item Production Rates for MDOT Projects	$74,801.37	9/30/02	Construction
01-MTU-6	John LaVoy	Comparison of MDOT Schedules as a Result of Special Provision for Progress Schedule, FUSP102G	$80,000.00	9/30/02	Construction
00-0781	Jeff Grossklaus	Effectiveness of the Lane Merge Traffic Control System at Construction/Work Zones	$101,119.96	12/31/01	Construction
00-MTU-4	Al Robords	Analysis of Bituminous Pavement Surface Characteristics & Their Effects on Friction Properties	$198,990.08	9/30/02	Pavement Design
00-MTU-6	John Barak	Synthesis & Rview of Superpave Implementation	$37,850.91	4/2/02	Pavement Design
00-1-1	Tom Hynes	Development of a Computer Program for Dynamic Backcalculation of Flexible Pavement Layer Moduli	$138,186.02	9/30/02	Pavement Design
99-2-1	Dave Smiley	Development of a Roughness Threshold for the Preventive maintenance of Pavements Based on Dynamic Loading Considerations & Damage Analysis	$175,819.06	11/1/01	Pavement Performance
00-4-1	Dave Smiley	Investigation of Early Cracking on Selected JPCP Projects	$28,000.00	1/14/02	Pavement Performance

98-8-1	John Staton	Transverse Crack Propagation of JPCP as Related to PCC Toughness	$217,301.95	1/29/02	Pavement Performance
00-3-1	Vern Barnhart	Identify Causes for UnderPerforming Rubblized Concrete Pavement Phase II	$160,732.22	9/30/02	Bridges
01-MTU-1	Steve Kahl	Development Length of Stainless Steel Reinforcing Bars	$64,149.75	2/7/02	Bridges
01-MTU-8	Roger Till	Forecast & Resolve Deterioration Problems With the Ends of PC Beams-Causes & Cures of PC Bridge Beam End Deterioration	$68,931.00	5/31/02	Bridges
01-MTU-9	Roger Till	Investigation of Current Bridge Loading vs Design Loading	$44,934.00	7/3/02	Bridges
01-0339	John Staton	Criteria & Benfits of Penetrating Sealants for Bridge Decks	$86,640.84	6/30/02	Bridges
01-0363	Roger Till	Investigation of Current Bridge Loading vs Design Loading	$33,098.00	7/3/02	Bridges
01-0364	Roger Till	Forecast & Resolve Deterioration Problems With the Ends of PC Beams-Causes & Cures of PC Bridge Beam End Deterioration	$99,876.00	5/31/02	Bridges
99-MTU-3	Bob Muethel	A Study of Materials-Related Distress (MRD) in Michigan's PCC Pavements	$295,503.99	5/31/02	Materials
01-MTU-3	John Staton	Field Performance of Polymer Concrete Bridge Deck Overlays in Michigan	$65,391.00	10/31/01	Materials
02-MTU-4	Frank Spica	Road Temperature Sensor Project	$15,000.00	9/30/02	Materials
02-MTU-6	Dick Endres	Mechanical Properties of Rock Cores	$3,956.00	9/30/02	Materials
		TOTAL	**$2,152,248.13**		

PROJECTS/CONTRACTS CLOSED FY 2003

PROJECT/CONTRACT NUMBER	MANAGER	TITLE	TOTAL EXPENDITURES	CLOSED DATE	TYPE
16	Roger Till	Administrative Operations for the Bridges & Structures Research Center of Excellence	$23,957.00	9/30/03	Management
01-0608	Sudhakar Kulkarni	Policy & Procedures Manual for University Research Program	$17,489.98	1/31/03	Management
03-MTU-3	Jon Reincke	Operation & Coordination of the Transportation Materials Research Center	$103,814.00	9/30/03	Management
03-MTU-1	Jon Reincke	Publication of the Research Record	$25,372.77	9/30/03	Management
03-MTU-4	Roger Till	Administrative Operations for the Center for Structural Durability @ MTU/WSU	$20,696.00	9/30/03	Management
99-0460	Jeff Grossklaus	Impact Performance Evaluation of Michigan's Guardrail System	$142,611.49	6/30/03	Construction
03-MTU-5	Tom Hynes	Phase I: Proposal for the Risk Assessment of the I-196 Interstate Section Located Over the Domtar Mine, Grand Rapids, Michigan	$8,932.92	2/1/03	Construction
02-0186	Jeff Grossklaus	Field Testing of Variable Speed Limits in Construction Work Zones NON SPR PROJECT	$177,687.30	9/30/03	Construction
28	Kevin Kennedy	Development of Improved Pavement Distress Index Models	$34,532.33	9/30/03	Pavement Performance
24	Vern Barnhart	Identification of the Causes of Top-Down Cracking of Flexible Pavements	$59,768.11	8/31/03	Pavement Performance
03-MTU-2	Frank Spica	Road Temperature Sensor Project	$15,000.00	11/30/02	Pavement Performance

10	Tom Hynes	Qualify Transverse Cracking in PCC Pavements From Loss of Slab-Base Contact	$163,137.82	12/20/02	Pavement Performance
02-0341 & 02-MTU-5	John Staton	Causes & Cures for Cracking of Concrete Barriers (Joint Project w/WSU & MTU)	$123,139.20	9/30/03	Pavement Performance
02-MTU-7	Bob Muethel	Preliminary Investigation of the Role of Bacteria in Concrete Degradation	$25,416.02	9/1/03	Pavement Performance
00-MTU-7	Frank Spica	Noise Generated by Vehicle/Road Surface Interactions	$104,933.34	11/30/02	Pavement Performance
15	Roger Till	Determine the Actual Response of Bridges to Load for Better Capacity Rating & Investigate Load Distribution of Heavy Trucks	$97,963.63	9/30/03	Bridges
01-0365	Roger Till	Sensors to Monitor Bond in Concrete Bridges Rehabilitated with FRP	$114,813.61	8/31/03	Bridges
02-MTU-8	Tom Hynes	Resilient Modulus Testing of Michigan Aggregates	$73,156.10	8/31/03	Materials
01-MTU-10	Al Robords	Mineral Characterization & Cataloging of Quarried Aggregate Sources	$118,975.63	9/30/03	Materials
		TOTAL	**$1,273,709.95**		

PROJECTS/CONTRACTS CLOSED FY 2004

PROJECT/CONTRACT NUMBER	MANAGER	TITLE	TOTAL EXPENDITURES	CLOSED DATE	TYPE
02-0223	Roger Till	Investigate Cause and Develop Methods to Minimize Early-Age Cracking on Michigan Bridge Decks	$158,313.00	12/31/03	Construction
25	Curtis Bleech	Preliminary Mechanistic Evaluation of PCC Cross-Sections Using ISLAB2000 - A Parametric Study	$136,056.98	1/22/04	Pavement Design
29	Tom Hynes	Effect of Michigan Multi-Axle Trucks on Pavement Distress	$182,237.00	1/31/04	Pavement Performance
19 (03-MTU-7)	Bob Kelley	Development of Steel Beam End Deterioration Guidelines	$66,760.60	9/30/04	Bridge
14	Roger Till	Determing the Impact of the AASHTO LRFD Bridge Code & Transition the Department into the use of the AASHTO LRFD Design Code	$174,277.00	5/31/04	Bridge
01-0367	Roger Till	Analytical Design Procedures & Load Rating for Isotropic Bridge Decks	$124,932.00	11/10/04	Bridge
27	Roger Till	Multiple Heat Straightening on Structural Steel	$175,000.00	9/30/04	Bridge
12	Roger Till	Durable Link Slabs for Jointless Bridge Decks Based on Strain-Hardening Cementitious Composites	$145,000.00	11/16/03	Materials
02-0513	Jeff Grossklaus	Development & Evaluation of an Advanced Dynamic Lane Merge Traffic Control Systems (LMTCS) for Three Lanes Reduced to Two Lanes During Construction on I-94 in Macomb County	$82,147.97	1/15/04	Traffic
		TOTAL	**$1,244,724.55**		

SUMMARY OF COMPLETED PROJECTS BY UNIVERSITY

FISCAL YEAR	UNIVERSITY	NUMBER OF PROJECT	EXPENDITURES
2000	Michigan Technological	3	$103,221.26
2000	Michigan State	6	$503,680.87
2000	University of Michigan	1	$42,229.98
2000	Wayne State	0	$-
2000	Lawrence Technological	0	$-
SUBTOTALS FY 2000		**10**	**$649,132.11**
2001	Michigan Technological	6	$167,916.51
2001	Michigan State	4	$521,656.22
2001	University of Michigan	3	$314,679.10
2001	Wayne State	0	
2001	Lawrence Technological	0	
SUBTOTALS FY 2001		**13**	**$1,004,251.83**
2002	Michigan Technological	14	$1,097,812.08
2002	Michigan State	4	$488,399.30
2002	University of Michigan	2	$245,301.95
2002	Wayne State	4	$320,734.80
2002	Lawrence Technological	0	$-
SUBTOTALS FY 2002		**24**	**$2,152,248.13**
2003	Michigan Technological	9	$496,296.78
2003	Michigan State	4	$386,801.35
2003	University of Michigan	3	$285,058.45
2003	Wayne State	0	$-
2003	Lawrence Technological	0	$-
2003	B. T. Harder	1	$17,489.98
2003	University of Nebraska	1	$142,611.49
2003	Joint Wayne State & Michigan Technological	1	$123,139.20
SUBTOTALS FY 2003		19	$1,451,397.25
2004	Michigan Technological	1	$66,760.60
2004	Michigan State	3	$493,293.98
2004	University of Michigan	3	$444,209.00
2004	Wayne State	2	$240,460.97
2004	Lawrence Technological	0	$-
SUBTOTALS FY 2004		9	$1,244,724.55
GRAND TOTALS		**98**	**$6,501,753.87**

Summaries – Management Projects
FY 2000

00-MTU-1 Publication of Research Record

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	443,447.00
Total Amount Spent:	$30,998.79
FY 2000 Expenditures:	$30,998.79
Completion Date:	9/30/2000

00-MTU-2 Operation & Coordination of the Transportation Materials Research Center (TMRC)

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$36,202.00
Total Amount Spent:	$33,130.08
FY 2000 Expenditures:	$33,130.08
Completion Date:	9/30/2000

00-6-2 Coordination & Management of the Pavement Research Center of Excellence (PRCE)

Project Manager:	Jon Reincke
Contractor:	Michigan State University
Total Project Cost:	$22,879.00
Total Amount Spent:	$16,556.66
FY 2000 Expenditures:	$16,556.66
Completion Date:	9/30/2000

Summaries – Construction Projects
FY 2000

99-MTU-5 Construction Project Scheduling at MDOT

Project Manager:	John LaVoy
Contractor:	Michigan Technological University
Total Project Cost:	$40,543.00
Total Amount Spent:	$39,092.39
FY 1999 Expenditures:	$21,983.92
FY 2000 Expenditures:	$17,108.47
Completion Date:	9/30/2000

The purpose of the research was to review current MDOT requirements for contractor-submitted schedules, identify the purpose, capabilities, or problems related to the process, along with associated recommendations for change including new scheduling techniques.

Research included collecting information from surrounding states relating to their methods of scheduling, conducting numerous interviews with contractors and MDOT personnel and an analysis of three test projects with various scheduling techniques such as Critical Path Method Scheduling, Bar Charts, and Linear Scheduling.

Findings, as a result of the above, confirmed that MDOT's current (pre-1999) requirements for contractor progress schedules reflected the potential for a level of inaccuracy. The typical Contractor did actually take the time to develop a reasonable plan for constructing the project, but the means for measuring progress throughout the duration of the project and using the submitted schedule to document evidence for justification of decisions relative to impacts to the schedule was not evident under the existing process. Suggested changes as a result of the study included introducing requirements that allow more accurate schedule submission, a review of the system MDOT uses to establish contract time, reevaluating of the need to require schedules on small projects, making the initial schedule projects optional with the contractor assuming all risk, the submission of more than the minimal information on projects, and the use of sophisticated scheduling techniques on high-impact projects.

Implementation - In conjunction with this study and other MDOT initiatives, several changes in the requirements for contractor-submitted work schedules have not been developed and are currently the standards in projects. Contractors' schedules now have the potential to be more realistic and reflective of reality on MDOT projects.

Summaries – Pavement Design Projects
FY 2000

96-1-0 Improvement of MichPave and MichBack

Project Manager:	Tom Hynes
Contractor:	Michigan State University
Total Project Cost:	$125,069.00
Total Amount Spent:	$125,068.43
FY 1996 Expenditures:	$11,233.76
FY 1997 Expenditures:	$16,709.87
FY 1998 Expenditures:	$62,586.21
FY 1999 Expenditures:	$34,538.59
Completion Date:	9/20/00

This research project, undertaken by Michigan State University (MSU), provided enhancements to the mechanistic pavement analysis program MichPave and the deflection back calculation program MichBack. It incorporated enhanced mathematical models that were developed under a companion project into the software. The two programs were converted from a DOS format operated in a Windows environment. **The two programs, in addition to a computerized version of the current AASHTO pavement design method, were combined into one interactive computer program called the Michigan Flexible Pavement Design System (MFPDS).**

If it is decided to implement mechanistic pavement design in Michigan, MFPDS will be implemented by MSU-sponsored training programs for region pavement designers. Potential benefits include more cost effective pavement designed and a better prediction of pavement life.

Summaries – Pavement Performance Projects
FY 2000

97-7-1 Factors Affecting Shear Capacity of Transverse Cracks in Jointed Pavement

Project Manager:	John Staton
Contractor:	Michigan State University
Total Project Cost:	$150,172.39
Total Amount Spent:	$128,021.28
FY 1997 Expenditures:	$17,075.96
FY 1998 Expenditures:	$37,818.92
FY 1999 Expenditures:	$55,841.12
FY 2000 Expenditures:	$17,285.28
Closed Date:	6/19/00

Environmental and/or traffic related stresses can lead to the development of transverse cracking in jointed concrete pavements (JCPs). Deterioration of transverse cracks over time can result in loss of serviceability and loss of structural capacity in such pavements. An understanding of the factors affecting transverse cracking in JCPs and the ability to assess when and how to repair pavements with this distress are, therefore, two issues of importance to transportation agencies. Addressing these issues, the primary objectives of this research was to study the effects of various factors on transverse cracking in JCPs and to demonstrate methods for evaluating these cracked pavements. Field data collected from in-service JCPs located throughout southern Michigan was used to accomplish these objectives. **Joint spacing, concrete coarse aggregate type, and shoulder type were found to have significant effects on transverse crack development and/or performance.** Three analysis procedures that are based on the use of falling weight deflectometer (FWD) data – back calculation of pavement support and stiffness parameters, determination of crack performance parameters, and assessment of void potential near cracks were demonstrated using data from this study and allow for evaluation of cracked JCPs. Results from these FWD analyses were used to develop threshold limits necessary for performing evaluations with these procedures.

In conjunction with the field testing, a laboratory study of large-scale concrete slabs was performed. This involved the collection and analysis of load transfer data from a variety of concrete slabs with different coarse aggregate types and blends. **This laboratory study verified findings from the field study in a controlled environment.**

98-2-1 Detecting and Quantifying Segregation in Bituminous Pavements and Relating Its Effect to Condition

Project Manager:	Mike Frankhouse
Contractor:	Michigan State University
Total Project Cost:	$200,328.00
Total Amount Spent:	$141,980.27
FY 1998 Expenditures:	$44,444.41
FY 1999 Expenditures:	$74,635.06
FY 2000 Expenditures:	$22,900.80
Closed Date:	7/13/00

The final report for this study was a collaborative effort between MDOT and Michigan State University.

