FINAL REPORT

LCMR WORK PROGRAM December 31, 1993



I. **Waste Crumb Rubber in Roadways**

Program Manager: Roger Olson
Research Operations
Minnesota Department of Transportation
Materials and Research Laboratory
1400 Gervais Avenue
Maplewood, Minnesota 55109
612-779-5517

A. M.L. 91 Ch. 254 Sec. 14 Subd: 13(b) Appropriation $100,000 Match $100,000
Balance ~~$ 21,189~~ 0 Balance ~~$ 21,190~~ 0

This appropriation is to the commissioner of administration for transfer to the commissioner of transportation to improve hot-mix asphalt pavement performance through the use of crumb rubber and selected polymer additives. The process will use waste tires generated in Minnesota. This appropriation must be matched by $100,000 from other sources.

B. Compatible Data Not applicable

C. Match Requirement $100,000
Funds raised to date $100,000*

* Funding sources:
$30,000 MPCA Waste Tire Unit
$50,648 Mn/DOT LRRB
$19,352 Mn/DOT Personnel

II. Narrative

Today's growing tire disposal problem has motivated many public and private agencies to engage in research to find useful and cost effective long-term uses for waste tires. Minnesota agencies were further motivated when landfilling waste tires became illegal in 1985.

Many creative applications have been derived for waste tires. The use of granulated crumb rubber particles in asphaltic concrete has been one of these. There are many variations of this process that have been tried by Mn/DOT as well as other agencies in the United States and other nations. Thus far, there has not been a particular process that has been able to command a large market, based on a cost-effective high performance product.

During the past several years many types of polymers have been introduced into the asphalt mixture market. These products have been used with varying degrees of success and are continuing to gain in popularity. The concept of combining the properties of crumb rubber and polymers to optimize asphalt concrete behavior has not been widely pursued. This study could provide an improved asphaltic concrete mixture while converting waste tires to a useable product.

III. Objectives

A. **Assess Laboratory properties of asphalt concrete mixtures modified with polymerized crumb rubber.**

A.1. Narrative: In order to develop an optimum design using a polymerized rubber asphalt concrete many variables need to be assessed. A wide variety of polymers, crumb rubber products and mix design components need to be evaluated. This objective will assess existing information, and proceed through establishing an experimental design and characterizing the materials properties.

A.2. Procedures

Task 1 - Literature Search and Review

The project would begin by identifying all pertinent books, reports, journals, and articles on the subject of modifying asphalt concrete behavior through the use of polymer additives. This would be done by conducting a computerized literature search of databases such as Compendex, the Transportation Research Information Service (TRIS), and the National Technical Information Service (NTIS). An annotated bibliography of certain articles from the last ten years would be obtained to select those having the most relevance for further study. It is expected that the majority of the information will be contained in publications by the Association of Asphalt Paving Technologists, the Transportation Research Board, and the American Society for Testing and Materials (ASTM). ASTM will be sponsoring a symposium on this topic at its December 1990 meeting in San Antonio, Texas.

The literature will be reviewed and summarized in a portion of the interim report to be submitted at the end of Phase I. This review will be confined to the use of polymer and tire rubber modifiers in hot-mix asphalt, and will not include such issues as chip-seal binders, interlayers, and crack or joint sealers. Any new or unique information obtained from the literature search will be considered for adjusting the experimental design parameters.

Task 2 - Experiment Design

A full or partial factorial experiment design will be developed to investigate the effects of mixture variables. These variables and their associated levels are as follows:

| Variable | Levels |
|---|---|
| Rubber Gradation | Fine |
| | Medium |
| | Coarse |
| Rubber Content | High |
| | Low |
| Asphalt Grade | 85-100 pen |
| | 120-150 pen |
| Polymer Type | None |
| | Polymer No. 1 |
| | Polymer No. 2 |

More precise definitions of the levels to be used in the laboratory experiment will be developed at the initiation of the project. Along with the modified mixtures, control materials using the two asphalt grades with no additives will be tested as reference points.

