



# ARTIC

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BIBLIOGRAPHY OF ARTICLES, REPORTS AND STUDIES

## FEDERAL REPORTS

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### **FEDERAL REPORTS: COST**

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FC.1 = RPA\_A1000.pdf

[Federal Highway Administration Programs](#)

Bernard, D.A.

FHWA, Demonstration Division, Region 15

1980

\*Also under Federal Performance

4 Pages

Key Words: chip seals, interlayers, bridge deck seals, embankment stabilization, asphalt-rubber, demonstration projects, cost, performance, reflection cracking

FHWA Demonstration Project No. 37 "Discarded Tires in Highway Construction" was initiated in 1976. Presentations have been made in 35 states and contracts have been negotiated to construct 43 demonstration installations. This includes 16 chip seals, 23 interlayers, 3 bridge deck seals, and 1 embankment stabilization. Total monies expended on these contacts exceed \$1,100,000.

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## **FEDERAL REPORTS: EMISSIONS**

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FE.1 = RPA\_A1025.pdf

**[A Study of the Use of Recycled Paving Material: Report to Congress](#)**

FHWA/USEPA

June, 1993

\*Also under Federal Performance & Federal Recyclability

47 Pages

Key Words: scrap tires, crumb rubber modifier, recycling, hot mix asphalt environmental assessment, comparative health risk, waste materials, reclaimed asphalt pavement, glass

The highway construction industry has a long history of using recycled products for highway construction. This report summarizes some of the industries' experiences and, where sufficient information exists, it provides documentation regarding the economic savings, technical performance, threats to human health and the environment, and environmental benefits of using recycled materials in highway devices and appurtenances and highway projects.

FE.2 = RPA\_A1002.pdf

**[Biological Monitoring Assessment of Road Paving Workers Exposed to Asphalt and Crumb Rubber Modified Asphalt](#)**

Levine, A.J., Ph.D.; Ralaska, G., Ph.D.; Bulter, M.A., Ph.D.; Miller, A., M.D.; Hanley, K., M.S., C.I.H.; Wallingford, K., M.S., C.I.H.; Lewtas, J., Ph.D. & Schurte, P., Ph.D.

NIOSH & USEPA

June 23, 1994

47 pages

The first objective of the present proposal is to determine if biological monitoring can add significantly to environmental sampling for CRM-asphalt-specific exposures. The specific aims associated with this objective are:

1. Determine if MIBK is present in any of the personal air-samples, as implied in the EPA summary of four comparative studies.
2. Determine if MIBK, or other constituent exposure measured in the CRM-asphalt but not in the post-shift urine of workers using regular-asphalt or who have no asphalt exposure.
3. Determine if there is an epidemiologic association between the presence of MIBK, or other constituent exposure measured in the personal air samples, and either the personal air-samples or the post-shift urine samples and the presence of self-reported symptoms.

The second of this study is to determine if US road paving workers have biologically relevant exposures to potentially carcinogenic PAH compounds.

FE.3 = RPA\_A1003.pdf

**[NIOSH Health Hazard Evaluation Report](#)**

Almaguer, Daniel, MS, RS; Miller, Aubrey K., MD, MPH & Hanley, Kevin W., MSPH, CIH, RS  
HETA 95-0118-2565, Martin Paving Company, Yeehaw Junction, Florida

US Dept. of Health & Human Services, Public Health Service, CDC & National Institute for Occupational Safety & Health

March, 1996

53 pages

Key Words: SIC 1611 (Highway & Street Construction), asphalt fume, bitumen, crumb rubber modifier, CRM, recycled tires, paving, interstate highways, polycyclic aromatic compounds, PACs, polynuclear aromatic hydrocarbons, PAH, total particulate, respirable particulate, benzene soluble particulate, volatile organic compounds, hydrocarbons, elemental carbon, eye irritation, respiratory irritation.

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

FE.4 = RPA\_A1004.pdf

**[NIOSH Health Hazard Evaluation Report](#)**

Hanley, Kevin W., MSPH, CIH & Miller, Aubrey K., MD, MPH

HETA 94-0408-2564, Granite Construction Company, Sacramento, CA

US Dept. of Health & Human Services, Public Health Service, CDC & National Institute for Occupational Safety & Health

March, 1996

54 pages

Key Words: SIC 1611 (Highway & Street Construction), asphalt fume, bitumen, crumb rubber modifier, CRM, recycled tires, paving, interstate highways, polycyclic aromatic compounds, PACs, polynuclear aromatic hydrocarbons, PAH, total particulate, respirable particulate, benzene soluble particulate, volatile organic compounds, hydrocarbons, elemental carbon, eye irritation, respiratory irritation.

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FE.5 = RPA\_A1005.pdf

**[NIOSH Health Hazard Evaluation Report](#)**

Hanley, Kevin W., MSPH, CIH and Miller, Aubrey K., MD, MPH

HETA 94-0365-2563, Spartan Paving Company, Lansing, Michigan

US Dept. of Health Human Service, CDC & National Institute for Occupational Safety & Health

March, 1996

54 pages

Key Words: SIC 1611 (Highway & Street Construction), asphalt fume, bitumen, crumb rubber modifier, CRM, recycled tires, paving interstate highways, polycyclic aromatic compounds, PACs, polynuclear aromatic hydrocarbons, PAH, total particulate, respirable particulate, benzene

soluble particulate, volatile organic compounds, hydrocarbons, elemental carbon, eye irritation, respiratory irritation.

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## **FEDERAL REPORTS: MISCELLANEOUS**

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FM.1 = RPA\_A1006.pdf

### **[State Scrap Tire Programs: A Quick Reference Guide](#)**

United States Environmental Protection Agency & Solid Waste and Emergency Response

April, 1993

52 pages

Scrap tire management has become a serious concern over the past several years. Every year, approximately 242 million scrap tires are generated in the U.S. The majority of these are added to the 2 to 3 billion scrap tires already in stockpiles across the country. Since the first scrap tire law was passed in 1985, 47 states have addressed scrap tire management through specific scrap tire laws and regulations, or through state solid waste or transportation legislation. The matrix summarizes each state's scrap tire management legislation and programs. It is intended to provide state regulators, as well as members of industry, with a quick reference on state scrap tire regulations across the country. The regulations summarized here address collecting, selling, hauling, processing, storing, and disposing of scrap tires. The matrix also includes information on market incentives, funding sources, special field tests or studies, and innovative uses for scrap tires within each state.

FM.2 = RPA\_A1007.pdf

### **[Summary of Markets for Scrap Tires](#)**

US Environmental Protection Agency & Solid Waste and Emergency Response

October, 1991

14 pages

This booklet summarizes EPA's *Markets for Scrap Tires*. It describes factors affecting the current supply and demand for scrap tires, and provides information on future market trends. It also explains how to obtain a copy of the full report.

FM.3 = RPA\_A1008.pdf

### **[Total Transportation Financial Needs During the Next Decade \(1981-1990\)](#)**

American Transportation Advisory Council

April, 1981

24 pages

The subject matter of the report was not novel since transportation is a highly capital intensive activity. The continuing investment of large sums of money, both public and private, is needed in order to sustain the efficient operation of the transportation system. The implementation of large capital projects often requires long periods of time. Consequently, the quantifications of capital needs projected into the future is extremely important. The 1977 ATAC report was developed by drawing upon a substantial number of earlier studies, some privately sponsored and some prepared by governmental agencies.

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## **FEDERAL REPORTS: PERFORMANCE**

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FP.1 – RPA\_A1009.pdf

### **[State-of-the-Art Survey of Flexible Pavement Crack Sealing Procedures in the United States](#)**

Army Corps of Engineers Cold Regions Research & Engineering Laboratory (CRREL)

Eaton, Robert & Ashcroft, Jane

Engineering & Housing Support Agency

September, 1992

24 pages

Key Words: crack sealing, pavements routing, national survey

A survey of all 50 United States was conducted in September of 1990 to determine the state of the art of crack sealing procedures on flexible asphalt concrete pavements. The results were tabulated and a summary report prepared.

FP.2            \$2.00

### **Use of Scrap Rubber in Asphalt Pavement Surfaces**

Army Corps of Engineers Cold Regions Research & Engineering Laboratory (CRREL)

Eaton, Robert A.; Roberts, J. & Blackburn, Robert

Strategic Highway Research Program, SHRP

December, 1991

17 pages

Key Words: asphalt concrete, pavements, tires, ice-pavement bonding, scrap rubber

Scrap tire rubber was mixed into an asphalt concrete wearing course to study the effect of ice disbonding from the pavement surface under traffic. Rubber contents of 0, 3, 6 and 12% by weight were studied. Initial laboratory ice disbonding test results led to the development of a new paving material, Chunk Rubber Asphalt Concrete (CRAC), that uses larger pieces of rubber in a much denser asphalt concrete mix. Strength values doubled and ice disbonding performance was enhanced.