The project was the **second phase of a segregation study**, which started in 1995. Both phases had the objective of developing an expedient field test to verify and quantify segregation in hot mixed asphalt (HMA) pavements. This report defines three degrees of segregation: light, medium, and heavy. It is shown that nuclear density testing can form the basis of an expedient field quality-control test to verify and quantify the existence of medium and heavy degrees of segregation. Statistical differences in nuclear density values are shown to be good predictors of actual aggregate gradation differences and are correlated to visual observations of medium and heavy degrees of segregation.

The focus of the study involved 20 test sites. At each site, a joint MDOT and MSU team mapped pavement segregation in detail for data gathering and evaluation purposes. The locations were chosen to reflect consistent descriptions of the various degrees of segregation, as well as non-segregated "control" areas.

The results of the study provided extensive and insightful information regarding density variations in pavements. An important finding of the study is as follows:

Statistical comparisons of nuclear density values provide a good indication of segregation, when (a) areas of medium or heavy segregation are visually identified, and (b) areas of non-segregation are visually selected from the same truck load during construction and at the same distance from the pavement edge as the segregated area.

As a result of this study, a special provision has been implemented on all surfacing projects that measures HMA surface uniformity, including a software program mbitseg.xls, to facilitate statistical calculations in the field and provide directions for resolving segregation problems in the field. In addition, during the two-year study, it was found that heavy segregation causes a minimum of 50 percent reduction in pavement service life for the affected areas.

99-3-3 Comparison of Concrete Pavement Performance Utilizing Different Types of Coarse Aggregate

Project Manager:	Dave Smiley
Contractor:	Michigan State University
Total Project Cost:	$8,000.00
Total Amount Spent:	$7,835.77
FY 2000 Expenditures:	$7,835.77
Closed Date:	6/30/00

This project was established to obtain student help in data analysis. **No report was required. No follow up is needed.**

99-4-3 Identify Causes for Under-Performing Rubbilized Concrete Pavement Projects Phase I – (See 00-3-1 for Phase II)

Project Manager:	Vern Barnhart
Contractor:	Michigan State University
Total Project Cost:	$91,549.79
Total Amount Spent:	$84,218.46
FY 1999 Expenditures:	$11,117.03
FY 2000 Expenditures:	$73,101.45
Closed Date:	9/5/00

The Report for Phase I of this project is an interim report. The items that have been brought out in this report can be implemented at this time and are as follows:

More preliminary engineering is needed to assure that the project selected to be rubbilized is well suited to be rubbilized.

Take cores through the concrete (driving lane) to determine the condition of the concrete.

Check the condition of the base, sub base, and sub grade under the concrete.

Read, follow, and enforce the current Special Provision for Rubbilizing Concrete Pavements that is being placed in proposals.

Summaries – Bridge Projects
FY 2000

98-1219 Development of a Guide for the Evaluation of Existing Bridges – Phase II

Project Manager:	Roger Till
Contractor:	University of Michigan
Total Project Cost:	$42,230.00
Total Amount Spent:	$42,229.98
FY 1999 Expenditures:	$42,229.98
Closed Date:	11/15/99

Report RC-1378. The objective of this report is to present the results of the field test carried out in 1999 by the team at the University of Michigan. The field tests were performed to determine the load distribution factors needed to evaluate bridges. The test program was a continuation of the field tests carried out in 1997-1998. The previous study focused on shorter spans (10-18m), and the present study covered spans from 20 to 30m. Six bridges were tested, all located in the Southern part of Michigan. Steel girders with a concrete deck slab were considered. The tests were performed using fully loaded 11 axle trucks (up to the legal limit). Strains were measured for a single truck and for two trucks side-by-side. Girder distribution factors (GDF) were calculated using the measured strains. The obtained GDF were compared with the code specified GDF. The tests confirmed previous observations that the code specified girder distribution factors are conservative. However, for the spans considered in this study (20-30m), the safety margin is smaller than for shorter spans. The tests also included measurement of dynamic loads and proof load testing. The dynamic load factor (DLF) for two fully loaded trucks side-by-side is practically less than 0.10. For a single truck, DLF is less than 0.20. Proof load tests were carried out using two M-1 tanks, each weighing about 62 tons, and two fully loaded 11-axle trucks. The bridge response (strains) was within linear elastic limits, even though the deflection exceeded 40mm. The results are summarized in the final chapter of the report. **Girder distribution factor results included in revised Bridge Analysis Guide.**

Summaries – Materials Projects
FY 2000

There are no projects in this category for this year.

Summaries – Management Projects
FY 2001

01-MTU-2 Operation and Coordination of the Transportation Materials Research Center (TMRC)

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$36,499.00
Total Amount Spent:	$31,619.93
FY 2001 Expenditures:	$31,619.93
Closed Date:	10/31/00

01-MTU-4 Administrative Operations for the Center for Structural Durability (CSD) at WSU/MTU Joint Venture

Project Manager:	Roger Till
Contractor:	Michigan Technological University
Total Project Cost:	$20,000.00
Total Amount Spent:	$20,000.00
FY 2001 Expenditures:	$20,000.00
Closed Date:	10/31/00

01-MTU-7 Publication of the Research Record

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$34,000.00
Total Amount Spent:	$14,235.14
FY 2001 Expenditures:	$14,235.14
Closed Date:	10/31/01

Summaries – Construction Projects
FY 2001

There are not projects in this category for this year.

Summaries – Pavement Design Projects
FY 2001

98-MTU-1 Modernization of the Illi-Slab Finite Element Analysis Program for Concrete Pavements

Project Manager:	Dave Smiley
Contractor:	Michigan Technological University
Total Project Cost:	$40,012.00
Total Amount Spent:	$40,012.00
FY 1998 Expenditures:	$11,325.07
FY 1999 Expenditures:	$28,686.93
Closed Date:	12/14/00

This was a pooled-fund project with Minnesota Department of Transportation. Michigan Technology University acted as our technical advisor/representative. **The only deliverable is a new software program**. Before implementation can take place, there is a need for assessment of the new software for Michigan designs/conditions. Also, there is a need for a user's operation manual. These items will be done as part of a follow up project for fiscal year 2000 with Michigan Technological University and Michigan State University.

00-MTU-8 Feasibility Evaluation for Enhancing Michigan's Procedures for Pavement Design and Selection

Project Manager:	Dave Smiley
Contractor:	Michigan Technological University
Total Project Cost:	$1,500.00
Total Amount Spent:	$679.44
FY 2001 Expenditures:	$679.44
Closed Date:	9/12/01

This project was established **to fund support for advisory consulting**, when required, from Michigan State University principal investigators for development of a work plan per the project title. The department is responsible for the work plan, which is incomplete.

00-5-1 Feasibility Evaluation for Enhancing Michigan's Procedure for Pavement Design and Selection

Project Manager:	Dave Smiley
Contractor:	Michigan State University
Total Project Cost:	$5,500.00
Total Amount Spent:	$5,285.52
FY 2000 Expenditures:	$5,033.82
FY 2001 Expenditures:	$251.70
Closed Date:	7/1/01

This project was established **to fund support for advisory consulting**, when required from Michigan State University principal investigators for development of a work plan per the project title. The department is responsible for the work plan, which is incomplete.

Summaries – Pavement Performance Projects
FY 2001

00-2-1 Evaluation of Alignment Tolerances for Dowel Bars and Their Effects on Joint Performance

Project Manager:	
Contractor:	Michigan State University
Total Project Cost:	$61,130.00
Total Amount Spent:	$59,652.64
FY 2000 Expenditures:	$106.88
FY 2001 Expenditures:	$56,562.13
FY 2002 Expenditures:	$2,982.63
Closed Date:	7/16/01

Report RC-1395 is available on compact disk. Dowel bars are placed at pavement mid-depth, and care is taken to minimize the detrimental effects of misalignment. Dowel bars at contraction joints should be exactly parallel to the surface and centerline of the hardened slab. If they deviate from the desired position, they are said to be misaligned. Misalignment may result from misplacement (initially placing the dowels in an incorrect position), displacement (movement during the paving operation), or both.

The objective of this study is to develop justifiable tolerance levels that ensure that doweled joints do not cause high levels of stresses due to misaligned dowels. This may lead to a possible construction cost savings without jeopardizing pavement performance. The first state of the project involves the development of finite element models capable of analyzing PCC stress due to dowel misalignment. The study reported herein included the development of several finite element models using a commercial finite element package – ABAQUS. **A comprehensive PCC-dowel interaction model was developed and calibrated/validated using the results of a pullout test.**

The second stage of the project included laboratory testing using various modified pullout tests to verify the stage one findings and misalignment tolerances will be recommended.

Summaries – Bridge Projects
FY 2001

96-1067 Repair and Strengthening of Reinforced and Pre-stressed Concrete Beams Using CFRP Glued-On Plates

Project Manager:	Roger Till
Contractor:	University of Michigan
Total Project Cost:	$149,670.00
Total Amount Spent:	$149,670.00
FY 1997 Expenditures:	$41,046.76
FY 1998 Expenditures:	$61,649.83
FY 1999 Expenditures:	$29,102.54
FY 2000 Expenditures:	$14,878.05
FY 2001 Expenditures:	$2,992.82
Closed Date:	1/25/01

Report RC-1372 and RC-1388. Repair and strengthening techniques using adhesive bonded carbon fiber reinforced plastic or polymeric (CFRP) laminates (also called sheets, tow sheets, and thin plates) form the basis of a new technology being increasingly used for bridges and highway superstructures. The study described in this report (Volumes 1 to 7) focused on the use of carbon fiber reinforced plastic (CFRO) laminates for repair and strengthening of reinforced concrete beams. Its primary objectives are as follows: (1) to ascertain the applicability of CFRP adhesive bonded laminates for repair and strengthening of reinforced concrete beams; (2) to synthesize existing knowledge and develop procedures for implementation in the field; (3) to identify key parameters for successful design and implementation, and (4) to adapts this technique to the specific conditions encountered in the State of Michigan.

Volume 1 – Summary Report
This volume summarizes the main findings of the project. Since the adhesive-bonded plate repair and strengthening technique applies to plain, reinforced and pre-stressed concrete structures, as well as steel and timber structures, the experience gained during this project and the technology transfer developed covered a wide range of future applications.

Volume 2 – Literature Review
This volume provides a review of existing literature on the repair and strengthening of reinforced concrete beams using external glued-on Fiber Reinforced Plastic (FRP) sheets, particularly Carbon Fiber Reinforced Plastic (CFRP) sheets. A special emphasis is placed at synthesizing the information so as to allow the reader to first comprehend the material, and then make rational decisions about its use. Useful sources of information and contact persons throughout the United States are also gathered. First, the mechanical properties of different FRP sheets, made with different types of fibers such as Carbon, Glass, and Aramid, are compared to the properties of steel plates. A summary of the technical data of the commercial CFRP sheets is then presented. Information about the epoxy necessary to glue the CFRP sheets to the structural element is provided as obtained from different suppliers. Different application procedures of CFRP sheets glued-on to the surface of concrete beams are documented. Specific information concerning surface preparation, mixing of adhesives, application of the CFRP sheet to the structure, and

additional limitations and safety precautions are presented for each procedure. The results of an extensive survey of a large number of research projects and field applications of glued-on FRP sheets for repair and strengthening of concrete structures in the United States are summarized. Whenever possible a summary of projects (research or field applications) that are deemed relevant to the current investigation, is presented. An analysis of the structural behavior of concrete beams externally strengthened by CFRP sheets is provided. Issues related to durability, which is of concern to the current study, are addressed. A summary of the recommendations for the current study based on what was learned from the literature review is presented, and an extensive list of references classified by source is provided.

Volume 3 – Behavior of Beams Strengthened for Bending
The part of the investigation dealing with reinforced concrete beams strengthened in bending is described in this volume, where the results are also analyzed, compared, and discussed. The experimental program comprised fourteen reinforced concrete T-beams. The test parameters included two levels of steel reinforcement ratios before strengthening, and up to four strengthening levels. Two commercially available strengthening systems were tested, the Sika CFRP plate system (CarboDur), and the Tonen CFRP sheet system. Other selective parameters investigated included two different concrete covers; two conditions of cover preparation, tree different end anchorage systems of the glued-on sheets, and preloading pre-yielding of the beam prior to strengthening. Conclusions are drawn and some recommendations for design are suggested.

Volume 4 – Behavior of Beams Strengthened for Shear
The parts of the investigation dealing with reinforced concrete beams strengthened in shear is described in this volume, where the results are also analyzed, compared, and discussed. The experimental program comprised three rectangular concrete beams and three T-beams. The test parameters included two different shear-span ratios. Two commercially available strengthening systems were tested, the Sika CFRP plate system (CarboDur), and the Tonen CFRP sheets system. Both systems were used for shear strengthening and for two specimens they were also used for shear and bending strengthening. Other selective parameters investigated included two levels of longitudinal steel reinforcement ratio before strengthening and two steel shear reinforcement levels. Conclusions are drawn and some recommendations for design are suggested.

Volume 5 – Behavior of beams Under Cyclic Loading at Low Temperature
The part of the investigation dealing with the tests in bending shear of strengthened beams under low temperature (-29°C) and high amplitude cyclic loading is the subject of this volume. Results are also analyzed, compared, and discussed. Four reinforced concrete beams strengthened with CFRP sheets were designed, prepared and tested under low temperature conditions (-29°C). Two beams were tested monotonically to failure and the other two were tested under high amplitude cyclic load (fatigue loads). Parameters investigated were: Low temperature and loading conditions. The four beams were tested under low temperature conditions (-29°C). Two beams were tested under a four-point load configuration, one monotonically and one in cyclic fatigue. These beams considered to fail in bending were strengthened with Sika system. The remaining two beams were tested under a three-point load configuration, also one monotonically and one in

cyclic fatigue. These beams considered to fail in shear were retrofitted with the Tonen system. The amplitude of the cyclic fatigue load was taken as 10 to 80 percent of the failure load from the monotonic test. Conclusions are drawn and some recommendations for design are suggested.

Volume 6 – Behavior of Beams Subjected to Freeze-Thaw Cycles
The part of the investigation dealing with the flexural testing of reinforced concrete beams with glued-on CFRP plates subjected to different numbers of freeze-thaw cycles is the subject of this volume. Results are also analyzed, compared, and discussed. The experimental program comprised 48 reinforced concrete beams. The specimens were subjected to up to 300 freeze-thaw cycles according to ASTM C666. For every parameter, three beams were tested in bending at 0, 100, 200, and 300 cycles. Parameters investigated were two different adhesive systems, the Tonen CFRP sheet system (Mbrace), and the Sika CFRP system (CarboDur); and a cracking stage where a pre-cracked condition simulates cracking conditions in the field prior to strengthening. Control specimens (RC beams with no CFRP laminate externally glued-on) were also subjected to 0, 100, 200, and 300 freeze-thaw cycles. Conclusions are drawn and some recommendations for design are suggested.

Volume 7 – Technical Specifications
Volume 7 provides technical specifications based on information provided by the manufacturers of the two CFRP strengthening systems used and augmented by the experience accrued during the course of this investigation. Since the adhesive-bonded plate repair and strengthening technique applies to plain, reinforced, and pre-stressed concrete structures, as well as steel and timber structures, the experience gained during this project and the technology transfer developed covered a wide range of future applications.

Special provision for CFRP sheets written. One construction project and one CFRP sheet demonstration project were completed in 2000.

The load tests performed on Bridge ID #B02-19031, carrying old US-27 over Holden Creek, in Clinton County is documented by report RC-1388. The objective of the load test was to verify the effect of a strengthening with carbon fibers on the behavior of a reinforced concrete deck slab. The tests were carried out prior to strengthening, on July 7, 2000, and after application of carbon fibers, on August 22, 200. Carbon fiber-reinforced polymer (CFRP) sheets were glued at the bottom of the deck slab to strengthen concrete in tension. The strains at the bottom of the slab and deflections were measured to find the effect of strengthening.