Task 3 - Materials Characterization

A program of laboratory testing will be undertaken to determine the properties of the various mixtures. This portion of the research will consist of the following activities:

Mixture Design by the Marshall Method

Sample Preparation

Bulk Specific Gravity

Resilient Modulus at 4 Temperatures

Creep Testing at 3 Temperatures

Indirect Tensile Strength at 2 Temperatures

Maximum Theoretical Specific Gravity

The methods used for mixture design, sample preparation, and testing will be carefully documented. The resulting data will be compiled for analysis in Task 4.

Task 4 - Data Analysis

The data collected in Task A.3 will be evaluated using appropriate statistical techniques to obtain mean levels and variances for the following properties:

Resilient Modulus

Creep Compliance

Bulk Specific Gravity

Air Void Content

Indirect Tensile Strength

The examination of the data should lead to conclusions regarding the potential for rutting under traffic loads, the susceptibility of the materials to thermal cracking, and the elasticity of the mixtures. The modified mixtures will be compared to the control mixtures (without modifiers) and those containing crumb rubber with no polymers.

Task 5 - Interim Report

A report will be prepared containing the results of the literature review, details of the experiment design, the methods of materials characterization, and the results of the data analysis. Recommendations will be made with respect to the conduct of the field investigation in Phase II.

A.3. Budget

| | Total Funds | LCMR Funds | Matching Funds |
|---|---|---|---|
| a. Amount Budgeted | $80,000 | $40,000 | $40,000 |
| b. Balance | 0 | $ 0 | $ 0 |

A.4. Timeline for Products/Tasks

| | Jan 92 | June 92 | Jan 93 | Jun 93 |
|---|---|---|---|---|
| TASK | | | | |
| 1 | XXXXXXXX | | | |
| 2 | XXXXX | | | |
| 3 | | XXXXXXXXXXXXXXXX | | |
| 4 | | XXXXXXXXX | | |
| 5 | | XXXXXX | | |

A.5. Status:

The literature review (Task 1), experimental design (Task 2), Materials Characterization (Task 3) and Data Analysis (Task 4) have been completed. This information is presented in the final report, which will be presented as the detailed version status report. This information analyzes the temperature susceptibility and low temperature behavior for both 85/100 and 120150 asphalt cements, all three levels of crumb rubber concentration (none, 3, and 5 percent) and two levels of polymer type (untreated and tall oil treated).

Since tall oil pretreated crumb rubber appeared to increase the moisture sensitivity of the mixture used in the Hennepin County field trials, moisture sensitivity laboratory tests were added prior to construction of the Babbitt project.

Also, a second crumb rubber pretreatment, Hydrolene 90, was selected to help the crumb rubber particles partially modify the asphalt cement rather than act as a inert elastic inclusion. This modifier was used for the Babbitt test sections so that the field performance can be compared to the laboratory test results.

A.6. Benefits: Collecting information from the literature and conducting a laboratory testing program will provide valuable information to help establish a mix design that would provide optimum benefits from the addition of polymerized rubber. This base information will determine the design used for actual field construction.

B. **Assess constructibility and field performance of asphalt concrete mixture modified with polymerized crumb rubber.**

B.1. Narrative: Based on the findings of the laboratory phase of this study, one or more designs will be used in constructing field test sections. The field test sections will help to determine constructibility and performance of this product as well as determine costs.

B.2. Procedures

Task 6 - Site Selection

In cooperation with the Minnesota Department of Transportation, the principal investigators will select a construction project for incorporating polymerized crumb rubber into the asphalt concrete. The project length should not be less than one mile, and the thickness of the asphalt concrete should be on the order of three inches or more for testing purposes. It is anticipated that the project will be an overlay of an existing pavement. A location near the Twin Cities would be preferable from the standpoint of monitoring the performance of the test section.