FP.3 = RPA\_A1011.pdf

### **[Evaluation of Asphalt Rubber Binders in Porous Friction Courses](#)**

Army Corps of Engineers

Anderton, Gary

Construction Productivity Advancement Research, CPAR, Program

February, 1992

109 pages

Key Words: asphalt modifiers, asphalt rubber, hydroplaning, open-graded pavement, pavement construction, pavement design, porous friction course, recycling, skid resistance

This report documents a laboratory research effort to determine the potential benefits of asphalt rubber binders when used in porous friction courses. The results of this research study

are also used to recommend the asphalt cement grades and mix design procedure required to achieve optimum field performance.

FP.4 = RPA\_A1012.pdf

**Asphalt-Rubber Open-Graded Friction Courses Volume 8**

Army Corps of Engineers Waterways Experiment Station

Anderton, Gary

Asphalt Rubber Producers Group

February, 1992

48 pages

The purpose of this research was to evaluate the effectiveness of using asphalt-rubber binders in open-graded friction courses. This research provides a sound basis for using asphalt rubber binders in order to provide a more durable, cost-effective open-graded friction course. The information provided by this research has the potential to increase the volume of open-graded friction courses constructed in the future and to make these future pavements longer lasting.

FP.5 = RPA\_A1013.pdf

**Comparison of Mix Design Methods for Asphalt-Rubber Concrete Mixtures Volume 4**

Army Corps of Engineers Waterways Experiment Station

Stroup-Gardiner, Mary

Asphalt Rubber Producers Group

February, 1992

10 pages

The use of conventional mix design methods for determining the optimum asphalt content for rubber mixtures.

FP.6 = RPA\_A1014.pdf

**Fatigue of Asphalt and Asphalt-Rubber Concrete Volume 7**

Army Corps of Engineers Waterways Experiment Station

AZ Transportation & Traffic Institute College of Engineering and Mines

Asphalt Rubber Producers Group

February, 1992

11 pages

This report is concerned with the research in ARC being sponsored by the Asphalt Rubber Producers Group (ARPG) and the Waterways Experiment Station of the Corps of Engineers (WES). The majority of the work was done by the University of Nevada, Reno (UNR) and WES. The University of Arizona's (UA) portion of the research was to perform flexure-fatigue tests on four mixtures utilizing our device called a deflectometer. The aggregate gradation and binder contents were set in consideration of optimum asphalt content values obtained by WES and UNR.

FP.7            \$2.00

**Low Temperature Cracking Characteristics of Ground Tire Rubber & Unmodified Asphalt Concrete Mixture Volume 6**

Army Corps of Engineers Waterways Experiment Station

Kurtz, Neil C. & Stroup-Gardiner, Mary

Asphalt Rubber Producers Group

February, 1992

18 pages

In recent years, modified asphalt mixtures have become increasingly popular in the construction of flexible pavements. These products have gained popularity because of their ability to increase resistance to rutting at warm temperatures while reducing the occurrence of thermal cracking at cold temperatures. This coupled with the growing problem of waste rubber tires, has led to the reprocessing (grounding) of tire rubber for use in asphalt concrete mixtures.

In order to investigate this hypothesis, a laboratory research program was designed in order to assess the potential benefits of asphalt-rubber concrete mixtures.

FP.8            \$2.00

**Permanent Deformation Characteristics of Recycled Tire Rubber Modified & Unmodified Asphalt Concrete Mixtures Volume 5**

Army Corps of Engineers Waterways Experiment Station

Kurtz, Neil C. and Stroup-Gardiner, Mary

Asphalt Rubber Producers Group

February, 1992

12 pages

The extended research program was designed to include four phases:

Phase 1: The use of conventional mix design methods for determining the optimum asphalt content for asphalt-rubber mixtures.

Phase 2: Permanent deformation characteristics of asphalt-rubber and unmodified mixtures.

Phase 3: Low temperature cracking resistance of asphalt-rubber and unmodified mixtures.

Phase 4: Fatigue characteristics for asphalt- rubber and unmodified mixtures.

This report will deal with the laboratory results from Phase 2 only. The scope of this research program includes one aggregate source, one gradation and six binders.

FP.9 = RPA\_A1017.pdf

**[Physical Properties and Aging Characteristics of Asphalt-Rubber Binders Volume 2](#)**

Army Corps of Engineers Waterways Experiment Station

Anderton, Gary

Asphalt Rubber Producers Group

February, 1992

51 pages

The purpose of this research was to evaluate the effectiveness of using asphalt-rubber binders in hot mix asphalt (HMA). This research provides a sound basis for using asphalt-rubber binders in order to provide a more durable, cost-effective HMA pavement.

FP.10 = RPA\_A1018.pdf

**[Summary of Research on Asphalt-Rubber Binders and Mixes Volume 1](#)**

Army Corps of Engineers Waterways Experiment Station

Asphalt Rubber Producers Group  
125 pages

This report digests the results obtained from the two-year asphalt-rubber research study.

FP.11            \$10.00

**Tensile Creep Comparison of Asphalt Cement and Asphalt-Rubber Binders Volume 3**

Army Corps of Engineers Waterways Experiment Station

Hansen, Kent & Stonex, Anne

Asphalt Rubber Producers Group

February, 1992

131 pages

This report presents our evaluation of tensile creep tests for the asphalt-rubber and asphalt cement binders used in the CPAR Asphalt-Rubber Concrete evaluation. Testing was conducted by Crafcoc, Inc. Crafcoc's test results were reported at the CPAR Advisory Committee Meeting on April 25, 1991.

FP.12            \$4.00

**Value Engineering Study of Crack and Joint Sealing**

Blais, Ernest J.

USDOT, Office of Implementation

December, 1984

53 pages

Key Words: value engineering, crack and joint sealing, Portland cement concrete, asphalt pavements

This report summarizes the results of a cooperative value engineering study of crack and joint sealing. The objective of the study was to optimize the expenditure of maintenance resource through an in-depth study of crack and joint sealing materials and placement techniques.

FP.13 = RPA\_A1021.pdf

**[Uses of Recycled Rubber Tires in Highways \(NCHRP\): Synthesis of Highway Practice 198](#)**

Epps, Jon A.

University of Nevada, Reno

January, 1994

171 pages

This synthesis of information defines the use of recycled rubber tires in highways and is based on the practices of state highway agencies through 1993 and a review of nearly 500 references. The synthesis addresses the use of rubber tires in asphalt paving materials as well as other applications, including Geotechnical and traffic operations. The various applications of rubber tires are identified, together with their design considerations, technical strengths, construction limitations, performance, costs, environmental considerations, and specifications, as well as current research activities, critical research needs, and legislative issues. This technology is a rapidly changing field; therefore, this synthesis represents the best available information at the time publication.

FP.14 = RPA\_A1022.pdf

**Discarded Tires: Energy Conservation Through Alternative Uses**

Gaines, L.L. & Wolsky, A.M.

Energy & Environmental Systems Division

December, 1979

52 pages

Scrap tires that are not recycled through retreading constitute a serious solid waste problem, but also offer energy conservation opportunities through their use as:

(1) solid fuel (displaced energy = 15,000 Btu/lb or 35 kJ/g), (2) derived fuel and chemical feedstock (11,000-23,000 Btu/lb or 25-53.5 kJ/g), (3) virgin rubber compound substitute in traditional rubber products (34,000-40,000 Btu/lb or 79-93 kJ/g), and (4) asphalt additive for paving applications (90,000 Btu/lb Or 210 kJ/g). Both the energy of the displaced fuel and material and the energy consumed preparing the tires for the above uses have been included, where possible, in these estimates. Also provided is a summary of the available data on the cost and requisite scale of operation for the various end use processes.

FP.15 = RPA\_A1023.pdf

**The Use of Scrap Materials in Highways**

Pillsbury, Hope

US EPA, Environmental Protection Agency, & Office of Solid Waste)

3 pages

EPA hierarchy for municipal waste management: 1) Source reduction including product reuse; 2) Recycling including composting; 3) Disposal which includes landfilling and incineration. EPA position on CRM is that there is no compelling evidence that the use of asphalt pavement containing recycled rubber substantially increases the threat to human health or the environment as compared to the threats associated with conventional asphalt pavements. These findings are based on the limited data from a few studies. These findings are based on the limited data from a few studies. These conclusions are subject to revisions as additional information is obtained and evaluated. In addition, there is no reliable evidence that asphalt pavements containing recycled rubber cannot be recycled to substantially the same degree as conventional hot mix asphalt pavements.