96-1068 Non-Metallic Reinforcement of Concrete Bridge Deck

Project Manager:	Dave Juntunen
Contractor:	Michigan State University
Total Project Cost	$262,226.00
Total Amount Spent:	$262,221.03
FY 1997 Expenditures:	$21,842.49
FY 1998 Expenditures:	$78,861.13
FY 1999 Expenditures:	$91,865.85
FY 2000 Expenditures:	$3,374.73
FY 2001 Expenditures:	$66,276.83
Completion Date:	3/20/01

Report RC-1392. A field demonstration project comprising a concrete bridge deck reinforced with an Aramid Fiber composite bar was implemented and is subjected of long-term monitoring. A field demonstration project (M-15 over Goodings Creek) was built using Aramid Fiber reinforcement, and it is being monitored. Building durable bridge decks using non-metallic reinforcement is feasible; however, at present, the cost and availability of the products are prohibitive. However, **the experience provided by this research has set the ground work for researchers and manufacturers of non-metallic reinforcement to develop second and third generation products that will be more competitive to steel reinforcement.**

96-1069 Polymer Composite Jackets for Column Repair

Project Manager:	Roger Till
Contractor:	Michigan State University
Total Project Cost	$194,981.00
Total Amount Spent:	$194,497.03
FY 1997 Expenditures:	$17,759.59
FY 1998 Expenditures:	$83,582.09
FY 1999 Expenditures:	$52,193.81
FY 2000 Expenditures:	$40,961.54
Completion Date:	1/25/01

Report RC-1386. Experiments were conducted to assess the effects of using fiber-reinforced polymer (FRP) wraps with fibers oriented in the hoop direction for rehabilitating corrosion-damaged columns. Issues that were explored are: (1) freeze-thaw durability of concrete square and cylindrical specimens wrapped with glass and carbon FRP and subjected to an internal expansive force; (2) effect of wrapping on the rate of corrosion in an accelerated corrosion test; Freeze-thaw and we-dry conditioning had no detrimental effect on carbon FRP panels other than a 28 to 36 percent reduction, respectively, in the ultimate strain. Glass FRP panels showed 21 and 20 percent reductions in ultimate strength and ultimate strain due to freeze-thaw conditioning, and 18 and 20 percent reductions in ultimate strength and ultimate strain due to wet-dry conditioning. The results of tension tests on carbon panels were somewhat unreliable.

Better grip fixtures should be used for future testing.

Both glass and carbon FRP panels did not display any significant damage due to the impact test.

At temperatures in excess of 200°C the epoxy in the FRP burn and evaporate and the individual plies of wraps unravel. Hence the wraps become ineffective at such high temperatures unless effective insulation is provided.

It is evident from the experimental study conducted that both carbon and glass wrap systems are sufficiently resistant to freeze-thaw cycles and reduce the corrosion rate by about the same rate. Therefore, three layers of glass wrap or two layers of carbon wrap may be used to repair Michigan bridge columns. **Special provision and use criteria for column wrapping were written.** Use criteria to be included in the Bridge Design Manual according to Bridge Committee Minutes of May 10, 2001. **One column wrapping demonstration project completed in 1999.**

98-1303 Research Study to Determine Procedures for Efficient Evaluation of Bridge Decks

Project Manager:	Dave Juntunen
Contractor:	University of Michigan
Total Project Cost:	$61,446.00
Total Amount Spent:	$61,359.10
FY 1999 Expenditures:	$43,340.56
FY 2000 Expenditures:	$14,365.39
FY 2001 Expenditures:	$3,122.36
FY 2002 Expenditures:	$530.79
Completion Date:	6/26/01

Report RC-1389. Objective of this project was to provide a guide for evaluating bridge decks. The report was to be used as a supportive document to the many guidelines and specifications either developed or recognized by MDOT. The guide was distributed to Regional Bridge Engineers and Bridge Inspectors. Upon receiving feedback from the users of the Guide, it can be updated to best meet their needs, and as Department procedures regarding bridge decks change, the Guide can be updated to stay current. The Guide will be distributed in electronic format (.pdf) for fast and economical distribution.

00-0341 Verification of Girder Distribution Factors for Steel Girder Bridges

Project Manager:	Roger Till
Contractor:	University of Michigan
Total Project Cost:	$103,650.00
Total Amount Spent:	$103,650.00
FY 2000 Expenditures:	$1,257.06
FY 2001 Expenditures:	$88,403.65
FY 2002 Expenditures:	$13,989.29
Completion Date:	7/9/01

Report RC-1393. The report documents the field testing and finite element analysis of steel girder bridges with spans from 10 to 45 m. A total of six bridges were instrumented and loaded with heavy 11-axle trucks. In addition, a truck survey was carried out to determine the frequency of simultaneous occurrence of two trucks in-lane and side-by-side. The field tests confirmed that the code specified GDF, for a single lane and for two-lane traffic, are conservative. An advanced finite element (FEM) analysis was performed using ABAQUS. The actual behavior was modeled by assuming a partial fixity of the supports (fixed hinges and restrained rotation). For the design of new bridges, it is recommended to use AASHTO LRFD (1998) GDF. For evaluation of existing steel girder bridges, it is recommended to use AASHTO LRFD (1998) GDF specified for a single lane even for two-lane structures, because of a reduced probability of a simultaneous occurrence of two heavy trucks side-by-side. The field study also confirmed previous findings related to the dynamic load factors (DLF). Therefore, for evaluation of existing steel girder bridges it is recommended to use DLF = 0.10 for two-lane loading, and DLF = 0.20 for a single truck load case. **Girder distribution factor results included in revised Bridge Analysis Guide.**

Summaries – Materials Projects
FY 2001

00-MTU-3 Aggregate Absorption as Related to Anti-Icing for Elastomeric Concrete Bridge Deck Overlays

Project Manager:	John Staton
Contractor:	Michigan Technological University
Total Project Cost:	$61,370.00
Total Amount Spent:	$61,370.00
FY 2000 Expenditures:	$48,612.37
FY 2001 Expenditures:	$12,757.63
Completion Date:	4/12/01

The use of freezing point depressants to remove hard packed snow and ice from pavements has been a common practice by highway maintenance crews for decades. The search for lower impacts on the environment has facilitated the search for methods to decrease volumes applied as well as alternative chemicals to be used in environmentally sensitive areas such as near lakes and streams. Each new chemical that is brought into the market has its own unique set of properties. Some are thicker than others, are more concentrated, have an unpleasant odor, work only at warm temperatures, and so on. In some cases more is needed to achieve the same melting ability. The property that is of highest interest to this study is the tendency for "residual effect."

Residual effect can be explained as the characteristic of a chemical that allows it to keep working for an extended period of time during a single storm event, and also has the potential to remain on the pavement for subsequent storms. This was a study of combinations of chemicals and aggregates that have the potential to greatly increase residual effect at the pavement surface.

Testing within the scope of this research project clearly shows that certain combinations of aggregate and deicing chemical can drastically reduce the formation of frost on pavements, as well as minimizing the bond potential between ice and the pavement. A limited number of combinations of aggregate and chemical were tested under this project, but good results were obtained.

Frost growth tests show that in some cases, the occurrence of frozen water vapor precipitation (hoar frost or rime ice deposit) is nearly eliminated. Some lime stones in combination with freezing point depressants show no freezing even after numerous washes. This has the potential for coating areas such as bridge decks that are highly susceptible to frost, and keeping the deck ice free through numerous storm events. In contrast, after a few washes, testing on low absorptive samples show rapid re-freezing. Tests with NaCl show that it will inhibit frost growth, but at a temperature slightly higher than the other three chemicals.

The same potential holds true for the reduction of bond strength with a single chemical application. In general, the same scenarios work well for residual effect for bond reduction as do frost mitigation. In both cases, the lime stones with medium absorptions perform well with all chemicals tested under this scope. **The CMA and NaCl appear to perform slightly better**

than the other two chemicals in all cases, but the difference is small enough to probably be insignificant.

In general, several different conclusions can be made from this testing. For both the frost and bond reduction testing, the time samples were chosen to simulate a non-absorptive pavement. This would be a pavement (i.e., bridge decks) consistently having frost and icing problems for nearly every frost or freezing event even after chemical were applied on the previous event. Any chemical that was applied has been washed off and there is little or no residual effect left. Considering the results for the tile samples, this is a good assumption. First, frost grows on these samples after the first set of washes. For the bond reduction, the bond strength rises to a level comparable to the "no chemical" state after only a few washes. This is shown graphically by the trend given by the linear regression of the data. These regression lines show how rapidly a combination returns to the "no chemical" state after application of chemical. A steep line depicts a poor tendency for residual effect with a flat slope showing good chemical retention.

Keeping the tile results in mind, and assuming that the tile samples simulate a surface that exhibits "poor" anti-icing attributes, what do the other combinations show? In contrast to tile, **Figures 23 and 25 (of the report) show combinations resulting in excellent residual reduction in bond strength. These are the TS-E lime stones with CMA and NaCl. Both of these show bond strengths well below the baseline values even after 16 washes.** This means that the pavement simulated by the tile samples could be coated with one of these aggregate/chemical combinations and the residual bonding could be drastically reduced. Further investigation of the frost results narrows this down even further. The CMA can eliminate frost down to 20°F on this aggregate with the NaCl is good to only about 23°F. This may not be a bad result; however, since frost events normally occur in the range of 30°F or warmer. In any case, both of these and several other combinations tested showed that a much safer pavement can be obtained by coating pavements that exhibit "poor" residual effect with "anti-icing" smart aggregate/chemical combinations.

The next step that is anticipated from this research is to use some of these concepts in the field. It is hoped that the aggregate types, and possibly others, can be crushed and graded, and used as broadcast aggregates with elastomeric coatings. One scenario may be to set up short test lanes of various combinations on a straight section of highway and monitor them through the winter. Some further laboratory studies could also be conducted. There are still some questions as to the setup for these trials, but it is hoped that they can be answered with this proposed further testing.

Summaries – Management Projects
FY 2002

02-MTU-1 Operation and Coordination of the Transportation Materials Research Center (TMRC)

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$103,848.00
Total Amount Spent:	$103,223.00
FY 2002 Expenditures:	$103,223.00
Completion Date:	9/30/02

02-MTU-2 Administrative Operations for the Center for Structural Durability (CSD) at WSU/MTU Joint Venture (See 01-0366)

Project Manager:	Roger Till
Contractor:	Michigan Technological University
Total Project Cost:	$20,340.00
Total Amount Spent:	$20,340.00
FY 2002 Expenditures:	$20,340.00
Completion Date:	9/30/02

02-MTU-3 Publication of the Research Record

Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$45,672.00
Total Amount Spent:	$24,740.98
FY 2002 Expenditures:	$24,740.98
Completion Date:	9/30/02

26 Coordination and Management of the Pavement Research Center of Excellence (PRCE)

Project Manager:	Jon Reincke
Contractor:	Michigan State University
Total Project Cost:	$13,662.00
Total Amount Spent:	$13,662.00
FY 2002 Expenditures:	$13,662.00
Completion Date:	9/30/02

Summaries – Construction Projects
FY 2002

01-MTU-5 Work Item Production Rates for MDOT Projects

Project Manager:	John LaVoy
Contractor:	Michigan Technological University
Total Project Cost:	$75,000.00
Total Amount Spent:	$74,801.37
FY 2001 Expenditures:	$38,082.79
FY 2002 Expenditures:	$36,718.58
Completion Date:	6/20/02

MDOT utilizes production rates from the MDOT Construction Manual to estimate overall contract time duration on new construction projects. Production rate data was found to be available from the FieldManager construction inspection records. A practical procedure was developed for MDOT to create and maintain a database of historical production rates. Testing the production rates developed against a completed MDOT project revealed a problem with the accuracy of applying the production rates to determining contract durations. It is believed that recording additional work item time data in FieldManager will improve production rate accuracy.

01-MTU-6 Comparison of MDOT Schedules as a Result of Special Provision for Progress Schedule, FUSP102G

Project Manager:	John LaVoy
Contractor:	Michigan Technological University
Total Project Cost:	$80,000.00
Total Amount Spent:	$80,000
FY 2001 Expenditures:	$38,852.94
FY 2002 Expenditures:	$41,147.06
Completion Date:	9/30/02

During the 2000 construction season, MDOT allowed contractors to submit a Progress Schedule with overlapping or concurrent controlling operations if an explanation in writing as to why the operations are overlapping is provided. The comparison revealed that in three of the four cases, the accuracy of Progress Schedules increased with the allowance of concurrent controlling activities. **Additionally, the twenty-two crush and shape and passing relief lane projects revealed that the accuracy of progress Schedules varied considerably over the three construction seasons.**

00-0781 Effectiveness of Lane Merge Traffic Control System at Construction/Work Zones

Project Manager:	Jeff Grossklaus
Contractor:	Wayne State University
Total Project Cost:	$101,755.00
Total Amount Spent:	$101,119.96
FY 2000 Expenditures:	$8,092.70
FY 2001 Expenditures:	$73,440.57
FY 2002 Expenditures:	$19,586.69
Completion Date:	12/31/01

The Michigan Dynamic Lane Merge System consists of traditional work zone control devices along with a system of dynamic "DO NOT PASS/WHEN FLASHING" signs, to create a no-passing zone to minimize late lane merges, to minimize aggressive driver behavior, and delay at the taper area. Wit the system implemented in advance of the taper section of the work zone compared to before it was implemented, the following was found:

The average travel speed based on the peak period, travel time increased
The average peak period travel time delay decreased
The average number of stops in the work zone decreased
The number of aggressive driver maneuvers during peak hours reduced dramatically.

Results of tests were presented to the MDOT Executive Operations Committee (EOC) for implementation. **The EOC endorsed the use of the Dynamic Lane Merge System as a "work zone toll." It can be used anywhere the specific criteria of traffic volumes and peaks are met. Potential benefits include smoother transition into a work zone, less aggressive driving behavior, and less delay at the taper areas.**

Summaries – Pavement Design Projects
FY 2002

00-MTU-4 Analysis of Bituminous Pavement Surface Characteristics & Their Effects on Friction Properties

Project Manager:	Al Robords
Contractor:	Michigan Technological University
Total Project Cost:	$201,135.70
Total Amount Spent:	$198,990.08
FY 2000 Expenditures:	$99,970.14
FY 2001 Expenditures:	$65,277.56
FY 2002 Expenditures:	$33,742.38
Completion Date:	9/30/02

No report available as of this printing.

00-MTU-6 Synthesis & Review of Superpave Implementation

Project Manager:	John Barak
Contractor:	Michigan Technological University
Total Project Cost:	$38,153.00
Total Amount Spent:	$37,850.91
FY 2000 Expenditures:	$3,229.91
FY 2001 Expenditures:	$34,621.00
Completion Date:	4/2/02

The purpose of this project is to **facilitate the review and exchange of new technologies and practices being undertaken across the United States in the asphalt materials area for the MDOT.** The focus areas were on hot mix asphalt. The information gained was from three primary areas: (1) new technology, (2) implementation of Superpave, and (3) areas that needed research. The information was transferred to MDOT through periodic meetings with presentations and quarterly reports. The final report acts as a final summary for the project.

00-1-1 Development of a Computer Program for Dynamic Back Calculation of Flexible Pavement Layer Moduli

Project Manager:	Tom Hynes
Contractor:	Michigan State University
Total Project Cost:	$138,939.00
Total Amount Spent:	$138,253.84
FY 00 Expenditures:	$20,927.04
FY 01 Expenditures:	$69,869.04
FY 02 Expenditures:	$47,457.76
Completion Date:	9/30/02

As of this printing, report not available.