Task 7 - Experiment Design

A minimum of three test sections should be incorporated into the field investigation. These will consist of one control section (without additives) and the other two being combinations investigated in Phase I which show promise. The minimum length of any section should be 1000 ft.

Task 8 - Materials Characterization

The materials proposed for use in the pavement will be first evaluated in the laboratory. This will include the Marshall mix design procedure for determining the optimum binder content, and the materials characterization done in Phase I. If the same materials are used in both Phases I and II, this task will not be necessary. However, this is an unlikely situation, and a complete analysis of the materials to be used in the roadway will be required due to possible interactions of aggregate and asphalt from another source.

Task 9 - Construction

Careful documentation of the pavement condition prior to overlay will be done to understand the subsequent performance of the overlay. For instance, if there is significantly more cracking in one section than in another, then there is a greater probability that the cracks will reflect through the overlay in that portion of the pavement.

Construction procedures for incorporating the polymerized crumb rubber into the asphalt concrete will be recorded to include modifications to the plant and any problems which might arise during placement and compaction.

Material samples will be taken from behind the paver prior to compaction and transported to the laboratory. Specimens will be compacted in the laboratory and tested for the properties noted in Phase I, Task I.3. This will serve to characterize the materials as they would appear during quality control testing.

Task 10 - Post-Construction Testing

Within one week after construction, the in-place materials will be sampled and tested in the laboratory. The in-situ material properties will provide information related to the performance of the pavement sections. It may not be possible to perform creep testing on these samples due to the constraint on sample height. To the extent possible, pavement performance monitoring will be done by periodic surveys, although the study will probably not last long enough for any conclusive long term results .

Task 11 - Data Analysis

All the data collected on the materials from the pre-construction evaluation, construction testing, and post-construction evaluation will be compiled and analyzed to determine what conclusions can be drawn about polymerized crumb rubber asphalt concrete.

Task 12 - Final Report

A final report will be prepared which contains all the information from Phases I and II of the project. Conclusions will be made regarding the potential for the use of polymerized crumb rubber in road construction, and recommendations for future investigations will be submitted. The report will be reviewed by interested parties in the Minnesota Department of Transportation, and their comments will be included in the final product.

B.3. Budget

| | LCMR Funds | Matching Funds | Total |
|---|---|---|---|
| a. Amount Budgeted | 60,000 | 60,000 | $120,000 |
| b. Balance | 0 | 0 | $ 0 |

B.4. Timeline for Products/Tasks

| Task | Jan 92 | June 92 | Jan 93 | Jun 93 | Jan 94 |
|---|---|---|---|---|---|
| 6 | XXXXXXXXXX | | | | |
| 7 | XXXXXXX | | | | |
| 8 | XXXXXX | | | | |
| 9 | XXXXXXXXXXXXXXXXXX | | | | |
| 10 | XXXXXXXXXXXXX | | | | |
| 11 | XXXXXXXXXXXXXXXXXX | | | | |

B.5. Status:

The scope of this section (Phase II) includes the evaluation of two separate field projects (Site Selection, Task 6): 1) Hennepin County project on County Road 13 in Dayton, Minnesota, and 2) St. Louis County project in Babbit, Minnesota. The Hennepin County project was constructed September 25, 1992 and consisted of four sections (Experimental Design, Task 7): 1) unmodified conventional 2341, 2) dense graded with 6% pretreated rubber substituted for the sand fraction of the mix, 3) an unmodified gap-graded mix, and 4) a gap-graded mix with 3 percent (by weight of mix) pretreated rubber. An interim report covering all laboratory and field testing was submitted to Mn/DOT May 10, 1993 (Task 12). A summary of the findings are: 1) the percent of crumb rubber needs to be kept to low, 2) moisture sensitivity testing has been added to the testing program, and 3) other crumb rubber pretreatments need to be investigated.