FP.16 = RPA\_A1024.pdf

**Crumb Rubber Modifier: Workshop Notes (Design Procedures and Construction Practices)**

FHWA, Office of Engineering

January, 1991

294 pages

The Intermodal Surface Transportation Efficiency Act of 1991, commonly referred to as ISTEA, initiated major changes in the Federal-aid highway program. Section 1038 of ISTEA contains provisions for each State to begin incorporating scrap tire rubber into their asphalt paving materials. A number of activities are underway as a result of Section 1028, and I would like to briefly highlight them for you. Then I will share some comments on the implications of the section. The workshop is one of our activities to address Section 1038. It is intended to "jump start" our understanding of HOW TO...HOW TO properly design and HOW TO properly construct asphalt pavements which incorporate scrap tire rubber. The workshop was developed through the cooperation of highway agencies and the asphalt industry and will discuss present

procedures and practices for this technology. The workshop is not intended to be a forum for debating the research or implementation provisions of ISTEA Section 1038.

FP.17 = RPA\_A1025.pdf

**[A Study of the Use of Recycled Paving Material: Report to Congress, June 1993](#)**

FHWA/USEPA

June, 1993

\*Also under Federal Emissions & Federal Recyclability

7 pages [Chapter 4: pages 26-29]

Key Words: scrap tires, crumb rubber modifier, recycling, hot mix asphalt, environmental assessment, comparative health risk, waste materials, reclaimed asphalt pavement, glass

The highway construction industry has a long history of using recycled products for highway construction. This report summarizes some of the industries' experiences and, where sufficient information exists, it provides documentation regarding the economic savings, technical performance, threats to human health and the environment, and environmental benefits of using recycled materials in highway devices and appurtenances and highway projects.

FP.18 = RPA\_A1026.pdf

**[Data Collection and Analyses Pertinent to EPA's Development of Guidelines for Procurement of Highway Construction Products Containing Recovered Materials](#)  
**Volume 1- Issues and Technical Summary Final Report****

Franklin Associates, Ltd. & Valley Forge Laboratories, Inc.

USEPA

July, 1981

192 pages

The primary objective of this study is to prepare a base of quantitative and qualitative information relating to the writing of guidelines for government procurement of four categories of recovered materials which are suitable for use in highway construction products: power plant ash, cement and lime kiln dusts, rubber tires, and incinerator residue. Specifically, the following kinds of information are to be provided to EPA:

1. Commercial availability of products containing recovered materials.
2. Indirect capacity to produce and supply those products.
3. Procuring agency demand.
4. Price ranges for products containing recovered materials.
5. Technical performance assessment.
6. Certification procedures.
7. Analysis of environmental, economic, and energy effects.
8. Assessments on a state-by-state basis of the past and present use or consideration of use of products containing recovered materials.

FP.19 \$8.00

**State of the Practice – Design and Construction of Asphalt Paving Materials With Crumb Rubber Modifier**

Heitzman, Michael A., P.E.

FHWA

May, 1992

105 pages

Key Words: asphalt additives, scrap tire rubber, crumb rubber modifier, wet process, dry process, asphalt rubber, rubber modified hot mix asphalt

This document is a comprehensive overview of the terminology, process, products, and applications of crumb rubber modifier (CRM) technology. This technology includes any use of scrap tire rubber in asphalt paving materials. In general, CRM technology can be divided into two categories – the wet process and the dry process.

FP.20 = RPA\_A1028.pdf

**[Criteria for Asphalt-Rubber Concrete in Civil Airport Pavements Volume 2-Evaluation of Asphalt-Rubber Concrete Final Report](#)**

Hoyt, Denise; Lytton, Robert L. and Roberts, Freddy, Texas Transportation Institute

USDOT/FHWA

March, 1987

246 pages

Key Words: asphalt-rubber concrete, materials characterization, modified ILLIPAVE, rutting, cracking

Asphalt-rubber concrete and an asphalt concrete control were tested in the laboratory and materials characterizations were generated, including Marshall Stability, resilient modulus, fatigue and fracture properties, creep compliance, and permanent deformation properties. The characterization parameter and an airport runway model for a municipal airport were input into the modified ILLIPAVE computer program for analysis of rutting and cracking damage and the relative lives of the materials in each of four climatic zones. An economic evaluation was then performed comparing the costs and service lives of each material in each zone.

FP.21 = RPA\_A1041.pdf

**[Investigation of Materials and Structural Properties of Asphalt-Rubber Paving Mixtures](#)**

Shuler, T.S.; Pavlovich, R.D.; Epps, J.A. and Adams, C.K., Texas Transportation Institute

USDOT/FHWA/TTI

September, 1985

111 pages

Key Words: asphalt-rubber, interlayer, seal coat, reflection cracking

Ground tire rubber is investigated as an additive in asphalt pavement construction. A blend of ground tire rubber and asphalt cement at elevated temperatures is called "asphalt-rubber". The blend consists of 18 to 26 percent ground tire rubber by total weight of the blend. Other systems in which rubber is considered an elastic aggregate were also studied. These mixtures are not considered asphalt-rubber because rubber is not blended with the asphalt cement prior to mixing with mineral aggregates. These materials are called "asphalt concrete rubber-filled" for dense graded mixes, and "friction course rubber-filled" for open graded mixes.

FP.22 = RPA\_A1030.pdf

**[Engineering Aspects of Recycled Materials for Highway Construction](#)**

FHWA/USDOT

June, 1993

\*Also under Federal Recyclability

223 pages

Key Words: recycled materials, highway construction, environmental, engineering characteristics, health, scrap tires, crumb rubber modifier

This report presents an assessment of environmental aspects and engineering factors related to the utilization of recycled materials in highway construction. A basic overview and assessment of different technologies, processes, and methods for recycling of various materials into highway appurtenances and for highway construction are presented with consideration of environmental/health risks.

FP.23 = RPA\_A1031.pdf

**[Background: EPA's Dilemma Under Section 1038](#)**

Harvey, Dr. Terry

Environmental Protection Agency

April 6, 1993

28 pages

Presents the EPA's proposed approach in conducting studies as required by Sec. 1038 of ISTEA. Sec. 1038 is interpreted not to require a "definitive scientific determination of the significance of the health and environmental risks posed by recycling waste tires into asphalt pavement..." Reviews the statutory text, legislative history and policy considerations that support this interpretation of ISTEA. It then shows that there is a wealth of data, including "reliable evidence" upon which the EPA can judge whether the manufacture use and recycling of rubber modified asphalt presents potential hazards to public (especially worker) health or to the environment. Finally, it discusses the short term and long term actions that should be undertaken, by the Government, industry, or both to develop the evidence needed to reliably assess the health and environmental risks of the waste tire recycling program.

FP.24 = RPA\_A1032.pdf

**[A National Overview - The Use of Discarded Materials and By-Products in Hot Mix Asphalt Concrete Pavements](#)**

Ciesuewski, Stanley, Ph.D., P.E.

Villanova University

October, 1993

16 pages

The objective of this paper was to research and investigate the potential specific disposal of waste materials by usage in Hot Mix Asphalt Concrete (HMAC) pavements. The particular purpose of this effort was to establish the current nationwide position of all of the fifty states and the District of Columbia in regard to the disposal and/or usage of various waste materials in HMAC mixtures as they apply to an asphalt concrete pavement.

FP.25 = RPA\_A1033.pdf

**[Crumb Rubber Modifiers \(CRM\) in Asphalt Pavements](#)**

USDOT/FHWA

October 1 – December 31, 1995

92 pages

The technological advances made in the use of crumb rubber modifier in hot-mix asphalt (CRM-HMA) indicate that if designed and placed properly, the performance of these mixes meets or exceeds the performance of conventional HMA. This report compiles the experience of various highway agencies with CRM-HMA and provides a set of general guidelines for the most effective use of these mixes in structural and functional rehabilitation of existing pavements. Uses of CRM-HMA in new pavements is also described.

FP.26            \$8.00

**Use of Crumb Rubber Modified Asphalt Technology**

E.H. Pechan & Associates, Inc.

January, 1993

108 pages

Clearly, the nation needs to find ways to reduce the scrap tire problem. There are many alternatives to landfilling scrap tires, including retreading, burning whole tires or tire chips for energy recovery and as fuel, and manufacturing products from scrap tire rubber. An application that appears to be particularly promising is to use crumb rubber made from scrap tires as a modifier to create modified asphalt paving materials.

FP.27 = RPA\_A1035.pdf

**Characterization of CRM Binder Using SHRP Technology**

Hanson, Douglas I. & Duncan, Gregory M.

National Center for Asphalt Technology

January, 1995

43 pages

The objective of the NCAT crumb rubber study was to evaluate the use of crumb rubber modified binders for use in HMA pavements.