Summaries – Pavement Performance Projects
FY 2002

99-2-1 Development of a Roughness Threshold for the Preventive Maintenance of Pavements Based on Dynamic Loading Considerations and Damage Analysis

Project Manager:	Dave Smiley
Contractor:	Michigan State University
Total Project Cost:	$217,665.00
Total Amount Spent:	$175,819.06
FY 99 Expenditures:	$68,158.27
FY 00 Expenditures:	$88,777.73
FY 01 Expenditures:	$18,883.06
Completion Date:	11/1/01

The objective of this study was to investigate the interaction between surface roughness, dynamic truck loading and pavement damage for the purpose of determining roughness thresholds. The research was successful at validating the above hypothesis by: (1) Identifying empirical relationships between roughness and distress using current indices from in-service pavements. (2) Developing similar relationships between surface roughness and theoretical pavement damage using the mechanistic approach. Consequently, a new roughness index, called the Dynamic Load Index (DLI), was developed for the purpose of identifying "unfriendly" pavement profiles from a dynamic truck loading aspect. The new index was used to develop tables showing the predicted life extension that would be achieved by smoothing a pavement section with a given remaining service life (RSL) for different DLI levels. These tables can be used to decide when smoothing action needs to be taken in order to get a desired life extension for a particular project. **Comparison with RSL-values derived using actual distress growth over time from in-service pavements allowed for determining the optimal range of DLI-values that would lead to the desired life extension upon smoothing the pavement surface. The results showed that such preventive maintenance smoothing action is best suited for rigid pavements.**

00-4-1 Investigation of Early Cracking on Selected JPCP Projects

Project Manager:	Dave Smiley
Contractor:	University of Michigan
Total Project Cost:	$28,000.00
Total Amount Spent:	$28,000.00
FY 00 Expenditures:	$21,653.60
FY 01 Expenditures:	$6,346.40
Completion Date:	1/14/02

As of this printing, report not available.

98-8-1 Transverse Crack Propagation of JPCP as Related to PCC Toughness

Project Manager:	John Staton
Contractor:	University of Michigan
Total Project Cost:	$244,347.00
Total Amount Spent:	$217,301.95
FY 98 Expenditures:	$49,155.27
FY 99 Expenditures:	$38,046.45
FY 00 Expenditures:	$110,439.16
FY 01 Expenditures:	$19,661.07
Completion Date:	1/29/02

This study determined the effects of coarse aggregate type and size on crack resistance (toughness) and propagation of the crack after it occurs. The coarse aggregate types were limestone, gravel and blast-furnace slag. Findings showed that there is a significant gain in load transfer when the aggregate is a larger size and tough. The projects results repeated previous research findings that aggregate quality features do have a significant affect on concrete pavement performance. **Generally, these results support the need to maintain a high feel of aggregate quality for the P1-mod concrete specification. They also add to the mounting evidence that selective, higher quality materials should also be used in standard specification applications.**

00-3-1 Identify Causes for Under Performing Rubbilized Concrete Pavement Phase II

Project Manager:	Vern Barnhart
Contractor:	Michigan State University
Total Project Cost:	$162,111.04
Total Amount Spent:	$160,732.22
FY 00 Expenditures:	$8,636.23
FY 01 Expenditures:	$74,874.45
FY 02 Expenditures:	$77,221.54
Completion Date:	6/20/02

It is strongly recommended that the following steps be adopted for immediate implementation: (1) Revise the acceptance criteria of the MDOT special provision for rubbilizing concrete pavements. (2) Strictly enforce the MDOT special provision for rubbilizing concrete pavements and quality control measures. (3) Provide the Regions and the Transportation Service Centers a list of deteriorated concrete pavements that should not be selected for rubbilization. (5) Implement the layer coefficients and/or modulus values of rubbilized materials. As an alternative to method specifications the following performance measures are highly recommended for inclusion in a five-year warranty period: (1) No longitudinal and/or transverse top-down cracks. (2) No reflective or regular transverse or longitudinal cracks. (3) No faulting (differential elevation) between two adjacent lanes. (4) No shear failure. (5) No raveling. (6) Less than 0.25-inch rut depth.

Implementation of the recommendations will be delayed until a new Pavement Selection Review Committee is formed in January of 2003. When the committee is formed, the report will be submitted to determine the best way to implement the recommendations.

Summaries – Bridge Projects
FY 2002

01-MTU-1 Reinforcement – Allowable Lap Lengths, Development Length & Concrete Covers

Project Manager:	Steve Kahl
Contractor:	Michigan Technological University
Total Project Cost:	$64,150.00
Total Amount Spent:	$64,149.75
FY 01 Expenditures:	$45,010.75
FY 02 Expenditures:	$19,139.00
Completion Date:	2/7/02

Concrete bridge decks in corrosive environments have utilized several methods to prevent corrosion of the reinforcing steel including the use of stainless steel as reinforcement. While proven for corrosion resistance, very little information is available about the bond strength of stainless reinforcement. The bond strength of stainless steel reinforcement in concrete compared to conventional carbon steel reinforcement was studied in working stress ranges between 34 and 100 percent of yield. One hundred and ninety-one bond tests were performed with beam-end specimens similar to the ASTM A944 (1995) specimen. Bar types used in the bond tests were conventional A615 Gr. 60 carbon steel reinforcement, 316LN stainless steel reinforcement, and 2205 Duplex stainless steel reinforcement. Bonded lengths of 4-inch to 10-inch were used for the No. 4 bars, and 5.5 inches to 12-inches for the No. 6 bars. Concrete clear cover for all tests was 1 ½-inch to conduce cracking bond failures. No transverse reinforcement was present in the tests. Comparisons of stainless reinforcement test results to predicted values revealed that there was no reason to believe the bond strength of stainless reinforcing bars, independent of bar type studied, was less than predicted. No. 4 reinforcing bar comparisons involving stainless steel reinforcement to carbon steel reinforcement showed that there was no reason to believe that the stainless steel bond strength was different from the carbon steel bond strength. The comparison of No. 6 stainless steel reinforcement bond tests to carbon steel bond tests revealed a weaker bond for some stainless bars. However, the conservatism of the AASHTO development length relationship (as well as other comparative relationships including OJB, ACI, and Darwin) predicted lower bond strengths than observed at all bonded lengths for all bar types. Therefore, no modifications are suggested when determining the development length of stainless reinforcement on a one-to-one replacement of stainless steel 316LN or Duplex 2205 for Gr. 60 A615 reinforcement, No. 4 to No. 6 bars.

The study was forwarded to bridge design unit managers. It is hoped that when using stainless for bridge decks, the development/lap lengths specified will be listed in bridge design guides for uncoated reinforcement. This will reduce the amount of steel needed in bridge decks, thus lower costs.

01-MTU-8 Forecast & Resolve Deterioration problems with the Ends of PC Beams – Causes & Cures of PC Bridge Beam End Deterioration (Joint Venture See 01-0364)

Project Manager:	Roger Till
Contractor:	Michigan Technological University
Total Project Cost:	$68,931.00
Total Amount Spent:	$68,931.00
FY 01 Expenditures:	$44,187.62
FY 02 Expenditures:	$24,743.38
Completion Date:	9/30/02

Pre-stressed concrete (PC) for highway bridges was first introduced in Michigan in the 1950s. In 2000, Michigan had more than 1,700 pre-stressed box beam and 700 pre-stressed I-beam structures. A recent study on the condition of Michigan's PC bridges revealed that while most were in fair or better than fair condition, older bridges are showing signs of deterioration, particularly in the ends of I-beam structures. End deterioration needs to be addressed through various inspections and repair techniques for these structures. The specific goals of this research were to (a) develop an inspection procedure for pre-stressed concrete I-beam bridges that will clearly distinguish distress severity and disclose potential problems, (b) identify preventive maintenance strategies to extend the service life of pre-stressed concrete I-beam ends, and (c) evaluate repair techniques for I-beam ends to avoid performing complete beam replacement.

The information presented begins with field survey inspection data and results of a multi-state survey to determine nationwide practices for inspection and repair of pre-stressed concrete I-beam ends. Analytical studies incorporated extensive field inspection data and showed beam-end deterioration to significantly influence the load path through the member to the bearing. An experimental investigation of shrinkage/cracking and adhesion of vertically patched shallow and deep repairs was conducted. Three repair materials were used in patches and specimens were thermally cycled. **All repair materials showed cracking larger than 6 mils and no material met the minimum bond performance criteria of 400 psi. A master listing of suggested preventive maintenance and repair techniques is provided.**

01-MTU-9 Investigation of Current Bridge Loading vs Design Loading (Joint Venture See 01-0363)

Project Manager:	Roger Till
Contractor:	Michigan Technological University
Total Project Cost:	$44,934.00
Total Amount Spent:	$44,934.00
FY 01 Expenditures:	$19,939.65
FY 02 Expenditures:	$24,994.35
Completion Date:	9/10/02

This report presents the process and results of a joint research effort between Michigan Technological University and Wayne State University to examine the adequacy of current vehicles loads used to design bridges in the State of Michigan. The target reliability index used in the AASHTO LRFD Bridge Design Specifications was used here as the criterion for evaluating the adequacy. Reliability indices were calculated for twenty different bridges selected randomly from the Michigan inventory of new bridges. The bridge suite included five bridges from each of four major types in Michigan. They were steel girder, pre-stressed I-beam, pre-stressed adjacent box girder, and pre-stressed spread box girder bridges. Existing weigh-in-motion data was processed to statistically characterize the truck load effect, i.e., moment, shear, and wheel loads. For moment and shear in girders, two strengths were used in the reliability analyses for: (1) strength as designed according to construction plans termed herein as as-designed; and (2) strength required by the current design code as the sum of factored design dead load and live load (HS25) termed herein as design-minimum. For wheel loads, punching shear capacities were used. The two different girder resistances resulted in different reliability levels for comparison. The reliability indices were calculated for each of those cases: (1) entire State of Michigan, and (2) Metro Region (Region 7). To cover the variation of truck traffic volume, two values of truck traffic were used in these analyses: 50^{th} and 90^{th} percentiles for several functional classes of roads.

The reliability indices were found to vary from bridge type to bridge type. The following conclusions are drawn based on the calculated reliability indices: (1) The 50^{th} and 90^{th} percentiles of traffic volume do not noticeably influence the reliability indices. (2) This also leads to an observation that the reliability indices for the entire state and for the Metro Region (Region 7) do not show significant differences. This is because both cases used the same VIM data collected from around the Metro Region. **(3) The current design load, HS 25, could be modified to achieve, on average, a reliability index of 3.5, which was used as the target index for the AASHTO LRFD Bridge Design Specifications. (4) The deck design load of HS 20 is adequate for reinforced concrete decks. It is recommended that a new design load level be considered for bridge beam design in the Metro Region.**

01-0339 Criteria & Benefits of Penetrating Sealants for Bridge Decks

Project Manager:	John Staton
Contractor:	Wayne State University
Total Project Cost:	$87,059.00
Total Amount Spent:	$86,640.84
FY 01 Expenditures:	$47,059.61
FY 02 Expenditures:	$39,581.23
Completion Date:	6/20/02

The study presented in the report evaluates the potential durability gained by the use of penetrating sealants on concrete bridge decks. The goal of the study was to evaluate the potential durability gained by the use of penetrating sealants on concrete bridge decks. The study did not endorse the use of sealants for bridge deck protection prior to reviewing controlled field implementations as well as the development and testing of QC/QA procedures. However, this study does conclude that sealants can provide effective deck protection if used once either for decks placed in the fall or at regular maintenance cycles. It is very obvious that the repeated use protocols may have a low benefit/cost when operational costs are considered.

The following recommendations are provided if the sealant use is adopted for deck protection:

1. Minimum sealant penetration depth of 0.25-inch is required to provide effective sealing layer for concrete bridge decks.

2. Neat silane can provide the required durability for bridge decks.

3. A single sealing cycle is sufficient for late construction if regular preventive maintenance cycles are not required. Otherwise, four to five-year sealing cycles are required.

4. Moisture is needed for sealant reaction, but it inhibits the sealant penetration. Therefore, the deck surface at least should be dry when the sealant is applied.

5. Deck cracks should be sealed. If the maximum crack width is less than 0.002-inches, silane sealers are adequate to seal the deck. When the crack width is less than 0.08-inches, silane and HMWM sealers can be applied provided adequate drying period is maintained between silane and HMWM applications.

01-0364 Forecast & Resolve Deterioration Problems with the Ends of PC Beams – Causes & Cures of PC Bridge Beam End Deterioration (Joint Venture See 01-MTU-8)

Project Manager:	Roger Till
Contractor:	Wayne State University
Total Project Cost:	$99,876.00
Total Amount Spent:	$99,876.00
FY 01 Expenditures:	$46,004.14
FY 02 Expenditures:	$53,871.86
Completion Date:	5/31/02

Pre-stressed concrete (PC) for highway bridges was first introduced in Michigan in the 1950s. **In 2000, Michigan had more than 1,700 pre-stressed box beam and 700 pre-stressed I-beam structures.** A recent study on the condition of Michigan's PC bridges revealed that while most were in fair or better than fair condition, **older bridges are showing signs of deterioration, particularly in the ends of I-beam structures.** End deterioration needs to be addressed through various inspection and repair techniques for these structures. The specific goals of this research were to (a) develop an inspection procedure for pre-stressed concrete I-beam bridges that will clearly distinguish distress severity and disclose potential problems, (b) identify preventive maintenance strategies to extend the service life of pre-stressed concrete I-beam ends, and (c) evaluate repair techniques for I-beam ends to avoid performing complete beam replacement.

The information presented begins with field survey inspection data and results of multi-state survey to determine nationwide practices for inspection and repair of pre-stressed concrete I-beam ends. Analytical studies incorporated extensive field inspection data and showed beam-end deterioration to significantly influence the load path through the member of the bearing. An experimental investigation of shrinkage/cracking and adhesion of vertically patched shallow and deep repairs was conducted. **Three repair materials were used in patches and specimens were thermally cycled. All repair materials showed cracking larger than 6 mils and no material met the minimum bond performance criteria of 400 psi. A master listing of suggested preventive maintenance and repair techniques is provided.**

Summaries – Materials Projects
FY 2002

99-MTU-3 A Study of Materials – Related Distress (MRD) in Michigan's PCC Pavements

Project Manager:	Bob Muethel
Contractor:	Michigan Technological University
Total Project Cost:	$295,504.00
Total Amount Spent:	$295,503.99
FY 99 Expenditures:	$29,642.26
FY 00 Expenditures:	$162,917.40
FY 01 Expenditures:	$61,110.10
FY 02 Expenditures:	$41,834.23
Completion Date:	9/30/02

Materials-related distress (MRD) is of concern to MDOT, potentially affecting all concrete transportation structures including pavements, bridges, retaining walls, barriers, and abutments. MRD is a direct result of a component breakdown within the concrete matrix due to the interaction between the concrete and its surrounding environment. The specific MRD mechanism and extent varies with location due to differences in local environmental factors, concrete constituent materials, construction practices, deicer applications, and traffic. MRD can occur even in properly constructed PCC pavements having adequate structural capacity, resulting in costly, premature concrete deterioration and eventual failure. This study investigated the occurrence of MRD in Michigan's concrete pavements, using a variety of investigative techniques, including visual assessment, nondestructive deflection testing, strength and permeability testing, micro structural characterization, and chemical methods to determine the causes of observed distress. Based on this investigation, specific recommendations were made regarding treatment of distressed pavements and approaches to avoid the occurrence of these distresses in future concrete pavement construction.