The Babbitt project involved placing 3,520 tons of crumb rubber modified hot mix pavement as part of the reconstruction of St. Louis CSAH 112 in the City of Babbitt. All of the test sections which contain crumb rubber, contained one percent (1%) CR-10 crumb rubber by weight of mix. Test sections were built using both treated and untreated crumb rubber as well as conventional mix.

Based on literature available to the U of M, an aromatic extender oil (Hydroline 90) from Sun Oil Company was chosen as the treatment in lieu of the tall oil pitch which was used on the Hennepin County project. Hydroline 90 has the consistency of a heavy lube oil. This material was blended, at a rate of 10% by weight of rubber, with the rubber at the plant. The rubber completely absorbs the oil and there is no oily feel to the treated rubber.

There were 35.2 tons of CR-10 rubber manufactured for this project (17.6 tons of both the treated and untreated). The rubber was placed in 50 pound bags for ease of transport and adding to the asphalt plant. This was enough rubber to place approximately 3,520 tons of crumb rubber modified hot mix.

**Costs**

The cost of the rubber was 13.5 cents per point ($270 per ton) for the untreated rubber and 16.5 cents per pound ($330 per ton) for the treated rubber. At the one percent rate, 20 pounds of rubber are added to every ton of hot mix. This results in an additional cost of $2.70 and $3.30 per ton of hot mix when using untreated and treated rubber respectively. This is the added cost for the rubber only, there are also additional costs involved in producing the rubber mixtures.

The added bid price for the rubber mixtures was $5.00 per ton. The additional cost relates to the hopper and conveyor, additional person and equipment time to add the rubber into the plant. In addition, due to the coarseness of the rubber mixture, the contractor needed to bring in more course aggregate to finish the project. This is due to the fact that the final mix designs were not done until the job was awarded and the stockpiles produced. the Contractor required approximately $5,0060 for additional material. This cost is related directly to the rubber and would have been necessary if the rubber mix gradation had been known up front.

When all three costs are added, the resulting costs were $20.01 per ton for conventional mix and $31.48 per ton for the rubber mixes. This is a 57% increase in cost over conventional mix.

This LCMR project was scheduled for completion on June 30, 1993. Because of the scheduling of the construction project utilizing the polymerized crumb rubber product, it was necessary to extend the completion date to December 31, 1993. The test sections selected are part of a street reconstruction in the City of Babbitt. The test sections were included in the asphalt paving portion of this project that follows initial grading, utility and reconstruction activities. Initially the project was delayed in letting and has fallen behind schedule because of bad weather. The construction of the test sections was completed by early September. The post-construction testing and analysis were completed by December 31, 1993.

**Note:** The oil overchange contract for this study runs through September 30, 1993.

B.6. Benefits: The field investigation of one or more sites containing polymerized crumb rubber will provide valuable information in determining pavement performance characteristics. The use of polymerized crumb rubber can be compared to conventional pavements and other pavements constructed with crumb rubber only. This information may lead to specifications using crumb rubber in asphalt concrete.

IV. Evaluation

The initial stage of this study will concentrate on conducting a laboratory investigation. This phase of the study will consist of conducting a literature search, developing an experimental design for characterizing materials, conducting a series of laboratory tests and evaluating the data. This phase of the study will be conducted by the Department of Civil and Mineral Engineering at the University of Minnesota with assistance by the Department of Transportation. The laboratory study will help determine how various combinations of the mixture ingredients, including the polymerized crumb rubber, will affect the mixture properties. This phase of the study including the interim report will be completed during FY 1992.

The second task under this study will involve construction of one or more field installations. Based on the laboratory phase of the study, one or more combinations of polymerized crumb rubber will be used for the field evaluation. The project will be at least one mile long and the pavement thickness will be two or more inches to allow for adequate quantities in the evaluation process. In addition to collecting data on the mixture properties: any equipment, placement or compaction problems will be noted. Samples will be taken during construction and tested for properties as defined in the laboratory study.