FP.28 = RPA\_A1036.pdf

**The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance**

FHWA/USDOT

1993

35 pages

This booklet summarizes the 1993 Congressional Report, starting with a "Report Card" for highways, bridges, and transit in 1991. For the first time, the report includes information on transit and environmental impacts. In fact, the transit and highway investment assessment methodologies are linked. A portion of the forecasted increase in travel demand is accommodated not by the addition of new highway lane-miles but by an aggressive, coordinated demand management program that includes increased transit participation. This increased transit participation is included in the transit investment analysis. Future reports will expand on integrating multi-modal and environmental issues in the surface transportation investment analysis.

FP.29 = RPA\_A1037.pdf

**Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier**

Heitzman, Michael A., P.E.

FHWA  
8 pages

Provides a concise overview of the terminology, process, products, and application for crumb rubber modifier (CRM) technology. Briefly discusses environmental and legislative issues, history, CRM processing, wet and dry processes including properties and construction practices and new technologies for using CRM for asphalt pavement construction.

FP.30 = RPA\_A1038.pdf

**[Development of a Physical Property Specification for Asphalt-Rubber Binder](#)**

Reese, Ron, Caltrans

FHWA/Caltrans

June, 1995

\*Also under California State Performance

72 pages

Key Words: asphalt-rubber binder, asphalt-rubber hot mix, rheology of asphalt-rubber binders

The performance of projects incorporating asphalt-rubber binders has been inconsistent. Thus, a method was needed to provide an understanding of binder physical properties associated with the desirable performance and to quantify them for specification purposes. It was proposed to use the capabilities of a dynamic shear rheometer for comparing the asphalt-rubber binder properties with project performance data to determine the potential for rheological specifications on job samples of the binder.

FP.31            \$2.00

**Evaluation of Rubber-Modified Asphalt Pavement Performance – Mt. St. Helen's Project**

Lundy, James & Hicks, R.G., Oregon State Univ., & Richardson, Emory, FHWA

Association of Asphalt Paving Technologies

September, 1986

24 pages

Key Words: rubber-modified asphalt concrete, modulus, fatigue, layer equivalency, skid resistance, surface texture

To aid in the evaluation of this product, the FHWA undertook a demonstration project to investigate rubber-modified asphalt mixtures. This paper documents the evaluation of this project, located in Washington State near Mt. St. Helens. The investigation included both laboratory and field evaluations. Comparisons were developed using conventional mixture as a control. Field evaluations have taken place at periodic intervals following construction in 1983.

FP.32 = RPA\_A1040.pdf

**[An Evaluation of Effects of Deicing Additives on Properties of Asphalt Mixtures](#)**

Mogawer, Walaa & Lee, K. Wayne, Univ. of RI, & Stuart, Kevin, FHWA

University of Rhode Island

1988

47 pages

This paper summarizes the results of an experimental study to evaluate the effects of two deicing additives, Verglimit and PlusRide, on the properties of asphalt mixtures in terms of their resistance to rutting, low temperature cracking and moisture damage. Verglimit consists mainly of calcium chloride and a small amount of sodium hydroxide. PlusRide is derived from granulating whole tires and tire buffings. These deicers, which are added to the mixture, are currently being used but their effects on mixture properties are not well established. Mixtures were cured for different periods of time and the following tests and incremental static-dynamic creep tests. In addition, the VESYS computer program were used to predict the performance of pavements with deicing additives.

FP.33 = RPA\_A1041.pdf

**Investigation of Materials and Structural Properties of Asphalt-Rubber Paving Mixes – Volume I – Technical Report**

Shuler, T.S.; Pavloich, R.D.; Epps, J.A. & Adams, C.K., Texas Transportation Institute  
USDOT/FHWA/TTI  
September, 1986  
111 pages

Key Words: asphalt-rubber, interlayer, seal coat, reflection cracking

Ground tire rubber is investigated as an additive in asphalt pavement construction. A blend of ground tire rubber and asphalt cement at elevated temperatures is called "asphalt-rubber". The blend consists of 18 to 26 percent ground tire rubber by total weight of the blend. Other systems in which rubber is considered an elastic aggregate were also studied. These mixtures are not considered asphalt-rubber because rubber is not blended with the asphalt cement prior to mixing with mineral aggregates. These materials are called "asphalt concrete rubber-filled" for dense graded mixes, and "friction course rubber-filled" for open graded mixes.

FP.34 = RPA\_A1042.pdf

**Waste Tire Utilization**

Hershey, Dr. Robert L.; Waugh, Martin D. & Hanny, EveLynn J., Science Management Corp.  
US Dept. of Energy  
April 30, 1987  
69 pages

Waste tire accumulations have become an increasingly important problem in recent years. This is of interest to DOE because the scrapped tires represent a large energy resource, and many requests for information have been received. Therefore, this report has been prepared to help in implementing waste tire utilization technologies.

FP.35 = RPA\_1043.pdf

**Use of Rubber Aggregate in a Strain Relieving Interlayer for Arresting Reflection Cracks in Pavement**

Gallaway, Bob M., Texas A & M Univ., & LaGrone, B.D., US Rubber Reclaiming Co.  
1971  
29 pages

One of the most troublesome problems encountered in design and maintenance of asphalt concrete pavements is that of reflection cracking. Reflection cracks are generally the result of some type of foundation movement or shrinkage problem and can reduce the effectiveness of

the pavement by loss of structural strength of the total pavement structure, by allowing intrusion of water into the pavement and down into the supporting structure, and/or by reducing the long-lasting smooth-riding quality of the surface.

FP.36 = RPA\_A1044.pdf

**[Aggregate and Paved Design and Rehabilitation Manual for Low-Volume Roads](#)**

Hudson, S.W.; McCullough, B.F. & Carmichael, R.F., III, Are Inc., Engineering Consultants  
FHWA/USDOT

October, 1986

271 pages

Key Words: low-volume roads, surface design, paved, aggregate, maintenance, rehabilitation

The considerations and constraints associated with the design process are discussed. These include drainage, geometrics, traffic, materials, surface characteristics, and shoulders. Design procedures especially for low-volume roads are given for both paved and aggregate surfaces. Paved surfaces include surface treatments, asphalt concrete, and portland cement concrete.

FP.37 = RPA\_A1045.pdf

**[Rubber-Asphalt Binder for Seal Coat Construction](#)**

Olsen, Robert E.

FHWA/USDOT

February, 1973

32 pages

This paper describes the development and use of a rubber-asphalt binder for seal coat construction. Whereas rubber has been added to asphalt in low percentages (3 – 5%) in the past, this binder uses high percentage (25 – 30%) additions of granulated tread rubber reclaimed from discarded automobile tires.

FP.38 = RPA\_A1046.pdf

**[Evaluation of Asphalt Rubber and engineering Fabrics as Pavement Interlayers](#)**

Army Corps of Engineers Waterways Experiment Station

Ahlich, R.C.

November, 1986

48 pages

Key Words: asphalt concrete overlay, asphalt-rubber interlayer, engineering fabrics, reflective cracking, stress relieving interlayer

Asphalt-rubber and engineering fabric interlayers have been used to retard reflective cracks in asphalt concrete overlays. These materials have generally performed satisfactorily in warm climates; however, performance in cold climates has been less than desirable. The information presented in this study was obtained from experimental projects conducted by state and federal agencies.

FP.39 = RPA\_A1047.pdf

**[An Economic Evaluation of Technical Systems for Scrap Tire Recycling](#)**

Goddard, Haynes C., Municipal Environment Research Laboratory

US Environmental Protection Agency, Office of Air, Land & Water Use

44 pages

A technological and economic assessment is made of alternative technologies to recover the waste rubber in scrap vehicle tires. The principal technical alternatives evaluated are ground scrap rubber as an asphalt additive, retreading, energy recovery, and carbon black recovery. The greatest potential benefits are seen to occur with retreading and asphalt additives, followed by carbon black and energy recovery.

FP.40 = RPA\_A1048.pdf

**Effects of Rubber Additives in Asphalt Concrete**

Stuart, Edward, III

US Forest Service, Region 5

December, 1965

11 pages

This investigation on the effects of rubber additives in asphalt mixes was accomplished in three phases. Initially, a research was made into the results of tests and uses of this type of admixture by other agencies. Secondly, the Materials Investigation Section programmed and performed a series of controlled laboratory tests comparing the effects of rubber additives on certain properties of asphalt mixes. Finally, an observation was made of a rubber additive – asphalt concrete resurfacing project in San Jose, California.

FP.41 = RPA\_A1049.pdf

**Development of Asphalts and Pavements Using Recycled Tire Rubber**

Bullin, J.A.; Davison, R.R.; Glover, C.J.; Estakhri, C.; Flumerfelt, R.W.; Billiter, T.; Chum, J.; Koo, H.; Sheth, V.; Elphinstone, G. and Eckhardt, C.