Specifically, it was observed that MDOT's current emphasis on screening aggregates using MTM 115 has been effective in preventing aggregate free-thaw deterioration in newly constructed pavements. But it was also found that in some cases the air-void system purposely entrained in the concrete to protect it against freeze-thaw damage was inadequate, making the concrete susceptible to freeze-thaw damage. Further, the air contents of mixtures made with blast furnace slag coarse aggregate were higher than desired indicating that some difficulties exist in controlling the air content of such concrete. Alkali-silica reactivity (ASR) was observed in over half the test sites evaluated. In recent projects, the ASR is predominately isolated to the chert constituents in the fin aggregate in concrete made with blast furnace slag coarse aggregate. No definitive conclusions can be drawn at this time regarding the interactions leading to this observation, but the evidence clearly indicates that some type of interaction exists. **It was also observed that in concrete made with blast furnace slag coarse aggregate, there is strong microscopic evidence of calcium sulfide dissolutions near the contact zone with the hydrated cement paste, a preponderance of calcium hydroxide in the hydrated cement**

paste, and secondary ettringite filling adjacent voids and cracks. Further investigations need to be conducted to confirm whether this is resulting in a type of internal sulfate attack. But mixtures containing Class F fly ash were observed to have markedly better durability, indicating the beneficial nature of this cement supplement/replacement.

01-MTU-3 Field Performance of Polymer Concrete Bridge Deck Overlays in Michigan Department of Transportation

Project Manager:	John Staton
Contractor:	Michigan Technological University
Total Project Cost:	$65,391.00
Total Amount Spent:	$65,319.00
FY 01 Expenditures:	$54,180.59
FY 02 Expenditures:	$11,210.41
Completion Date:	10/31/01

This study covered a large range of efforts pertaining to the use of sealers on bridge decks. One of the most important observations of all of the studies performed during this scope was that research in this area over the past 15 or more years has progressed development of these systems to a point where they are highly durable and will last long periods of time. Overall, these systems are quite useful for increased friction as well as prolonging the life of a pavement by sealing out unwanted moisture and chlorides. Service life will need to be monitored over the next few years since new materials addressing the needs of proper bridge overlaying have only been on the decks for five or so years. **Looking at some of the most recent projects and the limited wear on those, it is not hard to envision a 15-year or longer service life.**

02-MTU-4 Road Temperature Sensor Project for FY 2002

Project Manager:	Frank Spica
Contractor:	Michigan Technological University
Total Project Cost:	$15,000.00
Total Amount Spent:	$15,000.00
FY 02 Expenditures:	$15,000.00
Completion Date:	9/30/02

This project was not completed to the point it could be installed. It will be continued for the next fiscal year. **Upon completion of the project, frost tubes would be replaced by sensors that will allow remote reading of the temperature under the roadway at various depths.**

02-MTU-6 Mechanical Properties of Rock Cores

Project Manager:	Dick Endres
Contractor:	Michigan Technological University
Total Project Cost:	$5,000.00
Total Amount Spent:	$3,956.00
FY 02 Expenditures:	$3,956.00
Completion Date:	9/30/02

A bridge structure over the Sturgeon River is to be built on US-2 in Dickinson County. **For the pier foundations, drilled shafts will be advanced thru cobbles and boulders and socketed into the underlying bedrock. A rock core retrieved from the pier location was studied to gain knowledge of engineering properties.** It was determined that the drilled shaft sockets will be cut into the Curry Iron-Bearing member of the Vulcan Iron Formation. Samples of the rock core were tested for point load strength and correlated to uniaxial compressive strength using empirical formula. The uniaxial compressive strength of the rock is estimated between 30000 and 40000 psi with a Youngs Modulus of 9.5×10^6 psi and a Shear Modulus of 3.6×10^6 psi. The Mohs hardness of the iron ore was found to vary between 6.5 and 7.5 while the absolute density was 3.31 g/cm^3.

The research report is a contract document that was distributed to construction companies at a mandatory pre-bid meeting. **This information will make contractors aware of the site conditions and aid in the selection of equipment for drilling the rock sockets.**

Summaries – Management Projects
FY 2003

Contract/Authorization #:	95-0242, 16
Title:	**Administrative Operations for Bridges & Structures Research Center of Excellence**
Project Manager:	Roger Till
Contractor:	University of Michigan
Total Project Cost:	$23,957.00
Total Amount Spent:	$23,957.00
FY 03 Expenditures:	$12,963.18
FY 04 Expenditures:	$10,993.82
Purpose/Objective of Research:	Management
Summary/Description of Research:	Assisted in organizing the Call for Research meeting held at MDOT. Developed problem statements in response to MDOT's Call for Research. Developed proposals for MDOT's consideration. Presented papers based on research done through MDOT funding at conferences. Held seminars for students on MDOT bridge engineering practices. Coordinated activities between universities within the center. Developed concepts for MDOT research project management.
Findings:	Not Applicable
Implementation Plan/Deliverables:	Not Applicable

Contract/Authorization #:	01-0608
Title:	**Policy & Procedures Manual for University Research Program**
Project Manager:	Sudhakar Kulkarni
Contractor:	B. T. Harder, Inc.
Total Project Cost:	$20,450.00
Total Amount Spent:	$17,489.98
FY 02 Expenditures:	$10,699.98
FY 03 Expenditures:	$6,790.00
Purpose/Objective of Research:	Professional services to review and edit drafts of the Research Administration Manual compiled by MDOT.
Summary/Description of Research:	Not Applicable
Findings:	Not Applicable
Implementation Plan/Deliverables:	**Research Administration Manual**

Contract/Authorization #:	96-5434, 03-MTU-3
Title:	**Operation & Coordination of the Transportation Materials Research Center**
Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$109,040.00
Total Amount Spent:	$103,814.00
FY 03 Expenditures:	$103,814.00
Purpose/Objective of Research:	Management, operation & coordination of the center.
Summary/Description of Research:	Not Applicable
Findings:	Not Applicable
Implementation Plan/Deliverables:	Not Applicable

Contract/Authorization #:	96-5434, 03-MTU-1
Title:	**Publication of the Research Record**
Project Manager:	Jon Reincke
Contractor:	Michigan Technological University
Total Project Cost:	$47,083.00
Total Amount Spent:	$25,372.77
FY 03 Expenditures:	$25,372.77
Purpose/Objective of Research:	To publish research technology findings. Research Record editorial staff will interview the involved C&T personnel or university researchers and perform related information collection.
Summary/Description of Research:	Not Applicable
Findings:	Not Applicable
Implementation Plan/Deliverables:	**Approximately four publications of the Research Record are done a year.**

Contract/Authorization #:	96-5434, 03-MTU-4
Title:	**Administrative Operations for the Center for Structural Durability @ MTU/WSU**
Project Manager:	Roger Till
Contractor:	Michigan Technological University
Total Project Cost:	$20,696.00
Total Amount Spent:	$20,696.00
FY 03 Expenditures:	$20,696.00
Purpose/Objective of Research:	Management
Summary/Description of Research:	Developed problem statements in response to MDOT's Call for Research. Developed proposals for MDOT's consideration. Distributed research results at a national level. Presented papers based on research done through MDOT funding at conferences. Reviewed accounting of research projects. Coordinated activities between universities within the center. Held workshop on research findings and research in progress at the Michigan Bridge Conference.
Findings:	Not Applicable
Implementation Plan/Deliverables:	Not Applicable

Summaries – Construction Projects
FY 2003

Contract/Authorization #:	99-0460
Title:	**Impact Performance Evaluation of Michigan's Guardrail System**
Project Manager:	Jeff Grossklaus
Contractor:	University of Nebraska
Total Project Cost:	$143,658.76
Total Amount Spent:	$142,611.49
FY 00 Expenditures:	$63,717.38
FY 01 Expenditures:	$1,200.38
FY 02 Expenditures:	$18,996.80
FY 03 Expenditures:	$57,889.89
FY 04 Expenditures:	$807.04
Purpose/Objective of Research:	Evaluate the safety performance of Michigan's existing work-zone traffic control device through full-scale crash testing.
Summary/Description of Research:	Crash tested Type III barricades and 4'x 4' and 4'x 5' signs used in work zones to see if they meet FHWA crashworthy criteria. They did not meet the criteria. Redesigned and re-tested the 4'x 4' sign, where it now meets the criteria.
Findings:	Following the analysis of the crash tests results from other testing programs, it was found that slight variations in design features of the work-zone traffic control devices can lead to very different performance results.
Implementation Plan/Deliverables:	Once it was determined the Type III barricade did not meet requirements, MDOT opted to start using a Type III barricade designed by others. **The 4'x 4' new sign design is now MDOT's standard**. For both the Type III and 4'x 4' sign, a transition period was established to phase out old equipment. The new signs are to be in place by the letting of October 2004. No decision has been made on a new design for the 4'x5' sign. Report RC-1439.

Contract/Authorization #:	96-5434, 03-MTU-5
Title:	**Phase One Proposal for the Risk Assessment of the I-196 Interstate Section Located Over the Domtar Mine, Grand Rapids, Michigan**
Project Manager:	Tom Hynes
Contractor:	Michigan Technological University
Total Project Cost:	$8,943.00
Total Amount Spent:	$8,932.92
FY 03 Expenditures:	$8,932.92
Purpose/Objective of Research:	Assess the potential risk the gypsum mines poses to the stability of I-196.
Summary/Description of Research:	Assessment will be based on available mine & MDOT records, as well as data from a report prepared for Kent County entitled Kent County Geologic Stability Study for the John Ball Zoological Garden Expansion west of I-196.
Findings:	To date, no distresses have been observed on I-196 nor has any settlement been measured although many of the underground workings below the I-196 have collapsed and that the workings are now filled with water. It is believed, though, that in the future I-196 may experience some subsidence. However, the estimation of timing and amount of subsidence will require additional investigation. Consequently, it is recommended that continual observation of the area to the west of I-196 be conducted and that periodic monitoring of I-196 both for distresses and elevation changes be conducted.
Implementation Plan/Deliverables:	**A risk assessment of the stability of I-196 due to potential ground stability from the underground gypsum mining.**

Contract/Authorization #:	02-0186
Title:	**Field Testing of Variable Speed Limits in Construction Work Zones**
Project Manager:	Jeff Grossklaus
Contractor:	Michigan State University
Total Project Cost:	$177,687.00
Total Amount Spent:	$177,687.30
FY 02 Expenditures:	$97,039.48
FY 03 Expenditures:	$80,647.52
Purpose/Objective of Research:	To develop, test, and evaluate a variable speed limit (VSL) system to be used in work zones
Summary/Description of Research:	An intelligent transportation system was designed, built, tested, and evaluated in different scenarios in work zones.
Findings:	The VSL is not developed enough to use as a standard work zone system.
Implementation Plan/Deliverables:	This system was developed and 80 percent paid for by the FHWA. Two other states are/have developed their version of a VSL system and will be testing and evaluating. **The FHWA will look at all three systems and try to pick the best portions of all three. MDOT has no current plans to use the VSL again.** No report available as of this printing.

Summaries – Pavement Design Projects
FY 2003

No projects in this category for this year.

Summaries – Pavement Performance Projects
FY 2003

Contract/Authorization #:	94-1699, 28
Title:	**Development of Improved Pavement Distress Index Models**
Project Manager:	Kevin Kennedy
Contractor:	Michigan State University
Total Project Cost:	$34,812.00
Total Amount Spent:	$34,532.33
FY 02 Expenditures:	$12,495.30
FY 03 Expenditures:	$22,037.03
Purpose/Objective of Research:	Evaluate the suitability of the logistic growth function for predicting the distress index and to suggest specific ways to improve it, including use of other function forms.
Summary/Description of Research:	Alternative models to predict pavement distress index for different pavement/fix types were developed. The models were developed at the pavement/fix level for freeway and non-freeway routes. Future distress index values were predicted incrementally in two-year steps. The models are auto-regression type. The models predict a future distress index value based on its first lag and the corresponding chronological age. The models were developed for distress index values of up to 50, and as such may not be used for ranges beyond a distress index value of 50. The models were validated by testing their ability to predict past observed distress index values. The models were able to predict "observed" distress index values reasonably well although the accuracy differed among pavement types.
Findings:	**The data analysis showed clearly that significant variability exists among similar pavement sections of similar age, pavement type, and distress index values.** This suggests that other factors that impact distress progression are missing. Data on those factors should be assembled and used in future models and/or refine current models. Improvements or advantages offered by any modeling approach should not be a substitute for identifying and using missing relevant casual factors.
Implementation Plan/Deliverables:	Report RC-1436

Contract/Authorization #:	94-1699, 24
Title:	**Identification of the Causes of Top-Down Cracking (TDC) of Flexible Pavements**
Project Manager:	Vern Barnhart
Contractor:	Michigan State University
Total Project Cost:	$59,775.86
Total Amount Spent:	$59,768.11
FY 02 Expenditures:	$27,309.38
FY 03 Expenditures:	$32,458.73
Purpose/Objective of Research:	To determine the causes of TDC on asphalt pavements.
Summary/Description of Research:	Top down cracks (TDC) are longitudinal or transverse cracks that initiate at the pavement surface and propagate downward and outward. They have been observed with increasing frequency on roads in Michigan. In this study, field and laboratory investigations were conducted to determine the factors that affect the load-induced tensile stresses at the pavement surface and the tensile strength of the AC mixes, and hence, affect the susceptibility of the pavement surface to TDC potential.
Findings:	**Results of laboratory testing indicate that the AC mixtures used as surface courses in Michigan may be weakened by moisture damage.** Further, segregation increases the susceptibility of the AC mixtures to moisture damage, and hence, increases TDC potential. Finally, a crack propagation model was developed as a function of pavement age and degree of segregation based on distress survey data.
Implementation Plan/Deliverables:	Based on the results and conclusions of this study, it is strongly recommended that: 1. Crack initiation and propagation be included in the design/build warranty standards. 2. In the PMS database, differentiate between TDC and regular cracks. This can be achieved by implementing the TDC identification criteria developed in this study. The reason for such differentiation is that preventive maintenance and rehabilitation actions for pavements exhibiting TDC are much different than those exhibiting regular cracks (bottom-up cracks). 3. All asphalt mixes should be evaluated regarding segregation, moisture susceptibility and asphalt contents (to prevent dry mixes). 4. Explore more in depth the effects of segregation and aging on the properties of the asphalt mixes. Report RC-1440

Contract/Authorization #:	96-5434, 03-MTU-2
Title:	**Road Temperature Sensor Project for FY 2002/2003**
Project Manager:	Frank Spica
Contractor:	Michigan Technological University
Total Project Cost:	$15,000.00
Total Amount Spent:	$15,000.00
FY 03 Expenditures:	$15,000.00
Purpose/Objective of Research:	Design a transducer for monitoring the freeze depth below the road surface on Michigan highways.
Summary/Description of Research:	The project was to test the concept of detecting frost by means of measuring temperature and remotely access the stored data. The concept was tested in the lab and seemed to warrant field testing. A proto type sensor was built and installed in the field. The device leaked and filled with water, which destroyed the electronic circuit boards inside it. No further work was done by MTU.
Findings:	Remote storage and access of data is feasible; however, the device itself will have to be better constructed before any field testing can be completed.
Implementation Plan/Deliverables:	The faulty sensor was delivered along with the data storage equipment. The data storage equipment will be reused, but the sensor itself was a loss. Further research will have to be done before any implementation plan can be developed.