Post construction evaluation will include extensive condition surveys, non-destructive testing and additional materials samples. The final report will summarize laboratory and field tests and assess the costs involved with using crumb rubber. The evaluation will also include information on the processing and treatment of this waste tire product. The final report will discuss the properties of polymerized crumb rubber modified asphalt concrete as well as demonstrate a viable method of waste tire disposal. An implementation plan will be devised, based on economics, performance and constructibilty of the product.

V. Context

A. There has been a considerable amount of research conducted world-wide on the use of reclaimed tire rubber in asphalt mixes. In addition there has also been a major emphasis on polymer additives in asphalt concrete. There does not appear to be any one process that has given any notable enhanced performance to an asphalt pavement. Some polymers have shown promise but have not gained widespread acceptance. The use of polymers as a medium in the introduction of crumb rubber in asphalt may provide the properties that researchers have been looking for.

B. During the past ten years the Minnesota Department of Transportation has constructed several test sections using crumb rubber in asphalt pavements. Although some sections have performed adequately no one system has give enhanced performance. The issue of recycling waste tires has helped keep this concept alive and has been encouraged by many State and Federal Agencies. Although many other States are evaluating crumb rubber in asphalt, no one is known to be trying a polymerized system. Because of the Nation-Wide interest in the use of crumb rubber in asphalt, many agencies will be watching with interest.

C. The use of reclaimed rubber in asphaltic concrete has been undertaken by the Department of Transportation in a wide number of experimental sections. Several reports have been prepared describing these projects. The projects have been funded by Mn/DOT from the operations budget or by Federal Highway Administration Project funds. No LCMR funds have been used for any of these previous projects. No future LCMR funds should be required for this study unless information from this study would warrant further evaluation.

D. Not applicable

E. Biennial Budget System Program Title and budget: Not available at this time.

VI. Qualifications

1. Program Manager:

Roger Olson
Research Operations Engineer
Office of Materials and Research
Minnesota Department of Transportation

B.S. Civil Engineering, North Dakota State University, 1967
Registered Professional Engineer, State of Minnesota, No. 10173

Mr. Olson has held his position of Research Operations Engineer since 1978. He has supervised all of the research projects involving the use of crumb rubber as well as those involving polymer modified asphalts. Mr. Olson is a member of three Transportation Research Board committees including A2D02 "Non Bituminous Components of Asphalt Paving Materials", which deals with crumb rubber additives on a national level. Mr. Olson's primary role will be as program coordinator.

2. Major Cooperators

A. Dr. Andrew Drescher

Dr. A. Drescher received his Ph.D. degree in applied geomechanics in 1968 from the Polish Academy of Sciences, Warsaw, Poland. In 1982, he joined the faculty of the Civil and Mineral Engineering Department, University of Minnesota. His main fields of expertise are experimental methods and analysis in application to solid mechanics. He has designed and performed several test methods for determining viscous and plastic properties of soils, rocks, and high-polymers.

B. Dr. David Newcomb

Dr. David Newcomb joined the Civil and Mineral Engineering Department at the University of Minnesota in December 1988. Prior to this, he was an assistant professor at the University of Nevada, Reno where he taught courses in construction materials and pavement design. He received his Ph.D. from the University of Washington in 1986. His research interests include pavement design, evaluation and performance modelling as well as materials characterization. In 1989, he was the recipient of the Transportation Research Board's Fred Burggraf Award for excellence in transportation research.

VII. Reporting Requirements

Semiannual status reports will be submitted not later than January 1, 1992, July 1, January 1, 1993 and a final status report by ~~June 30, 1993~~ December 31, 1993.

1993 Research Project Abstract
For the period ending December 30, 1993

| | |
|---|---|
| Title: | Waste Crumb Rubber in Roadways |
| Program Manager: | Roger Olson |
| Organization: | Minnesota Department of Transportation |
| Legal Citation: | M.L.91 Ch254 Sec.14 Subd: 13(b) |
| Approp. Amount: | $100,000 |

## STATEMENT OF OBJECTIVES

The goal of this research program was to explore the use of pretreated ground waste tire rubber in hot mix asphalt concrete paving mixtures. The primary objectives included: 1) defining key asphalt cement and crumb rubber interactions, 2) evaluating the engineering properties of modified mixtures, and 3) trial field implementation based on the laboratory findings.