Texas Transportation Institute

June, 1996

153 pages

This report documents the technical progress made on the DOE funded project "Development of Asphalts and Pavements Using Recycled Tire Rubber" for the time period covering September 1, 1994 through August 31, 1995.

FP.42 = RPA\_A1050.pdf

**Use of Crumb Rubber Additives in Region 10**

Trunk, Julie

USDOT

October, 1990

86 pages

The use of crumb rubber additives (CRA) in hot mix asphalt concrete pavement has recently been receiving a great deal of national attention. It is being considered by some as the solution to our nations waste tire stockpile problem. Our environment and health are being jeopardized by this problem, which is growing at an alarming rate. The Environmental Protection Agency (EPA) estimates that 2 ½ to 3 billion tires are currently stockpiled and 280 million tires are wasted each year. Of these 280 million tires, approximately 85% will be added to stockpiles and only 15% will be recovered by recycling or by energy recovery. To solve our nations stockpile problem, recycling of waste tires needs to increase.

FP.43 = RPA\_A1051.pdf

**Evaluation and Characterization of a Rubber Modified Hot Mix Asphalt (RMHMA) Pavement (U.S. 82- Columbus, MS)**

Hanson, Douglas I. & Foo, Kee  
National Center for Asphalt Technology  
April, 1994

\*Also under Mississippi State Performance  
56 pages

The primary objectives of this study are 1) to evaluate the properties of a control (conventional) HMA and a rubber modified HMA (RMHMA) immediately after construction and at various times during the first two years of the pavement's life and 2) to compare these laboratory properties to observed in-place performance.

This report prepared immediately after evaluating the pavement performance for nine months, mainly focuses on evaluating the properties of the control and RMHMA mix during the first nine months of the pavement life. Comparison of laboratory properties to in-place pavement performance is not presented because pavement performance quantification is incomplete at this time.

FP.44            \$10.00

**Evaluation of the Effectiveness of Membranes for Prevention of Crack Reflection In thin Overlays**

Vedros, Jr., Philip J.  
US Army Engineer Waterways Experiment Station, Geotechnical Laboratory  
March, 1979  
146 pages

Key Words: asphalt-rubber membranes, concrete overlays, cracking (fracturing), membranes (airfields), membranes (roads), nonwoven fabric membranes, overlays (pavements), pavement performance & evaluation, pavements, reflection cracking

This report is an interim report resulting from case studies of pavement performance conducted by the US Army Engineer Waterways Experiment Station under contract order with the US Army Forces Command. The purpose of this study was to determine if a stress-absorbing layer consisting of an asphalt-rubber membrane or a nonwoven fabric placed under a thin asphaltic concrete overlay (2 in. or less) will stop reflection cracking from occurring in the overlay. Field tests of two asphalt-rubber membrane formulations and three nonwoven fabrics were placed on roads and airfield pavements at five Army installations in various areas of the United States. This report covers the construction of the test areas and performance after a 6-month period. A final report will be prepared on the performance of each material after a number of years of annual inspections.

FP.45 = RPA\_A1053.pdf

**Laboratory Evaluation of Verglimit and PlusRide**

Stuart, K.D. & Mogawer, W.S.  
FHWA  
March 1991  
125 pages

Key Words: Verglimit, PlusRide, deicers, asphalt additives, creep test, repeated load test, Resilient modulus, moisture susceptibility, low temperature cracking

The effects of two additives, Verglimit & PlusRide, on the laboratory properties of asphalt mixtures, in terms of their resistance to aging, moisture damage, rutting, and low temperature cracking were determined. These two additives have been used to control the formation of ice on pavements. Field studies have mainly consisted of determining the action of the additives on melting ice and the related changes in the number of traffic accidents. The effects of these two additives on laboratory mixture properties were not established in these field studies. Both Verglimit and PlusRide are added directly to the asphalt mixture at the mixing plant.

FP.48 = RPA\_A1055.pdf

**[Crumb Rubber Modifiers in Asphalt Pavements: Summary of Practices in AZ, CA, & FL](#)**

Hicks, Gary; Lundy, J.R.; Leahy, R.B.; Hanson, D. & Epps, J. Oregon State University

FHWA

September, 1995

108 pages

Key Words: crumb rubber modifiers, asphalt pavements, thickness design, mix design, construction procedures, quality control, pavement performance

Highway agencies have been evaluating crumb rubber modifier in hot mix asphalt since the 1970's. Three agencies, AZ, CA, & FL, currently use CRM in HMA at levels that would approach or exceed the mandate in section 1038 of the Intermodal Surface Transportation Efficiency Act of 1991. This report documents the use of CRM in HMA in these three States. In particular, it addresses issues including thickness design, materials and mix design, construction procedures, including quality control, and pavement performance. The report also addresses the following questions: (1) What processes are used? (2) Why are they used? (3) How are the products performing?

FP.49 = RPA\_A1056.pdf

**[Development of Superior Asphalt Recycling Agents Phase 1: Technical Feasibility](#)**

Bullin, Jerry A.; Glover, Charles J.; Davison, Richard; Lin, Moon-Sin; Chaffin, Jay; Liu, Meng & Eckhardt, Clint, TTI

U.S. Department of Energy

April, 1996

202 pages

This report documents the technical progress made on the DOE funded project "Development of Superior Asphalt Recycling Agents" for the time period covering August 2, 1994 through August 1, 1995. Cost sharing for this study is being supplied by the Texas Dept. of Transportation and the Texas Advanced Tech. Program. Bruce Crandford and Merrill Smith are the program managers for the DOE office of Industrial Technologies.

FP.50 = RPA\_A1057.pdf

**[Evaluating the Effects of Using Crumb Rubber Modifier in Hot Mix Asphalt with the Wet and Dry Processes](#)**

Buncher, Mark S., Auburn University

NCAT

16 pages

The objective is to compare the performance effects of adding CRM to HMA by the wet process versus the less expensive dry process, given the same CRM type, size and amount. Also this report compares both processes to a mix without CRM. This is presented in table format.

FP.51 = RPA\_A1058.pdf

**[Use of SuperPave Technology for Design and Construction of Rubberized Asphalt Mixture](#)**

Takallou, Barry; Bahia, Hussain; Perdomo, Dario & Schwartz, Robert

January, 1997

35 pages

The effect of different mixing times and mixing temperatures on the performance of asphalt rubber binder were evaluated. Four different types of asphalt rubber binders and neat asphalt were characterized using the SHRP binder method tests. Subsequently, mix designs were carried out using both the SHRP Level I and II mix design procedures as well as the traditional Marshall Mix design scheme. Additionally, performance testing was carried out on the mixtures using the SuperPave Repetitive Simple Shear Test at Constant Height to evaluate the resistance to permanent deformation of the rubberized asphalt mixtures.

FP. 52 = RPA\_A1059.pdf

**[Evaluating The Effects of the Wet and Dry Processes for Including Crumb Rubber Modifier in Hot Mix Asphalt](#)**

Buncher, Mark, Auburn University

NATC

August 30, 1995

186 pages

The conventional method of modifying asphalt cement with crumb Rubber Modifier is to blend and "react" ground CRM particles in the AC, prior to mixing with the aggregate to produce hot mix asphalt. This is known as the "wet process." The "dry process," where CRM is added directly to the aggregate, has historically used larger granulated CRM particles with an objective of "rubberizing the aggregate." Recently, a few states have successfully tried a new concept of adding exclusively minus 80 mesh CRM directly to the aggregate. This in effect combines the dry process method with wet process objective of modifying the AC. Adding the same CRM "dry" versus "wet" substantially lessens modification costs, but most feel the CRM "reaction" is very limited. The primary objective of this study was to compare the performance effects of adding the same ground CRM to HMA by the wet versus the dry process.

FP.53 = RPA\_A1060.pdf

**[Comparison of Carbon Black from Pyrolyzed Tires to Other Fillers as Asphalt Rheology Modifiers](#)**

Lesueur, Didier; Dekker, Don & Planche, Jean-Pascal

January, 1995

20 pages

In order to dispose of old tires, crumb rubber-modified asphalts have been introduced. However, the research done on these products shows that they don't necessarily enhance the field applications. Since carbon black can be extracted from old tires, it might be better way to

recycle tires. This paper presents carbon black from pyrolyzed tires as an asphalt modifier. For a comparison purpose, CB was compared to aggregate fillers and ball clay, and mixed with asphalt to form mastics with similar weight contents. As result, CB seems to be a good rheology modifier for binders having already a good low temperature behavior, such as polymer-modified asphalts.