Contract/Authorization #:	95-0242, 10
Title:	**Qualify Transverse Cracking in PCC Pavements From Loss of Slab-Base Contact**
Project Manager:	Tom Hynes
Contractor:	University of Michigan
Total Project Cost:	$182,428.00
Total Amount Spent:	$163,137.82
FY 01 Expenditures:	$69,150.07
FY 02 Expenditures:	$59,127.04
FY 03 Expenditures:	$34,860.71
Purpose/Objective of Research:	Determine the extent of permanent loss of slab support at the transverse joint. Including a determination of any intermittent loss of slab support from daily temperature gradient effects.
Summary/Description of Research:	Develop a procedural method of quantifying the loss of slab-base contact using the department's FWD, LISA, and "walking dipstick." Conduct field testing of various JPCP and JRCP projects to determine the relative change in longitudinal profile from temperature changes with different base support types. Perform data analysis of profile data together with distress and ride quality condition data to find any dependent relationships. Use study results to recommend appropriate changes in current slab designs, base types, or construction practices to negate the damaging effects from loss of slab-base contact.
Findings:	Report unavailable at the time of printing
Implementation Plan/Deliverables:	RC-1453

Contract/Authorization #:	96-5434, 02-MTU-5
Title:	**Causes & Cures for Cracking of Concrete Barriers Joint Venture With WSU (See 02-0341)**
Project Manager:	John Staton
Contractor:	Michigan Technological University/Wayne State University
Total Project Cost:	MTU $49,529.00 & WSU $106,550.97
Total Amount Spent:	MTU $49,529.00 & WSU $99,192.69
FY 02 Expenditures:	MTU $10,062.20 & WSU $25,542.88
FY 03 Expenditures:	MTU $23,946.51& WSU $73,649.81
FY 04 Expenditures:	MTU $15,520.29 & WSU $0.00
Purpose/Objective of Research:	Investigate the cause(s) of observed deterioration of concrete bridge barriers with the purpose of developing strategies to prevent such deterioration in future construction.
Summary/Description of Research:	This study will examine the problem in detail to determine the nature of the distress mechanisms and then devise materials selection, mixture design, and construction strategies to reduce premature bridge barrier deterioration in the future.
Findings:	Based on visual and stereo-optical inspection, all observed cores showed some king of consolidation problems. Entrapped air voids from varying sizes were common around aggregates and the steel reinforcement. No grossly low existing air contents were measured (using ASTM C457); however, one third of the samples had spacing factors that are considered marginal for protecting the paste from freeze-thaw damage. These high spacing factors were attributed to a lack of entrained air voids, an extensive amount of infilling or a combination of the two. In stereo and petrographic optical examination, alkali-silica reactivity was observed in the fine aggregate fraction of the two test sites containing blast furnace slag coarse aggregates. The reactivity of the cherts and siltstones particles in the fine aggregate was confirmed by x-ray miscroscopy. Similar siltstones were observed in concrete from another site that did not contain slag coarse aggregate; however in that case the siltstones were not observed to be reactive and the limited damage was attributed to freezing and thawing. The frost-susceptibility of the siltstones, as well as the presence of secondary ettringite in air voids, might also have exacerbated the distress caused by ASR in locations where slag coarse aggregate was used. Finally, significant steel corrosion was observed in only one location. In that case the corrosion was so severe that it had let to delamination of the concrete. The carbonation depths measured from samples obtained at this location were also higher than normal, which indicates the corrosion might result from a higher permeability to water and aggressive agents (deicer salts).

Implementation Plan/Deliverables:	Based on these observations, it is recommended that better consolidation of the concrete barriers be required, as this will minimize the ubiquitous entrapped air that was observed at all locations. This entrapped air reduces the strength of the concrete, as well as providing ready pathways for the ingress of water and aggressive chemical agents (e.g. deicers), reducing the life of the barriers. It is also recommended the air-void system parameters be verified for the specific job mix formula being used. It is well known that the ability of a given air entraining agent to created an adequate air-void system is affected by the cement and other admixtures used, and that the control of air volume alone is Report

Contract/Authorization #:	96-5434, 02-MTU-7
Title:	**Preliminary Investigation of the Role of Bacteria in Concrete Degradation**
Project Manager:	Bob Muethel
Contractor:	Michigan Technological University
Total Project Cost:	$25,146.00
Total Amount Spent:	$24,344.37 (holding one invoice for report)
FY 02 Expenditures:	$4,675.52
FY 03 Expenditures:	$19,668.85 (holding one invoice for report)
Purpose/Objective of Research:	Various types of bacteria are commonly found in nature, and are known to interact with inorganic materials in a variety of ways. Like any life form, their metabolic activity and by-products can chemically alter their surroundings. This project should help develop a better understanding of the role of bacteria in concrete degradation.
Summary/Description of Research:	Literature review to determine the state of knowledge regarding bacteria and concrete. Laboratory experimentation specimens were prepared to simulate the physical conditions of a pavement joint. Gather core samples from pavement joints and analyze for bacteria and evidence of concrete deterioration as a result of microorganisms.
Findings:	This preliminary laboratory study found that it is feasible that bacteria could contribute to concrete degradation, creating features similar to what would be expected from acid attack. Aggregate type did not influence the findings.
Implementation Plan/Deliverables:	The results of this study lay the groundwork for future studies to isolate specific biodegradation mechanisms that may occur in the field. Of particular interest would be to study available nutrient sources in concrete and pavement deicers that may sustain bacterial colonies. Report RC-1444.

Contract/Authorization #:	96-5434, 00-MTU-7
Title:	**Noise Generated by Vehicle/Road Surface Interactions**
Project Manager:	Frank Spica
Contractor:	Michigan Technological University
Total Project Cost:	$105,000.00
Total Amount Spent:	$104,933.34
FY 01 Expenditures:	$20,516.53
FY 02 Expenditures:	$51,227.73
FY03 Expenditures:	$33,189.08
Purpose/Objective of Research:	Increased pass-by noise levels along trafficked urban highways and other populated areas have resulted in an interest in understanding the perceived nature of sound generated by the vehicle tire/road surface interaction. To gain the most useful information about the subjective nature of this sound, an in-depth sound quality study must be performed.
Summary/Description of Research:	Researchers will make binaural (stereo) recordings with an Aachen Head designed to capture sound recordings for sound playback. The head will be placed at a distance representative of a house's distance from the roadway. Simultaneous with the acquisition of the stereo recording will be the acquisition of the sound generated in the near field of the tire, in the interior of the vehicle, and the vibration generated at the vehicle's suspension. The acquired recordings will be assembled into a group of recordings to be used in a sound quality jury study. The jury study will be designed to identify which road surface configurations generate noise most acceptable to a bystander.
Findings:	The most notable finding was that the noise produced by tires going over pavement joints was overwhelming any other noise and made it possible for the jurors to evaluate any of the different road surface treatments.
Implementation Plan/Deliverables:	A full research report was prepared and submitted by Michigan Technological University. As a result of the findings MDOT has narrowed its standard pavement joint, which has decreased the noise produced by the tire/pavement joint interaction.

Summaries – Bridge Projects
FY 2003

Contract/Authorization #:	95-0242, 15
Title:	**Determine the Actual Response of Bridges to Load for Better Capacity Rating & Investigate Load Distribution of Heavy Trucks**
Project Manager:	Roger Till
Contractor:	University of Michigan
Total Project Cost:	$98,000.00
Total Amount Spent:	$97,963.63
FY 02 Expenditures:	$15,872.70
FY 03 Expenditures:	$38,300.88
FY 04 Expenditures:	$43,790.05
Purpose/Objective of Research:	Develop and calibrate an objective & straightforward method of calculating bridge load ratings based on a desired reliability level. Generalize the method so that it can be applied by MDOT engineers to similar bridges that have not been load tested, but were designed using the same code.
Summary/Description of Research:	This project entails field testing & analysis of continuous steel girder bridges. The objective of the tests was to provide a basis for recommended girder distribution factors (GDF) for interior girders and dynamic load factors (DLF), suitable for evaluation of existing continuous steel girder bridges. A total of six bridges were instrumented & loaded with heavy 11-axle trucks.
Findings:	The maximum measured strain was about 240 μ strain for positive moment at mid-span, and 150 μ strain for negative moment over support locations. Lower than expected strain values were due to partial fixity of supports, & flexural stiffness of the deck slab, sidewalks, parapets & curbs. An advanced finite element (FEM) analysis was performed using ABAQUS. The FEM results are compared with the test results. **The field study confirmed some of the previous findings related to the dynamic load factors (DLF). In general, DLF for continuous spans are lower than DLF for simple spans. DLF are lower for a negative moment (over the support) than for a positive moment (mid-spane).** The test results showed that DLF for a single heavy truck is less than 0.15. For two trucks side-by-side, DLF is 0.05-0.07 for the tested bridges. The field tests showed that the live load moment distribution is different for continuous spans compared with simple spans (tested in previous years). In general, the distribution is more uniform for continuous spans, & this applies mostly to the negative moment. The superposition of truck loads in one lane and two adjacent spans produces a larger strain than measured during the field tests. **The tests confirmed that the code specified GDF, for a single lane & for multi-lane traffic, are adequate or conservative, for both AASHTO LRFD (1998) & AASHTO Standard (2002).**

	AASHTO Standard (2002) provides more conservative GDF.
Implementation Plan/Deliverables:	Research Report RC-1429

Contract/Authorization #:	01-0365
Title:	**Sensors to Monitor Bond in Concrete Bridges Rehabilitated with FRP**
Project Manager:	Roger Till
Contractor:	Michigan State University
Total Project Cost:	$114,814.00
Total Amount Spent:	$114,813.61
FY 01 Expenditures:	$28,899.20
FY 02 Expenditures:	$45879.76
FY 03 Expenditures:	$40,034.65
Purpose/Objective of Research:	Will adapt existing sensor technology developed by DACCO SCI, Inc. for use on bridge components rehabilitated with carbon fiber reinforced polymer (FRP). The objectives are to utilize the sensors to detect debonding of the FRP from the concrete substrate, and to ascertain that the sensors are durable under the environmental conditions in Michigan.
Summary/Description of Research:	To develop a non-destructive monitoring method for MDOT to use in retrofit techniques that employ carbon fiber reinforced polymer (FRP).
Findings:	**Electrochemical impedance spectroscopy (EIS) based sensor technology is used for the NDE of the bond between external CFRP reinforcement and concrete in beams.** Copper tape on the surface of the CFRP sheet, stainless steel wire embedded in the concrete, and reinforcing bars were used as the sensing elements. Laboratory experiments were designed to test the capability of the sensors to detect the debonding of the CFRP from the concrete and to study the effect of short-term (humidity and temperature fluctuations and chloride content) and long-term (freeze-thaw and wet-dry exposure and rebar corrosion) environmental conditions on the measurements. The CFRP sheet was debonded from the concrete and impedance measurements were taken between various pairs of electrodes at various interfacial crack lengths. The dependence of the impedance spectra, and of the parameters obtained from equivalent circuit analysis, on the interfacial crack length was studied. Capacitance parameters in the equivalent circuit were used to assess the global state of the bond between CFRP sheets and concrete. Impedance measurements taken between embedded wire sensors were used to detect the location of debonded regions. Although the measurements are sensitive to short- and long-term environmental effects, measurements at high frequencies and the capacitance parameters resulting from equivalent circuit analysis are insensitive to these factors.
Implementation Plan/Deliverables:	The EIS-based sensor technology shows strong promise for effective NDE of concrete structures strengthened with CFRP sheets. However, results from this purely experimental research

	indicate that the EIS-based impedance measurements are influenced significantly by environmental conditions and different effective electrode areas especially in the low- and mid-frequency range. It is also observed that the measured impedance can have significant sample-to-sample variation. A significant contribution to the further enhancement of this work would be the development of a numerical approach for modeling the charge transfer process through the specimen. This can be most effectively done at the macro-scale by using a 3-D finite element model to represent the concrete structure, reinforcement and sensors and effective electrical properties to represent the current condition through the various component. The effective electrical properties of concrete would need to be characterized with respect to temperature, humidity, chloride content, and micro crack width and density. Once such a model is developed it can be used to study different structural components reinforced with CFRP, develop optimal sensor arrangements, and develop monographs that can be used for diagnosis of CFRP debonding. Research Report RC-1435

Summaries – Materials Projects
FY 2003

Contract/Authorization #:	96-5434, 02-MTU-8
Title:	**Resilient Modulus Testing of Michigan Aggregates**
Project Manager:	Tom Hynes
Contractor:	Michigan Technological University
Total Project Cost:	$76,079.00
Total Amount Spent:	$67,239.23 spent to date
FY 02 Expenditures:	$2,922.91
FY 03 Expenditures:	$64,316.42
FY 04 Expenditures:	Not all expenses for project have been paid
Purpose/Objective of Research:	Develop resilient modulus database.
Summary/Description of Research:	Proposed AASHTO guidelines incorporate the resilient modulus for base and sub-base material as a design parameter. The proposed guideline is based on the NCHRP-SHRP protocol P46 developed a number of years ago and the current revision of this standard AASHTO T307 entitled *The Standard Method of test for resilient Modulus of Unbound Granular Base/Sub-base Materials and Sub-grade Soils*. Unfortunately the complexity of both the testing process (T307) and analysis requires a significant investment in equipment, certification, and operator training. It is proposed that a database of resilient modulus values be developed. This database provides producers, contractors, contracting agencies, and pavement engineers with information that aids in the selection and utilization of various aggregates or for the selection and acquisition of future aggregate reserves.
Findings:	No report received as of printing of this report.
Implementation Plan/Deliverables:	NA – See Findings

Contract/Authorization #:	96-5434, 01-MTU-10
Title:	**Mineral Characterization & Cataloging of Quarried Aggregate Sources**
Project Manager:	Al Robords
Contractor:	Michigan Technological University
Total Project Cost:	$126,298.00
Total Amount Spent:	$118,975.63 spent to date
FY 01 Expenditures:	$47,552.31
FY 02 Expenditures:	$66,129.58
FY 03 Expenditures:	$5,293.74
FY 04 Expenditures:	Not all expenses for project have been paid
Purpose/Objective of Research:	The physical and chemical properties of quarried aggregates play an important role in their suitability for use in Portland cement concrete. Mechanical strength, coefficient of thermal expansion, chemical reactivity, and soundness are a few of the hardened concrete's properties that are significantly affected by the aggregate's attributes. To ultimately integrate knowledge about quarried aggregate properties into modern construction practices, it is necessary that quarried aggregate sources be characterized and catalogued in a user accessible database for easy reference.
Summary/Description of Research:	A literature review to establish what is known about aggregate reactivity and soundness in wet-freeze environments with common de-icers. **Thirteen most likely quarried aggregate sources used in Michigan will be identified.** Within each source, different aggregate types will be identified by visual characteristics and samples will be obtained by hand sampling production material. Specimens will be analyzed in MTU laboratories. The analysis will be performed on polished slabs and thin sections produced from larger pieces of aggregate sampled from each source. Mineralogy, grain size, porosity, pre geometry, and chemical composition will be determined. **Data will be entered into an accessible ArcView database.** Compare measured attributes to those same parameters from other wet-freeze states with reactive aggregates.
Findings:	No report received as of printing of this report.
Implementation Plan/Deliverables:	NA – See Findings

Summaries – Management Projects
FY 2004

No projects in this category for this year

Summaries – Construction Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization #	02-0223
Project #	76932
Title:	Investigate Cause and Develop Methods to Minimize Early-Age Cracking on Michigan Bridge Decks
Project Manager:	Roger Till
Consultant:	Wayne State University
Total Project Cost:	$158,313.00
Total Amount Spent:	$158,313.00
FY 02 Expenditures:	$25,193.15
FY 03 Expenditures:	$121,806.85
FY 04 Expenditures:	$11,313.00
Purpose/Objective of Research:	The research identified the major parameters influencing the concrete transverse deck cracking and made recommendations to modify these parameters in order to minimize deck cracking.
Report #:	RC-1437
Summary/Description of Research:	The synthesis of the data collected revealed that the tensile stress due to early-age thermal load alone could cause deck cracking.
Findings:	Volume change of concrete due to temperature and shrinkage occurs simultaneously. An increase in drying shrinkage arising from delays in concrete placement and wet curing also affect the deck cracking. Additionally, drying shrinkage, beyond the very early ages, increases the crack widths that have previously formed due to thermal loads. Concrete parameters influencing the thermal load levels are: cement type, content, and fineness, ambient temperature at the time of concrete placement, and the time of inception of curing.
Implementation Plan/Deliverables:	An important recommendation of this study is the implementation of measures to control and manage thermal and shrinkage stresses in RC decks. The first conclusion is related to current practice. If the curing related stipulations of the Michigan Department of Transportation - Standard Specifications for Construction is strictly adhered to, the density of transverse deck cracks will be reduced. This research established that approximately a 20 F of thermal load initiates deck cracking. Second, in order to reduce transverse cracking, the primary recommendation is to develop and optimize project specific mix design for the minimization of thermal load. Additional recommendations include the reduction and/or substitution of cement with mineral admixtures and use of current and forecast weather data in optimizing the mix design and placement time in order to minimize the thermal loads.