## RESULTS

The key to desirable asphalt-rubber interactions can be expressed in terms of the compatibility between the components; this can be represented by the molecular weight of the asphalt cement. Lower molecular weight, less than 700 g/mole, asphalts appear to accentuate the ability of the crumb rubber to act as a partial polymer modifier of the asphalt concrete. Any pretreatment product with similar properties could result in increased ability of crumb rubber to partially polymerize the asphalt cement without the traditional long blending and reaction times, as well as expensive plant modifications. Conversely, if the crumb rubber is to act as an aggregate, then little or no interaction between the rubber and the asphalt cement is desired. Therefore, any pretreatement should reduce the compatibility between the crumb rubber and asphalt cement. Based on this finding, two crumb rubber pretreatments were selected for both laboratory and field evaluations.

Laboratory results indicated that the first pretreatment, tall oil pitch, reduced the interaction between the asphalt and crumb rubber so that the crumb rubber could be considered a separate phase in the mixture rather than an asphalt cement modifier. Properties of the mixtures indicated that the temperature susceptibility of the modified mixtures were similar to unmodified materials. However, crumb rubber modification reduced the stiffness through a temperature range by about 30 percent. This reduction in strength increased with increasing crumb rubber content. There was some indication that the ability of the mixture to resist thermal cracking was enhanced with the use of tall oil pretreated crumb rubber. A field trial in Hennepin County with this type of material indicated that the elastic nature of the crumb rubber particles made the mixtures difficult to compact unless the aggregate gradation was gap graded. Tall oil pretreated crumb rubber appeared to increase the moisture sensitivity of the mixture which led to premature failure of the test sections. These results led to the inclusion of a moisture sensitivity laboratory test prior to the construction of the second field project.

The second crumb rubber pretreatment, Hydrolene 90, was selected to help the crumb rubber particles partially modify the asphalt cement rather than just act as an inert elastic inclusion. This pretreatment was a petroleum based product commonly used in the manufacture of the tire rubber; it has a molecular weight of less than 400 g/mole. Initial laboratory results indicated that this pretreated crumb rubber would produce a modified mixture with acceptable temperature and moisture sensitivity properties similar to that of the unmodified control mixture while showing a potential for improving the mixtures' resistance for thermal cracking at cold temperatures and rutting at warm temperatures. The field test sections placed in Babbitt, Minnesota in the fall of 1993 showed that crumb rubber modified mixtures could be placed with little impact on either the plant or construction processes. Crumb rubber modified mixtures, either pretreated or treated showed the same initial mixture properties. Differences between the treated and untreated crumb rubber are expected to become increasingly obvious as the pavement is subjected to both environmental and traffic distresses.

## PROJECT RESULTS USE AND DISSEMINATION

The results and recommendations resulting from this study may be used to continue to explore the use of pretreated crumb rubber in hot mix asphalt concrete. The ability to add crumb rubber without first blending and reacting it with the asphalt cement can save contractors expensive plant modifications as well as increase the plant production rate. Use of this process would also provide a market for Minnesota-produced crumb rubber since the crumb rubber can be used without modifications or purchase of an out-of-state crumb rubber product.

Dr. David Newcomb has presented a summary of the findings at the State District Materials Engineers meeting in May 1992. Ms. Mary Stroup-Gardiner of the University of Minnesota has presented portions of the findings at the annual Transportation Research Board (a division of the National Research Council) meeting (January, 1992). This work will be published in the near future. She has also presented portions of the research at the annual Center for Transportation Studies meeting in May, 1993.

Disk: U of M II
File: rubber\LCMR-abs.ltr