FP.54 = RPA\_A1061.pdf

**[The Effect of Asphalt composition on the Formation of Asphaltenes and Their Contribution to Asphalt Viscosity](#)**

Lin, Moon-Sin, Chaffin, Jay; Liu, Meng; Glover, C.J.; Davison, R.R. & Bullin, J.A., Texas A&M University

27 pages

Interactions among asphalt components have significant effects on the performance of asphalt binder. To understand those interactions, four asphalts, SHRP AAA-1, AAD-1, AAF-1, and AAG-1, were fractionated into three generic fractions according to Corbett's procedure and reblended into asphaltenes/aromatics/ saturates ternary mixtures in various ratios. Mixtures were oxidatively aged with atmospheric air at temperatures of 87.7, 93.3, and 98.8 for 5 to 33 days. The changes in chemical composition and physical properties were monitored using fourier transform infrared spectroscopy and dynamic mechanical rheometry. The data collected in this study indicate that the saturate content in the maltene phase has a profound impact on the contribution that asphaltenes have on the viscosity of aged asphalt.

FP.55 = RPA\_A1062.pdf

**[Rheological Properties of Rubber-Modified Asphalt](#)**

Zaman, A.A.; Fricks, A.L. & Beatty, C.L., Univ. of Florida

7 pages

The performance of rubber as an asphalt cement modifier was evaluated by performing experiments on the shear-flow properties and creep-rupture behavior of modified asphalt cements. Results indicate that various asphalt/rubber samples exhibit shear-thickening, Newtonian, and shear-thinning behavior depending on the shear rate. The shear viscosity, linear viscoelastic functions, elasticity, and creep resistance of asphalt cement increased with the addition of rubber. These increases indicate that the addition of rubber will improve the low temperature properties of asphalt cement, and that such modifications are necessary to reduce the tendency of asphaltic-paving materials to crack in cold climates and to increase the life cycle of the road.

FP.56 = RPA\_A1063.pdf

**[Weathering Behavior of Asphalt-Rubber Mixes](#)**

Andrady, Anthony L.

SHRP

August, 1993

63 pages

The demand for automobile tires has steadily increased over the years, while the reuse/recycle rate has declined. While the advent of durable, superior tires has somewhat slowed new tire production since the late 1980's, the number of waste tires entering the municipal solid waste stream has continued to increase consistently in recent years. This report covers then effect of CRA on Asphalt mix properties, impact of using CRA in pavements, optimization of the CRA

additive, preparation of Rubber-Asphalt mixtures, and the results and discussions of the experimental procedures.

FP.57 = RPA\_A1064.pdf

**[History of Use of Crumb Rubber in Asphalt Paving Materials](#)**

Brown, Ray

NCAT

8 pages [Session 4.0 Pages 4-0 to 4-7]

The potential benefits of adding rubber to asphalt cement have been discussed for many years however its use was delayed due to lack of technology and equipment to economically mix the rubber in asphalt cement. The use of natural rubber in asphalt cement was first introduced in the 1840's. The concept of adding the rubber to asphalt cement was developed in the 1950's. It was not until 1964 that the use of crumb rubber modifier in asphalt mixtures was first applied.

FP.58 = RPA\_A1065.pdf

**[A Laboratory Evaluation on the Effects of Ground Tire Rubber on Strength Performance of Concrete](#)**

El-Boulaki, Hesham; Pace, Randy & Garbee, Cabell W., North Carolina DOT

FHWA/ U.S. DOT

October, 1993

12 pages

This research provides a laboratory evaluation of the effects of adding ground tire rubber on the performance of concrete. The underlying objective of this investigation is to assess the possibility of partially substituting the fine aggregate with ground tire rubber particles in concrete pavements and other highway applications. Only the strength and workability properties were examined for the modified concrete under study. The various test methods and their ASTM designations are listed. A description grounding/preparation process of the rubber tire aggregate in this evaluation is included.

FP.59 = RPA\_1066.pdf

**[Research, Development, and Implementation Plan for Crumb Rubber Modifier](#)**

Epps, Jon & Middlebrooks, Joe, Univ. of Nevada

National Cooperative Highway Research Program

January, 1995

93 pages

The federal government, states and industry have performed a considerable amount of short term, limited-budget research on crumb rubber modified asphalt binders. This research has contributed to a limited understanding of the technology but has yet to evaluate many technological issues. This has been the overriding factor basis. Some of the remaining unanswered questions raised by federal legislation and of concern to the federal government and between CRM and asphalt cement, identification of cost effective used of CRM, recyclability of pavements containing CRM, air quality during construction and recycling, work force health and safety during construction and recycling, and effects of CRM on water quality. There is also a need for guidelines and/ or standards for CRM in hot mix asphalt pavements that can be used by agencies with the assurance that successful pavements will result.

FP.60 = RPA\_A1067.pdf

**Investigation of Exothermic Reaction in Tire Shred Fill Located on SR 100 in Ilwaco, Washington**

Humphrey, Dana

FHWA

March, 1996

71 pages

Tire shreds and tire shred/soil mixtures have been used on highway projects as lightweight embankment fill, lightweight retaining wall backfill, drainage layers, thermal insulation to limit frost penetration beneath roads, and replacement for soil or rock in other fill applications. More than 70 successful projects have been constructed on state, local, and private roads. Tire shreds have proved to be very economical compared to other types of lightweight fill. Moreover, a large number of waste tires can be used in this application. There have been several state highway projects that used 100,00 to more than 1 million tires per project. Thus, use of tire shreds for highway applications has the potential to make significant contribution to solving out nation's waste tire disposal problem.

FP.61 = RPA\_A1068.pdf

**Annual Progress Report Information and Evaluation of Crumb Rubber Modifier**

University of Nevada/ Tech. Transfer Center

January, 1994

45 pages

This annual report has been prepared to summarize the activities conducted under the National Cooperative Highway Research Program Project 20-7, Task 58 on "information and Evaluation of Crumb Rubber Modifier Technology" for the calendar year of 1994.

FP.62 = RPA\_A1069.pdf

**Briefing for Honorable James W. Garner on Department of Highways and Transportation use of Rubber Asphalt Seals**

Heiman, G.H.

June, 1982

10 pages

Saskatchewan Roadbuilders made a request of the Minister for a re-evaluation of the Rubber Asphalt Seal Program. The following points were to be addressed.

- 1.) The success of the R.A.S. program questions.
- 2.) Equipment purchased was manufactured in the U.S.A.
- 3.) High cost of aggregate.
- 4.) Department pays royalties.
- 5.) Rubber Asphalt Program future in U.S.A.
- 6.) Department position on R.A.S. program cancellation.
- 7.) R.A.S future.

FP.63 = RPA\_A1070.pdf

**Interim Report: Construction Guidelines for Crumb Rubber Modified Hot Mix Asphalt**

Hanson, D.I.; Epps, J.A. & Hicks, R.G.

NCAT/FHWA

August, 1996

161 pages

Key Words: crumb rubber modifiers, asphalt pavements, mix design, construction procedures, quality control, and pavement performance

In recent years there has been increased interest in the use of crumb rubber modified hot mix asphalt pavements. This report presents the current technology for the construction of CRM HMA pavements. The major component of CRM is scrap tire rubber. The agency currently specifying CRM HMA pavements generally agree on the chemical and foreign matter requirements for the CRM, but differ on the CRM gradation. The gradation chosen will impact the end result of the material and the level of modification of the asphalt cement. There are two processes for manufacturing CRM HMA mixtures- the wet process and the dry process. The wet process is any process where the CRM is blended with the asphalt cement before the modified binder is added to the heated aggregate. The dry process is where the CRM is mixed with the aggregate before the asphalt cement is added.

FP.64 = RPA\_A1071.pdf

**[Applications of Carbonous Residue Recovered From Co-Retorting Tires with Waste Oils in Highway Construction](#)**

Khaled Ksaibati, Yul Cha, Chang, & Henry Plancher

October 1993

11 pages

A two-step thermal process was developed to co-recycle scrap tires with waste oils to produce a soft particulate carbonous residue. This solid carbonous residue has applications as a modifier for bituminous binders and Portland concrete. Addition of carbonous residue to bituminous binders causes a reinforcing effect similar to that reported for carbon black; reduces levels of oxidation and long-termed embrittlement and in bituminous mixtures reduces the effects of moisture-induced damage and stress-induced deformation (ruts). In Portland concrete applications the darkened concrete adds both artistic and practical benefits such as improved adhesion to metallic materials and deicing of concrete surfaces. Test results indicate the benefits derived from these carbonous residue modifications place added value to the use of carbonous residue as a modifier and as a result enhance the economics of the scrap tire/waste oil recycle process.