Summaries – Pavement Design Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization #	94-1699/25
Project #	76940
Title:	Preliminary Mechanistic Evaluation of PCC Cross-Sections Using ISLAB2000 - A Parametric Study
Project Manager:	Curtis Bleech
Consultant:	Michigan State University
Total Project Cost:	$164,852.00
Total Amount Spent:	$136,056.98
FY 02 Expenditures:	$34,335.66
FY 03 Expenditures:	$50,699.90
FY 04 Expenditures:	$51,021.42
Purpose/Objective of Research:	To evaluate the enhanced ISLAB2000 software that will be used by pavement designers and researchers at MDOT.
Report #:	RC-1441
Summary/Description of Research:	A parametric study will be performed to test the accuracy and robustness of the software.
Findings:	It was determined that the accuracy of the software was within the established results of other models used in this type of analysis. Additionally, it was found that the software was robust and user friendly.
Implementation Plan/Deliverables:	The software may be used to analyze pavement designs using finite element modeling. It can be used for forensic investigations of distressed or failed Portland cement concrete pavements.

Summaries – Pavement Performance Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization # :	94-1699/29
Project # :	76942
Title:	Effect of Michigan Multi-Axle Trucks on Pavement Distress
Project Manager:	Tom Hynes
Consultant:	Michigan State University
Total Project Cost:	$246,047.00
Total Amount Spent:	$182,237.00
FY 03 Expenditures:	$119,199.95
FY 04 Expenditures:	$63,037.05
Purpose/Objective of Research:	To determine the effects of heavy multiple axle Michigan trucks on pavement distress.
Report #:	RC-1461
Summary/Description of Research:	Major focus is on quantifying the effects of trucks with different configurations.
Findings:	Multiple-axle groups were found to be less damaging per tonnage compared to single axles. Increasing the number of axles carrying the same load results in less damage. This decrease in damage was found to be more significant between single, tandem and tridem axles, while it starts to level off at higher axle numbers. Similar results were obtained for trucks where trucks having more axles and axle groups had lower truck factors per tonnage than those with single axles.
Implementation Plan/Deliverables:	This is phase one of the research project.

Summaries – Bridge Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization # :	96-5434/19 (03-MTU-7)
Project # :	76974
Title:	Development of Steel Beam End Deterioration Guidelines
Project Manager:	Bob Kelley
Consultant:	Michigan Technological University
Total Project Cost:	$68,005.00
Total Amount Spent:	$66,760.60
FY 03 Expenditures:	$35,781.97
FY 04 Expenditures:	$30,978.63
Purpose/Objective of Research:	
Report #:	RC-1454 (Report is not complete as of printing of this report)
Summary/Description of Research:	
Findings:	
Implementation Plan/Deliverables:	

PROJECT SUMMARY 2004	
Contract/Authorization #	95-0242/14
Project #	76931
Title:	Determine the Impact of the AASHTO LRFD Bridge Code & Transition the Department Into the Use of the AASHTO LRFD Design Code
Project Manager:	Roger Till
Consultant:	University of Michigan
Total Project Cost:	$174,277.00
Total Amount Spent:	$174,277.00
FY 02 Expenditures:	$15,788.84
FY 03 Expenditures:	$94,607.29
FY 04 Expenditures:	$63,880.87
Purpose/Objective of Research:	State DOT's are expected to use the new AASHTO LRFD bridge design code by 2007. There are many considerable differences between the AASHTO Standard Specifications and AASHTO LRFD Code, including the reliability-based limit state approach, new live load and dynamic load, methods of analysis, design of deck slabs, unified approach to reinforced concrete and pre-stressed concrete design, shear design for concrete. There is a need for the review of the current Michigan practice and identification of differences between it and LRFD code. Therefore, the main objective of the project is the development of the training program for MDOT technical staff and consultants.
Report #:	RC-1457 (Not yet received as of printing of this report)
Summary/Description of Research:	The tasks involved preparation of handout materials, presentations, and design examples.
Findings:	For training purposes. See objectives and deliverables.
Implementation Plan/Deliverables:	The training program was carried out in two series of five workshops. The workshops covered the following areas: loads and load combinations, slab design, pre-stressed concrete design, steel design, and design of abutments and piers. Each workshop was planned for two days. The instructors were faculty members at the University of Michigan and Michigan State University.

PROJECT SUMMARY 2004	
Contract/Authorization # :	01-0367
Project # :	76928
Title:	Analytical Design Procedures & Load Rating for Isotropic Bridge Decks
Project Manager:	Roger Till
Consultant:	University of Michigan
Total Project Cost:	$124,932.00
Total Amount Spent:	$124,932.00
FY 01 Expenditures:	$29,729.27
FY 02 Expenditures:	$74,705.17
FY 03 Expenditures:	$20,497.56
Purpose/Objective of Research:	In this project, the behavior of reinforced concrete isotropic decks with empirical reinforcement supported on girders spaced up to 10 feet is considered.
Report #:	RC-1430
Summary/Description of Research:	Stress/strain analysis was performed based on finite element models of the bridge superstructure. Two types of decks were investigated, one supported on steel girders, and the other on pre-stressed concrete girders. The study involved field testing and analysis. The bridge superstructures were modeled using the finite element method (FEM) and the ABAQUS program. The analytical models were calibrated using the field test data. The computations were performed to determine stress values in the deck under a service load represented by 11-axle trucks. Stress distribution was investigated at the top and bottom of the deck, and transversally through the thickness of the deck. The possibility of cracking was analyzed for various load combinations.
Findings:	It turned out that the stress due to the dead load and live load is less than the cracking limit, and that the empirical deck design method provides an adequate amount of reinforcement in the deck. However, the restrained shrinkage analysis, based on the finite element model, and the analytical model developed to calculate shrinkage stress in composite sections, revealed that the tension stress can exceed the modulus of rupture for concrete. It was found that the restrained shrinkage stress in concrete decks can be affected by the geometry of a composite section, the girder stiffness, and girder spacing. The transversal shrinkage cracks first develop along the longitudinal edges of the deck and then propagate towards the middle sections. Isotropic concrete decks, supported on deeper steel girders (48 in or more), or on Type IV (depth of 54 in.) pre-stressed concrete girders, may require additional reinforcement to resist restrained shrinkage stress.
Implementation Plan/Deliverables:	The recommendations for changes in the design requirements for deck reinforcement are cited in report RC-1430.

PROJECT SUMMARY 2004	
Contract/Authorization # :	94-1699/27
Project # :	76937
Title:	Multiple Heat Straightening on Structural Steel
Project Manager:	Roger Till
Consultant:	Michigan State University
Total Project Cost:	$175,000.00
Total Amount Spent:	$175,000.00
FY 02 Expenditures:	$11,078.15
FY 03 Expenditures:	$78,936.00
FY 04 Expenditures:	$84,985.85
Purpose/Objective of Research:	Heat straightening is a cost-effective and efficient technique for repairing steel beam bridges damaged by over-height trucks or loads and is commonly used by the Michigan Department of Transportation for damaged steel bridge girders. In some cases, the same steel bridge is damaged by over-height loads several times over its years of service. Heat straightening can be used to economically repair the damaged steel bridge after each damage event. However, there is a lack of knowledge of the effects of multiple damage events followed by heat straightening repair on the fundamental structural properties including the fracture toughness and the microstructure of steel.
Report #:	RC-1456
Summary/Description of Research:	The results of a comprehensive review of literature relevant to this topic are presented. The results of a survey of all state DOTs in the U.S. in regards to their current heat straightening procedures and knowledge are presented. The results from the analysis of the 1976-2001 Michigan high-load hits database used to identify the steel types and structure types most frequently damaged and repaired in Michigan are presented. Three field visits to heat straightening sites, and the results of metallographic inspections and hardness testing of steel cores obtained from the repaired beams are presented.
Findings:	Experimental investigations were conducted to evaluate the effects of multiple damage-heat straightening repair cycles, i.e., multiple cycles of damage followed by heat straightening repair on the fundamental structural properties of typical bridge steels ASTM A36, A588, and A7. The damage and repair parameters considered in the study are the damage strain (ed), the restraining stress (sr), the number of multiple damage-repair cycles (Nr), and the maximum heating temperature (Tmax). The effects of these parameters are evaluated on the following structural properties: (a) elastic modulus, (b) yield stress, (c) ultimate stress, (d) percent elongation, (e) surface hardness, and (e) fracture toughness. Ninety-one laboratory-scale specimens made from A36, A588, or A7 steel were subjected to multiple damage-repair cycles, and their effects on the structural properties were

	evaluated. A total of six large-scale steel beam specimens made from A36, A588, and A7 steel were subjected to three damage-heat straightening repair cycles, and their effects were evaluated.
Implementation Plan/Deliverables:	The major findings from the comparisons of Tasks III and IV were as follows: The results for A7 steel from Tasks III and IV compare favorably. Based on the fracture toughness results of Tasks III and IV, it is recommended that A7 steel beams should not be subjected to more than three damage-heat straightening repair cycles. Smaller damage strains are more detrimental to A7 steel as compared to larger damage strains. The results for A36 steel from Tasks III and IV compare favorably. Based on the fracture toughness results of Tasks III and IV, it is recommended that A36 steel beams should not be subjected to more than three damage-heat straightening repair cycles. Overheating the A36 steel during damage-repair improves its material properties and fracture toughness significantly. The results from Tasks III and IV for A588 steel compare favorably. A588 steel is an extremely resilient material that can undergo several (up to five) damage-repair cycles without significant adverse effects on the structural properties including fracture toughness. It is recommended that A588 steel beams can be subjected to several (up to five) damage-heat straightening repair cycles. Lower restraining stresses should be used preferably. However, higher restraining stresses can also be used without impacting the material properties adversely.

Summaries – Materials Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization #	95-0242/12
Project #	76935
Title:	Durable Link Slabs for Jointless Bridge Decks Based on Strain-Hardening Cementitious Composites
Project Manager:	Roger Till
Consultant:	University of Michigan
Total Project Cost:	$145,000.00
Total Amount Spent:	$145,000.00
FY 02 Expenditures:	$89,266.14
FY 03 Expenditures:	$46,226.98
FY 04 Expenditures:	$9,506.88
Purpose/Objective of Research:	Development of durable link slabs for jointless bridge decks based on strain hardening cementitious composite - engineered cementitious composite (ECC). Specifically the superior ductility of ECC was utilized to accommodate bridge deck deformations imposed by girder deflection, concrete shrinkage, and temperature variations, providing a cost-effective solution to a number of deterioration problems associated with bridge deck joints.
Report #:	RC-1438
Summary/Description of Research:	Current design concept of link slabs was first examined to form the basis of design for ECC link slabs. Microstructurally optimized ECC material, with good workability and satisfactory mechanical properties was then developed. After the material design, the shrinkage, shrinkage crack resistance and the freeze-thaw behavior of the pre-selected mix proportion was investigated and revealed excellent for the durability concern. Improved design of ECC link slab/concrete deck slab interface was confirmed in numerical analysis and further strengthened by excellent reinforcement pullout and shear stud pushout behavior in ECC. Based on the above findings, monotonic and subsequent cyclic tests of full-scale ECC link slab specimens were performed and compared with those of a conventional concrete link slab.
Findings:	It was revealed that the inherent tight crack width control of ECC decouples the dependency of crack width on the amount of reinforcement. This decoupling allows the simultaneous achievement of structural need (lower flexural stiffness of the link slab approaching the behavior of a hinge) and durability need (crack width control) of the link slab
Implementation Plan/Deliverables:	Overall investigation supports the contention that durable jointless concrete bridge decks may be designed and constructed with ECC link slabs. Finally, a simple design guideline is presented.

Summaries – Traffic Projects
FY 2004

PROJECT SUMMARY 2004	
Contract/Authorization #	02-0513
Project #	76957
Title:	Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control Systems (DLMTCS) for Three Lanes Reduced to Two Lanes During Construction on I-94 in Macomb County
Project Manager:	Jeff Grossklaus
Consultant:	Wayne State University
Total Project Cost:	$82,148.00
Total Amount Spent:	$82,147.97
FY 02 Expenditures:	$5,777.51
FY 03 Expenditures:	$54,360.14
FY 04 Expenditures:	$22,010.32
Purpose/Objective of Research:	The majority of safety hazards and resulting traffic crashes that occur in lane closure areas in work zone are often due to the aggressive behavior of some drivers. The late lane merge phenomenon occurs when some drivers try to avoid slow moving traffic by traveling in the lane that is about to end, and then attempt to force a merge in the through lane at the last moment. In an attempt to alleviate such aggressive driver behavior at work zones an innovative traffic control system was developed in Michigan for two (2) to one (1)-lane transition areas in work zones, which was found to be effective. In the current study, The Michigan Department of Transportation (MDOT) and Wayne State University Transportation Research Group have jointly developed a advanced dynamic early lane merge traffic control system (DELMTCS) for three (3) to two (2)-lane transition areas in work zones, creating an enforceable no passing zone to encourage motorists to make an early merge.
Report #:	RC-1451
Summary/Description of Research:	The effectiveness of the DELMTCS in terms of reducing delay, aggressive driver behavior and increasing average travel speed was evaluated using the field data collected at the study area before and after implementing the DELMTCS
Findings:	Results of the evaluation study indicate that a smoother traffic flow is achieved by the installation of the DELMTCS. Also, the average delay per vehicle to pass through the work zone and the number of aggressive driving maneuvers decreased due to the installation of the DELMTCS in a work zone on the I-94 freeway in Michigan.
Implementation Plan/Deliverables:	The DLMTCS has been approved by EOC to be used as a work zone tool. The implemantation plan is to: a. Develop a letter of "work zone tools", explaining the Dynamic Lane Merge System; the criteria when it should be used; and encourage use of the system. The letter will be distributed to all MDOT parties involved in developing project traffic control plans. b. Refine the Special Provision for Dynamic Lane Merge System.