FP.65 = RPA\_A1072.pdf

**[The Kansas Experience](#)**

University of Nevada

National Research Council

November, 1994

2 pages

This is a publication summarizing the twelve projects Kansas has used Asphalt Rubber and it also gives the preliminary review results of the projects.

FP.66 = RPA\_A1073.pdf

**[The Illinois Experience](#)**

University of Nevada

National Research Institute

October, 1994

2 pages

This is a publication summarizing mix design, production, construction, testing, performance and costs of Asphalt Rubber.

FP.67 = RPA\_A1074.pdf

**[Design of Open-Graded Asphalt Friction Courses](#)**

Smith, R.W.; Rice, J.M. & Spelman, S.R.

FHWA/ U.S. DOT

January, 1974

44 pages

Key Words: Asphalt concrete, open-graded, design method, skid resistance, porous overlay, surface treatment, plant mix seal

Efforts to improve pavement skid resistance have shown the advantages of using open-graded asphalt paving mixtures. Extensive implementation of these mixtures has been hampered, however, due to some difficulties encountered during construction and some deficiencies observed in service performance. These problems are partially attributable to a number of uncertainties involved in existing design methods. The described method is relatively new, but has been used successfully on several FHWA, R&D Demonstration Projects. It is believed that the proposed method provides technological improvements over existing methods, and its use is recommended for immediate experimental application.

FP.68 = RPA\_A1075.pdf

**[FHWA Position on Crumb Rubber Additive \(CRA\) for Asphalt Products](#)**

5 pages

The issue of scrap tires and their potential use of an additive for asphalt paving products have technical, economic, and environmental implications. Even though the technology exists to incorporate scrap tire rubber into asphalt paving products, there are still some long-term effects from using this recycled product, which have not been adequately addressed. This paper provides an overview of the Federal Highway Administration's background on these matters, a summary of the state-of-the-practice, a discussion of our long-term concerns, and a picture of the present and projected costs.

FP.69 = RPA\_A1076.pdf

**[Field Performance of Rubber Modified Asphalt Paving Materials](#)**

Shuler, T.S.; Pavolich, R.D. & Epps, J.A.

1985

52 pages

The following discussion describes the types of pavement construction studied by this research. A blend of ground tire rubber and asphalt cement is used as a binder in various types of pavement construction. This blend is called "asphalt-rubber" and consists of 18 to 26 percent ground tire rubber by total weight of the blend. The blend is formulated at elevated temperatures to promote chemical and physical bonding of the two constituents. Various petroleum distillates are sometimes added to the blend to reduce viscosity and promote workability. Asphalt-rubber is used as a binder in chip seal and dense and open graded

asphalt concrete construction. An asphalt-rubber chip seal, or seal coat, applied beneath an asphalt concrete overlay is called an "asphalt-rubber interlayer."

FP.70 = RPA\_A1077.pdf

**[Minimizing Reflection Cracking of Pavement Overlays](#)**

Sherman, George

ASHTO

September, 1982

44 pages

Synthesis of available information on reflective cracking and guidance on methods of preventing this problem. Asphalt rubber chip seals and interlayers are discussed. The asphalt rubber interlayer, along with other overlay systems, is mentioned as effective in retarding reflective cracking of asphalt concrete overlays on old asphalt concrete pavements. Results of two field experiments, which included asphalt-rubber interlayers, are included in the appendix.

FP.71 = RPA\_A1078.pdf

**[Use of Waste and By-Products in Highway Construction](#)**

Ormsby, W.C. & Fohs, D.G.

FHWA

January, 1990

6 pages

\* Presented at TRB

A short summary of use of scrap rubber and coalmine wastes in highway construction.

FP.72 = RPA\_A1079.pdf

**[Use of Waste Rubber in Highway Construction](#)**

Swain, Bob & Craig, Howard

FHWA

October, 1980

9 pages

In recent years, there has been a growing interest in the use of rubber from discarded tires in various highway construction and maintenance operations. Applications of asphalt-rubber materials currently being examined include: Seal coats, Joint and Crack fillers, & Strain relieving interlayers.

FP.73 = RPA\_A1080.pdf

**[The Search for the Optimal Asphalt](#)**

Chollar, Brian & Momon, Mohammed

FHWA

2 pages

The FHWA is constantly looking for new materials and methods to improve quality of our nation's highway system. This report summarizes the use of chemically modified crumb rubber (CMCR) to improve both high- and low-temperature performance grade specifications in many types of asphalts.

FP.74 = RPA\_A1081.pdf

## **Crumb Rubber Modifier (CRM) in Asphalt Pavements Quarterly Progress Report**

Yapp, Margot, Nichols Consulting Engineers

U.S. DOT

January, 1998

14 pages

This report summarizes the technical accomplishments of October 1 through December 31, 1997 quarterly report. Also this presents the activities planned for next quarter are presented for each task.

FP.76 = RPA\_A1082.pdf

## **SUPERPAVE Asphalt Mixture Design Illustrated Level 1 Lab Method S**

Anderson, R.M. & Mcgennis, R.B., Asphalt Institute

FHWA

November, 1994

77 pages

Key Words: Asphalt mix, asphalt cement, gyratory compactor, indirect tensile tester, level 1 design, mixture design, shear tester, SHRP, Superpave

This manual provides sequential, illustrated steps for performing the SUPERPAVE test procedures on asphalt mixtures, level 1 design. It also serves as a self-contained laboratory reference document on those procedures. These tests and procedures represent the results of the SHRP 5-year research effort to investigate and improve asphalt mix design technology. This manual was developed under the FHWA's National Asphalt Training Center.

FP.77 = RPA\_1083.pdf

## **The Legislative Process in the Arizona Senate**

State Senator Randall Gnant

1996

76 pages

Anyone reading this booklet should understand that with the exception of a few guidelines set forth in the Arizona Constitution, the entire legislative process is by Senate and House of Representatives Rules, which are adopted by a majority of the currently sitting Senate and House members. The process today is not the same as it has been in the past; the process may change in the future. While there are rules and a certain order to legislative process, there are also numerous methods and opportunities to avoid the rules and disrupt the order of things. It seems, at times, that there is at least one exception for every rule.

FP.78 = RPA\_A1084.pdf

## **Specification Guidelines**

Heitzman, M.A.

FHWA

20 pages

Specification guidelines for hot mixes and surface treatments that use CRM. Separate specifications are provided for: CRM; asphalt rubber binder; surface treatments with asphalt rubber binder; hot mix asphalt with asphalt rubber binder; and rubber modified hot mix asphalt.

FP.79 = RPA\_A1085\_1.pdf and RPA\_A1085\_2.pdf

**National Seminar on Asphalt-Rubber Pages 1-200**

**National Seminar on Asphalt-Rubber Pages 201-293**

U.S. DOT/FHWA/Texas State Dept. of Highways

October, 1981

293 pages

Eighteen presentations based on preprinted papers were made at the seminar in San Antonio, Texas. Included in this report are the eighteen reports presented at this seminar.

FP.80 = RPA\_A1086.pdf

**Use of Engineering Fabrics and Asphalt Rubber Interlayers to Minimize Reflective Cracking in Pavements**

U.S. Army Corps of Engineers

December, 15, 1985

7 pages

This letter provides guidance for minimizing reflective cracking of asphaltic concrete pavements.

FP.81            \$4.00

**An Investigation of Field and Laboratory-Compacted Asphalt-Rubber, SMA, Recycled and Conventional Asphalt-Concrete Mixes Using SHRP Project A-003A Equipment**

Harvey, John, Visiting Assistant Research Engineer; Monismith, Carl, University of CA & Sousa, Jorge, Applied Paving Technologies

1994

50 pages

The report considers the effect of laboratory compaction procedures on simulation of field compaction using permanent deformation as the criteria of effectiveness of the several procedures. Laboratory compaction procedures included Texas gyratory, (SHRP gyratory device was available for only a single set of measurements), rolling wheel (University of California, Berkley device), ASTM kneading compactor, and Marshall hammer. Laboratory predictions of permanent deformation were based on measurements made with the SHRP A-003 Universal Testing Systems (UTS using constant height repetitive shear). Mixes were collected from three sites with thirteen test sections included asphalt-rubber, dense graded, recycled hot mix, and SMA. Conclusions of the study include: 1) Long term hardening of the binder must be considered as part of the laboratory preparations process; 2) This study confirms previous conclusions that the Texas gyratory method produces mixes with the least resistance to permanent deformation; kneading compaction produces aggregate structures with the most resistance to permanent deformation, and rolling wheel compaction produced mixtures with resistance between gyratory and kneading compaction; 3) UTS is an improved testing method to capture the most critical mechanisms affecting flexible pavement performance.

FP.82 = RPA\_A1088.pdf

**Demonstration Projects Program**

US Dept. of Transportation

Federal Highway Administration

January, 1986

15 pages

This is a listing of the projects included in the Demonstration Projects Program and the Experimental Projects Program.

FP.83            \$4.00

**Tires: Decreasing Solid Wastes and Manufacturing Throughput  
Markets, Profits, and Resource Recovery**

Westerman, Robert R.

California State University, Sacramento

July, 1978

31 pages

The focus of this study is upon the solid waste tires segment of the tires system. We examine and measure a broad range of costs and benefits, however, including profits, costs, consumers, and job affects. The broad scope of this study, in lieu of myopic environmental management, is appropriate if the tires system is to be managed with equal respect allotted to each segment.

FP.84 = RPA\_A1090.pdf

**Edge Drainage in Pavement Rehabilitation**

Hallin, John P.

Federal Highway Administration

September, 1987

2 pages

Excess moisture in the pavement structure has long been recognized as a primary cause of pavement distress. Moisture related flexible pavement failures are characterized by excessive deflection, cracking, reduced load-bearing capacity, raveling, and disintegration.

FP.85 = RPA\_A1091.pdf

**Quality Management**

Gendell, David S.

Federal Highway Administration

September, 1987

2 pages

Since the first paved pathways recognized as roads were built in biblical times, through the Roman era and into modern times, someone has been interested in the quality of what was being done. Whether it was the size of the stone in a cobblestone street or the amount of air entrainment in portland cement concrete, we, as highway builders, have been concerned about providing a high quality product; that is, are specifications met, are the right materials being used, are construction procedures adequate, can we account for what we've done? In other words, is the taxpayer receiving a product that gives satisfactory performances at a reasonable cost?

FP.86            \$2.00

**The Photoelastic Stress Analysis of a Preformed Compression Seal**

Cook, John P.

Dept. of Civil Engineering, University of Cincinnati;

Committee on Sealants and Filters for Joints and Cracks in Pavements

1970

8 pages

This paper shows that the photoelastic method of stress analysis is well suited for studying the stresses in preformed compression joint seals. A sample problem is given to illustrate the method. A typical chevron seal shape is chosen for analysis. Photographs of photoelastic stress clearly show the points of stress concentration and the magnitude of the stresses. An appendix includes photographs of the phototelastic stresses in other joint seal configurations.

FP.87            \$2.00

**Hot-Poured Sealants**

Dzimian, Raymond J.

U.S. Rubber Reclaiming Co., Inc.

Committee on Sealants and Filters for Joints and Cracks in Pavements

1970

5 pages

Hot-poured sealants are either straight asphalt cements or asphalts that have been modified with fillers or rubber or both. They are the lowest in cost and the most widely used sealing materials available today. Specifications for hot-poured sealants are being written based on laboratory tests that often do not correlate with actual field performance. Sealant performance depends on type, quality, and quantity of materials used. It is suggested that materials requirements be included in sealant specifications. Various types of rubber used and manufacturing costs involved in the production of rubberized asphalt sealants are discussed. Installation procedures and problems affecting service life of the sealant are given. Cost comparisons are made between hot-poured sealants and other joint-sealing materials. Research is suggested that should result in a better understanding and improved quality of hot-poured sealants.

FP.88            \$2.00

**Evaluation of coatings on Coastal Steel Bridges, 16-year Period**

Rooney, Herbert A.; Woods, Albert L. & Shelly, Thomas L.

California Division of Highways

Committee on Coatings, Signing and Marketing Materials

1970

7 pages

The California Division of Highways investigated a wide spectrum of coatings for the protection of steel from corrosion in an aggressive marine environment for 16 years in the period 1952-1968. Evaluation of test sections of two bridges to which the coatings were applied showed that the best system after a 10-year exposure was an inorganic post-cure zinc-pigmented sodium silicate primer having a vinyl finish coat. This system was rated 9+, with 10 being perfect. Evaluation of the inorganic self-cure zinc-pigmented silicate primers will not be available for another 6 to 10 years. All other systems provided definitely inferior protection, the next best being an all-vinyl type.

FP.89            \$2.00

**Evaluation of Welded Deformed Wire Fabric Reinforcement in Machine-Made Concrete Pipe**

Heger, Frank J. & Chambers, Richard E., Simpson Gumpertz and Heger, Inc.;

Podolny, Walter & Ballard, Lawrence L., United States Steel Corp.

Committee on Culverts and Culvert Pipe

1970  
14 pages

A research project was undertaken to evaluate the structural behavior of machine-made concrete pipe reinforced with welded deformed wire fabric and to determine the validity of previously developed design methods for this type of pipe. Test results indicate significantly greater variability of both 0.01-in. crack strength and ultimate strength for machine-made pipe compared to the previously tested cast pipe. As long as this possibility of greater strength variability is recognized, the design formulas previously developed for 0.01-in. crack strength and ultimate flexural strength of cast pipe also apply to machine-made pipe. The design formula for ultimate diagonal tension strength may also be applied to machine-made pipe, but only with a larger safety factor and with certain modifications of provisions tentatively suggested in earlier work. Comparison of test results on companion pipe indicates that deformed wire fabric offers higher 0.01-in. crack strength than smooth wire fabric. For pipe made by the Packer-head process, the degree of improvement is even greater than was previously found for cast pipe.

FP.90            \$2.00

**A Concept of Preengineered, Prefabricated, Prestressed Modular and Multimodular Sealing Systems for Modern Bridges and Structures**

Watson, Stewart C.

Watson-Bowman Associates, Inc.

Committee on Sealants and Filters for Joints and Cracks in Pavements

1970

9 pages

Single module, modular, and multimodular sealing systems appear to offer long-term, maintenance-free solutions to newly developing problems at bridge joints being brought about by new design sophistication. The need for armored joints and their damping effect together with improved embedment practices are discussed. Upward and downward vertical forces, rotation, deflection, and horizontal thrust movements and their effect on seal shapes are illustrated. The typical bridge-joint environment clearly dictates the need for heavy-duty seal configurations. Web, top, and side minimums, depth-to-width ratios, and pressure-generation requirements are presented and analyzed. Some methods of reliable deck temperature determinations and adjustment for temperature are given. Creep-shrink calculations and testing of modular and multimodular systems are illustrated.

FP.91            \$2.00

**Bridge Expansion Joint Sealants**

Gunderson, Bruce J.

California Division of Highways

Committee on Sealants and Filters for Joints and Cracks in Pavements

1970

11 pages

Bridge joint seals placed in the field have been inspected and their effectiveness evaluated. Of the materials tested, seals of polyurethane seals, if properly installed, will effectively seal joints having up to ½ in. of movement. Poor construction practices account for a number of seal failures. Joints for preformed elastomeric seals should be engineered to fit the given

conditions. A "movement-rating" system, which determines the movement capability, has been developed for preformed elastomeric joint seals.

FP.92 = RPA\_A1098.pdf

**CPAR – Asphalt Rubber Research Study**

**Corps of Engineers Research Update**

September 13, 1990

27 pages

This report consists of lab tests completed since San Francisco project meeting (6/20/90). Includes binder tests, accelerated aging, and open-graded mixes.

FP.93 = RPA\_A1099.pdf

**Worker Health Aspects Associated with Crumb Rubber Modifier in Hot Mix Asphalt: Minutes of Meeting**

FHWA

April 20, 1994

7 pages

The objective of the meeting is to build consensus among interested groups for the proposed study plan by the Federal Highway Administration (FHWA) and National Institute for Occupational Safety and Health (NIOSH). The objective of the study is to examine potential worker health effects associated with the use of crumb rubber modifier (CRM) in hot mix asphalt (HMA) pavements as compared to conventional pavements. Today's meeting is also intended to serve as a platform for interested groups to provide input into the proposed study approach.

FP.94 = RPA\_A1100.pdf

**Worker Health Aspects Associated With Crumb Rubber Modifier in Hot Mix Asphalt**

FHWA

June 28, 1994

10 pages

The following were addressed: 1) Status of FHWA/NIOSH Interagency Agreement. Received FHWA clearance and has been forwarded to NIOSH; 2) Status of State Participation/Site Selection. Five sites will be selected by state highway agencies; 3) EPA/NIOSH Biological Monitoring Study. EPA received a preliminary proposal for NIOSH. There appears to be a gap between proposed work and resources that will require NIOSH to submit an alternate proposal within the week; 4) Health Hazard Evaluation Protocols. Suggestions by NAPA and the Asphalt Institute were received; 5) NAPA Summary on Environmental Controls Study. NAPA study is underway to determine the efficiency of equipment to reduce exposure of workers to asphalt fumes. Field experiments will be conducted next year. Attendees are listed and the NIOSH proposal is appended.