APPENDIX

POOLED-FUND PROJECTS						
Any federal, state, regional or local transportation agency may initiate a pooled-fund research study to address a common challenge. Participants contribute money, talent, or other resources to the study, resulting in a larger effort than any one agency could have undertaken and avoiding costly duplication.						
PROJECT ID	**LEAD AGENCY**	**PROJECT TITLE**	**MDOT PLEDGE**	**DURATION**	**RESEARCH CATEGORY**	**MDOT CONTACT**
SPR-2(212)		Non-Nuclear Testing of Soils & Granular Bases Using the GeoGauge	$45,000		Pavement Design	Tom Hynes
SPR-3(040)	NCAT	New Generation Open-Graded Friction Course Mix Design Procedure	$20,000		Pavement Design	Mike Frankhouse
SPR-3(044) TPF-5(021)	Indiana DOT	North Central Superpave Center (76981)	$50,000	2 years	Pavement Design	Gary Mayes
SPR-3(068)	Ohio DOT	Field Evaluation of CTCLS Series Traffic Signal Load Switches	$112,994		Construction	Frank Spica
SPR-3(081)		HERMES II (High-Speed Electromagnetic Roadway Mapping & Evaluation System	$100,000		Pavement Performance	
SPR-3(083)	Kansas DOT	FIXS: Fabrication Error Indexed eXamples & Solutions	$25,000		Bridges	Steve Cook
SPR-3(093)		Environmental Durability Evaluation of Externally Bonded Composites	$50,000		Bridges	Jon Reincke
SPR-3(097)	Illinois DOT	Machinability of High Performance Steel	$10,000		Bridges	Steve Cook
SPR-3(104)	AASHTO	Training System on Anti-Icing/Road Weather Information Systems	$30,000		Pavement Performance	Bard Lower
TPF-5(004)	FHWA	LTPP Specific Pavements Study (SPS) Traffic Data Collection (76982)	$100,000	2 years	Pavement Performance	Tom Hynes
TPF-5(013)	Pennsylvania DOT	Effect of Multiple Freeze-Thaw Cycles Versus Deep Frost Penetration	$90,000		Pavement Performance	Tom Hynes

TPF-5(045)	FHWA/Virginia Transportation Research Council	Performance Guidelines for the Selection of Hot-Pour Crack Sealants (78608)	$80,000	2 years	Materials	Mike Eacker
TPF-5(051)	Kansas DOT	Construction of Crack-Free Concrete Bridge Decks (76991)	$60,000	5 years	Bridges	John Staton
TPF-5(066)	FHWA	Material & Construction Optimization for Prevention of Premature Pavement Distress (76990)	$30,000	5 years	Construction	John Staton
TPF-5(068)	Iowa DOT	Long Term Maintenance of Load & Resistance Factor Design Specifications (76989)	$40,000	1 year	Bridges	Roger Till
TPF-5(003) TPF-5(075)	US Army Corps of Engineers	Extending the Season for Concrete Construction & Repair - Phase II (Continuation of TPF-5(003) (76983)	$60,000	2 years	Construction	John Staton
TPF-5(086)	ITS Institute, University of Minnesota	Reducing Crashes at Rural Intersections (79444)	$66,000	2 years		Dale Lighthizer

17 Pooled-Fund Projects Total Cost of $968,994

SUMMARY OF TECHNICAL INVESTIGATIONS (TI)

TI projects are two to three years in duration established to investigate requests from outside state agencies, regions, and transportation service centers. Technical investigations look into critical problems during design,construction, or maintenance. This can involve structures, noise, pavements, or materials.

PROJECT NUMBER	RESEARCH CATEGORY	PROJECT TITLE	PROJECT LEADER	REQUESTED BY
TI-1933	S	Ultrasonic Inspection of Anchor Bolts	L. Pearson	T. Mullin
TI-1934	S	Tower Lighting Inspection IM/82194/38100A	L. Pearson	C. Dargin
TI-1935	C-V	Vibration Monitoring - Martin Residence	C. Davis	R. Ostrowski
TI-1936	C-V	Vibration Monitoring - Carlson Residence	C. Davis	A. Rhodes
TI-1937	B	Bridge Painting Over Railroads	B. Beck	Bridge Committee
TI-1938	C-V	Vibration Monitoring on Wood Street near I-94 in St. Clair Shores Buier, Thibault, Hefferan Residences	C. Davis	R. Ostrowski
TI-1939	B	Establish QPL for Undercut Anchors	D. Needham	S. Beck
TI-1940	B	Guidelines for Retrofit of Non-Redundant Pin & Hanger Systems	D. Needham	Bridge Committee
TI-1941	B	Use of Precast Barriers on Bridges	D. Juntunen	Bridge Committee
TI-1942	C-N	Noise Analysis: I-69/Old US-27 DeWitt Township, Clinton County	R. Holcom	DeWitt Township
TI-1943	S	Inspection of ITS Infrastructure	D. Juntunen	T. Mullin
TI-1944	C-N	EA Noise Analysis M-61/M-18, Gladwin County	R. Holcom	T. Peek
TI-1945	C-V	Vibration Monitoring M-55 near Prudenville	C. Davis	R. Oswald
TI-1946	C-V	Vibration Monitoring US-31 over Commercial Avenue, R01 of 10032	C. Davis	D. Pax
TI-1947	C-N	Noise Analysis: M-59 from S02 over I-96 to Booth Street	R. Holcom	T. Peek
TI-1948	B	S05 of 82251 Fire Damage Assessment	D. Juntunen	C. Idusuyi
TI-1949	B	Prestressed Bridge Beam Repair on I-69 Railroad Bridge North of M-50	F. Spica	C.A. Hull Company
TI-1950	C	Upgrade of LISA Machines	F. Spica	C&T
TI-1951	S	Culvert Investigation C02 of 72052	L. Pearson	R. Kelley
TI-1952	B	Verification of Girder Distribution Factors for Steel Girder Bridges	R. Till	R. Till

TI-1953	C-V	Vibration Monitoring in New Haven	C. Davis	D. Buckner
TI-1954	C-V	Vibration Monitoring on Proposed US-131 near Cadillac	C. Davis	J. Oryszczak
TI-1955	B	Motor Room Deck Cracking Investigation B02 of 70014 - Grand Haven Bascule	D. Juntunen	A. Dionise
TI-1956	B	Deck Cracking on R01 of 73171	D. Juntunen	G. Bukoski/J. Friend
TI-1957	C-V	Vibration Monitoring Dauksas Residence in Hazek Park	C. Davis	E. Savas/R. Ostrowski
TI-1958	B	Bridge Mounted Sign Investigation	D. Juntunen	D. Gould
TI-1959	C-N	Assessing Noise Levels on Existing Asphalt and Concrete Surfaces in Michigan	R. Holcom	S. Bower
TI-1960	S	Fabrication of Reference Station Antenna Mounts	L. Lass	B. Jersey
TI-1961	C	Evaluation of Non-Nuclear Testing of Soils & Granular Bases Using the GeoGauge (Soil Stiffness Gauge)	J. Sweeney	FHWA
TI-1962	S	Historic Building near Bridge Construction Investigation	C. Davis	R. Jildeh
TI-1963	C	Monitoring of Temperature and Humidity for Design Surveys	F. Spica	B. Jersey
TI-1964	B	Evaluate Type 4 and Aesthetic Barriers	R. Till	S. Beck
TI-1965	P	Hot Mix Asphalt Splitters	L. Lass	M. Frankhouse
TI-1966	P	Hot Mix Asphalt Quartering Table - Jackson Lab	L. Lass	S. Hawker
TI-1967	P	Hot Mix Asphalt Quartering Table - Metro Lab	L. Lass	R. Ostrowski
TI-1968	C-N	I-496 Reconstruction, Before, During, and After Noise Study	R. Holcom	T. Kratofil
TI-1969	C-V	B01 of 78061 - Vibration Monitoring	C. Davis	M. Labar
TI-1970	C-V	I-94/Dequindre Yard Bridge Reconstruction - Kwik Paint Building - Vibration Monitoring	C. Davis	R. McKinney
TI-1971	C-V	B01 of 77091, M-25 over Black River Spillway Vibration Monitoring	C. Davis	C. Cook
TI-1972	B	Tilt Monitoring - Pier I International Bridge	L. Pearson	P. Becker
TI-1973	C	Development of a Laser Macrotexture Measurement Device	T. Hynes	T. Hynes

TI-1974	B	Repair of Prestressed Concrete Beam I-75 over 12 Mile Road, S04 of 63174 - Madison Heights	F. Spica	E.C. Korneffel Co.
TI-1975	C-V	Vibration Investigation, Trowbridge Rd. to NB US-127	C. Davis	J. Gutting
TI-1976	S	Bridge Mount Sign Failure Investigation	A. Gilani	T. Pozola
TI-1977	C-V	Vibration Investigation, I-94 near Mr. Jayyousi Residence	C. Davis	R. Ostrowski
TI-1978	C-V	Vibration Investigation, Southfield Freeway (M-39) near Mr. Warner's	C. Davis	M. Gorman
TI-1979	C-V	Vibration Investigation, Northwestern Highway	C. Davis	D. Cooper
TI-1980	B	MMFX Reinforcement Steel	S. Kahl	S. Beck
TI-1981	P	Evaluation of Odin Anti-Icing System	F. Spica	Grand Region
TI-1982	P	Approach Slab Treatment for Integral Abutment Bridges	D. Juntunen	S. Beck
TI-1984	B	Hanger Assembly Calculations	S. Kahl	P. Grotenhius
TI-1985	C-V	I-696 Vibration Monitoring - Hughes Residence	C. Davis	R. Ostrowski
TI-1986	C	Update Design Provisions for Adhesive Anchors in Concrete	D. Juntunen	R. Till
TI-1987	C	Evaluate Accelerated Recoat Times for Coating Systems for Structural Steel	B. Beck	G. Bukoski
TI-1988	C-V	Vibration Investigation, I-75 near Mr. John Peck's Residence	C. Davis	R. Ostrowski
TI-1989	B	Evaluate Categories of Deck Deterioration	S. Kahl	P. Grotenhius
TI-1990	B	Ultrasonic Testing of Pins on P08 of 82194	L. Pearson	M. Tarazi
TI-1991	C	Vibration Monitoring at I-94 and Inkster Road DWSD Watermain	C. Davis	W. Erben
TI-1992	C	Upgrade of RTP 02-3245	F. Spica	J. Reincke
TI-1993	P	US-24 HMA Demonstration Project	J. Sweeney	MAPA Request
TI-1994	B	Develop Laser Bridge Under Clearance Measurer	F. Spica	Bridge Operations Unit
TI-1995	B	Emergency Bridge Repair I-196 - R08 of CS 41029 in Grand Rapids	F. Spica	Region
TI-1996	B	Tilt Monitoring - Structure Number R01 of 82075	L. Pearson	A. Dionise
TI-1997	B	Steel Pier Cap - S05 of 63103	R. Till	G. Bukoski

TI-1998	B	Pier Cap Analysis - S21 and S23 of 82252	R. Till	P. Grotenhius
TI-1999	C-V	Vibration Investigation, Mr. Ouozza Residence, Detroit, MI	C. Davis	R. Ostrowski
TI-2000	C-V	Vibration Monitoring of Allen Residence, Taylor, Michigan	C. Davis	M. Sanders
TI-2001	C-V	Vibration Monitoring During Removal of B01 of 76012	P. Jansson	R. Jildeh
TI-2002	B	Cracked Pier Column on R02 of 25042	R. Till	D. Juntunen
TI-2003	B	Ultrasonic Testing of Welds on S01 of 33172 US-127 SB under Lake Lansing Rd.	L. Pearson	C. Idusuyi
TI-2004	B	Monitoring and Survey of Ontonagon Swing Bridge B12 of 66013	L. Pearson	D. Juntunen
TI-2005	C-V	Vibration Monitoring During Compaction of SuperPave Mix on US-24	C. Davis	B. Erben
TI-2006	S	Ground Mount Sign Support Selection Chart	P. Jansson	M. Bott
TI-2007	B	Monitor Pier Tilt on S04 of 63043, M-59 under Adams Road	L. Pearson	J. Garcia
TI-2008	C	Salt Dispensing Circuit	G. Palmer	
TI-2009	B	Investigate Fatigue Cracks on B02 of 82122, I-96 over Rouge River	L. Pearson	D. Juntunen
TI-2010	B	Investigate Fire Damage on R02 of 25084, I-69 over Railroad	L. Pearson	D. Juntunen
TI-2011	B	Investigate Prestressed Box Beam Deterioration, B01 32021, M-142 over Pigeon River	S. Kahl	D. Juntunen
TI-2012	B	Investigate High Load Hit Beam Damage of R01 of 58033, Ann Arbor Railroad Bridge Over US-23	L. Pearson	C. Idusuyi
TI-2013	C-V	Vibration Monitoring B01 of 45012, M-22 over Crystal River	L. Pearson	D. Pax
TI-2014	C-V	Vibration Monitoring at Niesen Residence on US-31	C. Davis	R. Liptak
TI-2015	C-V	Vibration Monitoring During Strain Pole Removal	C. Davis	D. Pax
TI-2016	B	B01 of 11111, I-196/US-31 Over the Paw Paw River, Pier Analysis	P. Jansson	D. Juntunen
TI-2017	B	Detailed Inspection of P02 of 63101	L. Pearson	S. Galindo

TI-2018	B	Fatigue Crack Inspection of B01 of 73101, I-675 Over Saginaw River & M-13	C. Davis	L. Taylor
TI-2019	C-V	Vibration Monitoring Pavement Removal Along US-12 in Dearborn	C. Davis	M. Frankhouse
TI-2020	C-V	Vibration Monitoring Linch Residence Near WB I-696 in Detroit	C. Davis	S. Datta
TI-2021	B	Bridge Life Cycle Cost Analysis	S. Kahl	D. Juntunen
TI-2022	B	Deck Resurfacing of S05 of 23081, I-496 Under Creyts Road	S. Kahl	G. Feuerstein
TI-2023	C-V	Vibration Monitoring Batts Residence Near WB I-96 in Detroit	L. Pearson	M. Grazioli
TI-2024	C-V	Monitor Vibrations at Carpenter Residence (6421 Northpointe Court) Near M-6/US-131 Interchange in Wyoming	C. Davis	E. Kind
TI-2025	B	Prestressed Concrete Beam Repair R01 of 58034, US-23 Monroe County	F. Spica	
TI-2026	B	Fire Damage on S26 & S30 of 82251 I-75/I-94 Interchange	L. Pearson	J. Garcia
TI-2027	B	Shear Cracks in Box Beam Bridges, S07 and S08 of 23152, I-96 Over Canal Road	S. Kahl	J. DeVinney
TI-2028	S	Review Concrete Bebo Arch	P. Jansson	R. Till
TI-2029	B	Investigate Damage to Pot Bearings at Expansion Joints in Zilwaukee Bridge	R. Till	R. Smith
TI-2030	C-V	Vibration Monitoring near Church on Ottawa Street in Lansing - Capitol Loop	C. Davis	J. Gutting
TI-2031	S	Timer for Permeometer	G. Palmer	B. Redmond
TI-2032	B	Tilt Monitoring on B01-1 and -2 of 11111, I-196 Over Paw Paw	C. Davis	J. Covey
TI-2033	S	Inspection of Cantilever Sign Support Hit by Vehicle	L. Pearson	P. Sekela
TI-2034	C-V	Vibration Monitoring of Mackinaw Bridge During Running Race	L. Pearson	K. Nowack
TI-2035	B	Build 8 Systems to Measure Bridge Underclearance for Regions	G. Palmer	T. Frake & B. Jersey
TI-2036	B	Monitor Bridge Bearings, NB Creyts Road Over I-496, S05 of 23081	P. Jansson	C. Idusuyi & J. Devinney
TI-2037	B	Investigation of Cracked Link Plate, US-127 SB over College Road, S07 of 33035	S. Kahl	D. Juntunen
TI-2038	P	Wear Track Repair and Recalibration	T. Miller	B. Muethel

TI-2039	B	Investigation of Pier Cap Cracking, 68th Avenue Over I-96, S04 of 70063	S. Kahl	E. Burns
TI-2040	B	Beam Rotation During Deck Pour on Bridge S41 of 82123, I-96 Ramp Over I96	R. Till	M. Chynoweth
TI-2041	B	Tilt Monitoring, Column 1-S East Pier, EB I-94 Over 12th Avenue, S04 of 39024	S. Kahl	C. Idusuyi
TI-2042	P	Multi-State Coarse Aggregate Freeze-Thaw Comparison	T. Woodhouse	J. Staton
TI-2043	B	Monitoring Precast Deck Panels and Pier Caps, S01 of 39041	S. Kahl	Z. Liu
TI-2044	B	Investigation of Pier Cap Cracking, US-12 EB	S. Kahl	T. Johnson
TI-2045	B	Investigation of Box Beam Cracking, US-12 Over Conrail	S. Kahl	T. Johnson

PROJECT TYPE	DESCRIPTION	TOTAL NUMBER
S	Structures	8
B	Bridges	35
P	Pavements	6
C-N	Construction - Noise	8
C-V	Construction - Vibrations	27
C	Construction	6

FISCAL YEAR	TOTAL NUMBER OF PROJECTS
2000	30
2001	23
2002	21
2003	26
2004	14

Notes: