Polymer-Modified Asphalt Emissions from Alaskan Hot Plants

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A questionnaire and a literature study were conducted to collect information regarding the emissions produced when using polymer-modified asphalt (PMA) pavements in Alaska. The purpose of the study was to investigate if the emissions could be eliminated or reduced with existing experiences and information. And if existing know-how is not adequate, to propose a research plan to handle the emissions.

The emphasis of the study was to investigate factors such as equipment, method of mixing asphalt and aggregate, fuel used to heat aggregate, and the materials used that might be causing the emission problems.

On the basis of the research, it was concluded that the existing mixing plants are mostly drier drums older than 10 years, and the asphalt is mixed with aggregate through superheated air in the drum. The most commonly used fuel is diesel #2. The materials used included base asphalts AC-5 and AC-2.5, SBS and crumb rubber modifiers, and proprietary blends. Based on the small amount of materials used, it was impossible to determine which materials create most emissions. Recommendations were given to reduce emissions.

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Abstract

A questionnaire and a literature study were conducted to collect information from private contractors regarding the emissions produced when using polymer-modified asphalt (PMA) pavements in cold regions. The purpose of the study was to investigate if the emissions could be eliminated or reduced with existing experiences and information.

The emphasis of the study was to investigate factors such as equipment, method of mixing asphalt and aggregate, fuel used to heat aggregate, and the materials used that might be causing the emission problems.

On the basis of the research, it was concluded that the existing mixing plants are mostly drier drums older than 10 years, and the asphalt is mixed with aggregate through superheated air in the drum. The most commonly used fuel is diesel #2. The materials used included base asphalts AC-5 and AC-2.5, SBS and crumb rubber modifiers, and proprietary blends. Based on the small amount of materials used, it was impossible to determine which materials create most emissions. Recommendations were given to reduce emissions by using batch plants or modifying existing dryer drums to include special compartments for the mixing of asphalt with the aggregate, and by not exceeding the ideal mixing temperatures.

Summary of Findings

Based on the Environmental Protection Agency's (EPA) studies asphalt plants produce emissions and as a consequence EPA regulates them. According to the questionnaire study conducted, the responders did not have specific problems related to emissions. However, one of the Alaskan responders reported increased emissions with increased mixing temperatures. Another contractor using proprietary blends reported no increased emissions with temperatures. The responders used drier drum plants, and two of the three contractors have modified the plants to reduce emissions. There was not enough data to determine if any specific material or heating fuel causes excessive emissions.

Based on this study's results, the following recommendations to reduce emissions are given:

- Avoid spraying the asphalt onto the aggregate through the superheated air in the drum by modifying the plant or using a batch plant.
- Use pre-blended proprietary polymer-modified asphalts or conduct a product development program to reduce emissions.
- Do not exceed indicated ideal mixing temperatures.

1. Introduction

A questionnaire study was funded by the Alaska Department of Transportation and Public Facilities (AKDOT&PF) to collect information from private contractors regarding the emissions produced when using polymer-modified asphalt (PMA) pavements in cold regions. The use of PMAs has been recommended to control pavement rutting, cracking and premature aging. However, a concern has been raised that PMAs increase emissions from hot plants. At the same time, asphalt plant emissions are increasingly scrutinized by the Environmental Protection Agency (EPA) and Alaska Department of Environmental Conservation (ADEC) due to tighter regulations brought about by the Clean Air Act. Successful use of PMAs in cold regions depends on the ability of paving contractors to meet specifications, create the proper mix, install the pavement properly, and keep the production of asphalt-aggregate mix in accordance with the guidelines set forth by government agencies.

The purpose of the study was to investigate the emissions from Alaskan hot mix plants producing PMA mixtures and determine if the emissions could be eliminated or reduced through past experiences and existing information. This was done by collecting information from local and out of state contractors. If the existing knowledge is not adequate, a research plan to expand current knowledge is to be proposed. The emphasis of the study was to investigate factors that might be causing the emission problems. These factors include:

- mix producing equipment (age and type),
- the materials used (type of base asphalt, polymers, other additives)
- method of mixing asphalt and aggregate, and
- fuel used to heat aggregate.

The investigation was done as a questionnaire and literature study.

2. Questionnaire Study

A total of thirteen contractors in Alaska, Arizona, and California were contacted by either phone or mail. Seven contractors who responded that they are using PMA mixtures (or thought they had used them in the past) received a questionnaire given in Table 1. A summary of contacts, responses and responders is given in Table 2. The list of contractors-producing asphalt cements in Alaska was received from the AKDOT&PF. The others were received through personal contacts. After the questionnaire was sent out three times, three of the four contractors using PMAs responded. Their answers to the questionnaire are given in Table 3 and summarized in the following sections.

Table 1. Questionnaire

1.	What is the make and model of the hot mix equipment used at the plant?
2.	Is it a batch-type hot plant or a drier drum mix plant?
3.	What is the age of the equipment?
4.	Have any modifications, improvements, or other alterations been made to the equipment in an attempt to reduce emissions? What and when?
5.	What type of emissions scrubber is currently used on the plant?
6.	Which method of mixing the asphalt and aggregate is used?
	☐ The asphalt is sprayed through the super-heated air in the drier drum.
	☐ The asphalt is added to the aggregate in a separate custom-built compartment.
	☐ The asphalt is added in the pug mill of a batch plant.
	☐ Other:
7.	What are the typical mixing temperatures with:
	• Polymer-modified asphalts
	• AC-5
	• AC-2.5
	• Other grades (give grade)
8.	Is there a specific mixing temperature at which you notice more or less emissions?
9.	What fuel type is used to fuel the burners at the plant?
10.	Do you store the asphalt-aggregate mixture after mixing? Where and for how long?
11.	What types of materials are used? • Polymer type/grade: • Polymer concentration (if known): • Base asphalt (source and grade): • Proprietary products: • Non-polymer modifiers:
12.	Are air quality records available for the plant (records while using polymers and records when polymers were not added)?
13	Has the plant had an air emission source test (permit compliance test required by ADEC) done while producing the polymer mix? • If so, what were the derived particulate matter emission rates with polymers? • What were they without the polymers?
14.	Have any specific problems been encountered which would affect the quality of emissions from the plant?

Table 2. Contractors Contacted

Contractor	Phone Interview: Do you use PMAs?	Questionnaire Mailed:	Response Received:
Summit Paving and Construction, AK	YES	YES	YES **Gerald DesJarlais, President**
Quality Asphalt Paving, AK	NO	NO	NO
H&H Contractors, AK	NO	NO	NO
Alaska Road Builders, AK	NO	NO	NO
GMG General, AK	NO	NO	NO
Herndon and Thompson, AK	NO	NO	NO
Wilder Construction, AK	YES	YES	YES **Jeff Kron, Plant Manager**
South Coast Construction, AK	Maybe in the past	YES	NO
Northstar Paving, AK	NO	NO	NO
Tanner Companies, AZ	YES	YES	YES **Donald Green, P.E., Director**
ATA Construction Company, AZ	YES	YES	NO
Silva Construction, CA	No interview	YES	NO
Union Rock and Materials Corporation, AZ	No interview	YES	NO

Table 3. Questionnaire Responses

Questions 1-5

Location	Company	1. Make/ Model	2. Batch or Drier Drum?	3. Age of Plant	4. Modifications?	5. Type Emissions Scrubber
Anch. AK	Wilder Construction	DM 65 Barber Green Drum Mix	Drier drum	20+ years	No	Bag house
Anch. AK	Summit Paving & Construction	Boeing 400	Drier drum	12 years	No	Bag house
Phoenix, AZ	The Tanner Companies	9 Drum Plants of different configurations	Drier drum	<15 years	No	Bag house

Table 3. Continued, Questionnaire Responses
Questions 6-10

Location	Company	6. Mixing Method	7. Typical Mixing Temperatures	8. Effect of Mixing Temperature?	9. Type of Fuel	10. Storage of mixture
Anch. AK	Wilder Construction	Asphalt pumped in at end of drier at metered quantity.	PMA : 155° C AC-5 : 135° C AC-2.5: 135° C	As temperatures rise, so do emissions	Diesel #2	None
Anch. AK	Summit Paving & Construction	Special injection chamber in the drum to minimize air exposure	PMA : 168° C AC-5 : 138°-149° C	Increased emissions as temperatures exceed the indicated temperatures	Diesel #2	4 hour max storage time in silo
Phoenix, AZ	The Tanner Companies	Sprayed through super heated air in drum, added to aggregate in special compartment, added in the pug mill	PMA : 166° C AC-5 : N/A AC-2.5 : N/A Other : 157° C	No	Reclaimed Oil Diesel #2 Natural Gas	Several hour storage in silos

Table 3. Continued, Questionnaire Responses
Questions 11-14

Location	Company	11. What types of material are used?	12. Air Quality Records	13. Permit requirement ?	14. Specific Problems?
Anch. AK	Wilder Construction	Polymer: Rubber Concentration: 3% Base Asphalt: AC-5, AC-2.5 Proprietary Products: None Non-Polymer Modifiers: None	DEC Required stack test completed	N/A	Jobs specifying warm ATB should include specifications for virgin rock and not RAP. The RAP produces blue smoke as the asphalt is burned off.
Anch. AK	Summit Paving & Construction	Polymer: SBS : PG58-28 Concentration: 3% Base Asphalt: Williams-Tesoro-AC-5 Proprietary Products: None Non-Polymer Modifiers: None	No	N/A	No
Phoenix, AZ	The Tanner Companies	Terminal blends Crumb Rubber	No	No	No

Background: Use of Polymer-Modified Asphalt Pavements in Alaska. PMAs have been used in pavements for up to 15 years. In previous studies, mixing temperature at the hot mix plant was always higher than that of conventional mixes (Zubeck et al 1999). Also, the effects of ambient or outside air temperature are more critical with PMA mixes than conventional mixes, which means that the ideal mixing temperatures for PMAs must be maintained high. This is a specific concern in Alaska, where, in general, air temperatures are much lower than other states. Most agencies specify the minimum air temperature at which the asphalt mix can be placed. Alaska prohibits placing HMA unless the roadway surface temperature is 5°C (41°F) or warmer.

2.1 Summary of Responses

General: PMA use in Alaska is not routine practice, and only a few contractors have dealt with the emissions implications of this type of application.

Equipment: Questions about the equipment were asked 1) to develop a database, and 2) because of the authors' hypothesis that emissions from batch plants are less than that from drier drum plants, and that modifications such as special compartments to mix asphalt with aggregate reduce emissions.

All responders are using drier drum plants that are over 10 years old. There is no common brand of drum plant being used neither in Alaska nor in Arizona. All plants are outfitted with baghouse filter emission scrubbers. None of the responders reported modifications to their plants. However, answers to question 6 (about the mixing method) revealed that in two plants, one in Alaska and one in Arizona, the asphalt is sprayed in a "special compartment" or "special injection chamber" added to the pug mill. These are the kinds of modifications that the authors were expecting to find.

Asphalt-Aggregate Mix Production: Questions about mix production were asked to create a database and because of the authors' hypothesis that the following factors increase emissions:

- Asphalt is sprayed or injected onto the aggregate in the drum through superheated air that is actually hotter than the specified mixing temperature. The gases in the drum may be higher than 300°C, whereas the needed spraying temperature is much lower. (Figure 1, FHWA, 1999)
- Increased mixing temperature increases emissions in some cases.
- A specific fuel used to heat the aggregate.
- Long storage time of asphalt-aggregate mixture.

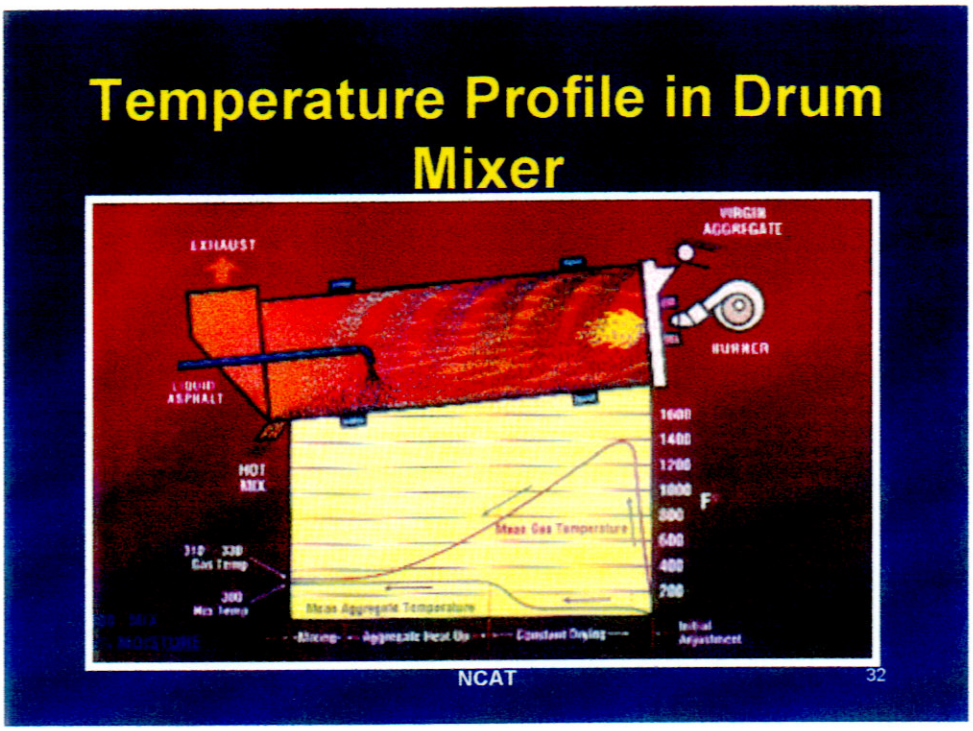

Figure 1. Temperature Profile in Drum Mixer (FHWA, 1999)

Two of the three responders reported using special "injection chambers or compartments" in which the asphalt is mixed with aggregate to reduce emissions and asphalt aging. The typical mixing temperatures for the PMAs varied from 155 to 168°C, for the AC-5's from 135 to 149°C and for the AC-2.5 a mixing temperature of 135°C was reported. One of the responders from Alaska reported that emissions increased with increased mixing temperature. The other responder from Alaska reported increased emissions above the indicated ideal mixing temperatures. The responder from Arizona did not experience more emissions with increased mixing temperature.

All responders used diesel #2 as a heating fuel for the plant. The Arizona contractor also uses reclaimed oil and natural gas. The storage time for the asphalt-aggregate mixture varies from zero to several hours. One of the responders in Alaska reported a maximum storage time of four hours.

Materials: Questions about the materials were asked to create a database and because the authors' hypothesis that the following factors may increase the amount of emissions:

- Mixing polymers with base asphalts that are not developed for polymer-modified asphalts.
- Certain polymer types.
- Increased polymer concentration.
- Additional modifiers, e.g. other oil products that may produce emissions when heated.

Based on the study by Zubeck et al. (1999) pre-blended, often proprietary, blends do not produce excessive emissions. These products are the end result of a comprehensive research and product development program that considers mixing temperatures and emissions.

The Alaskan responders reported that they mix a polymer with local base asphalts, AC-5 or AC-2.5. They are not using pre-blended proprietary products or non-polymer modifiers. The reported polymers were "rubber," which may be a styrene-butadiene-rubber (SBR), or styrene-butadiene-styrene (SBS). The polymer concentration was 3%. The responder from Arizona uses "terminal blends" that the authors call proprietary blends. They also use crumb rubber from recycled vehicle tires.

Air Quality Records: In order to find out which factors affect the amount of emissions, contractors were asked if they have air quality measurements on file. None of the responders had any records collected. One of the contractors from Alaska reported that they completed the stack test required by the ADEC. None of the responders had the air emission source test conducted (compliance test required by ADEC).

Specific Problems: Two of the responders had no specific problems. The third reported that recycled asphalt mixture (RAP) produces blue smoke when heated at high temperature.

3. Literature Study

In addition to the questionnaire study, information was researched from other sources. The following sections include summaries from emission publications by the EPA and the National Asphalt Pavement Association (NAPA). Internet search results and agency requirements are also summarized below.

EPA and NAPA Studies: The data in the following informational section is from the "Hot Mix Asphalt Plants Emission Assessment Report (DRAFT)" EPA-454/R-00-0XX. The information is included to provide a basis for future comparison of emission composition between Alaskan drum plants and the national average. The national averages were derived from a study, which consisted of a detailed examination of approximately 350 drum plant emissions records.

The EPA has developed a means of estimating the amount of emissions from these drum plants. In 1996, over 500 million tons of hot mix asphalt (HMA) were produced in the United States. Of this, an estimated 1,300 drum plants produced approximately 260 million tons. This yields approximately 200,000 tons a year for a typical drum plant. Approximately 85% of the plants being constructed today are drum mix plants.

HMAs produce two major categories of emissions: ducted sources (those vented to atmosphere via a stack, vent, or pipe), and fugitive sources (emitted directly from the source to open air).

The primary emission source of a drum plant is the mixers. These mixers produce particulate matter (PM) along with a variety of other gaseous pollutants and are the focus of the EPA study. The PM emissions associated with these HMA production facilities include PM-10 and PM-2.5 (particulate matter less than 10 and 2.5 micro meters diameter respectively), hazardous air pollutants (HAP), and metals and associated organic compounds. Other sources of emissions include storage silos, truck load-out emissions, hot oil heaters, and emissions from the HMA in the truck beds.

The EPA developed a set of factors to estimate the quantity of emissions from a HMA plant for a given period of time using data from the test reports. The factors are

derived by dividing the measured emission rate by the measured HMA production rate. These estimates and factors are based on several assumptions:

- Mixers are fired with natural gas
- Mixer emissions are controlled with fabric filter
- PM emissions from load out and silo filling are all PM-10
- Annual HMA production rate for a typical drum mix facility is 200,000 tons/year

Table 4 shows estimated annual emissions for a typical drum mix plant. Table 5 presents a detailed list of specific emission types and quantities for drum mix plants. The data provided by the EPA is only in draft form, and revisions are pending. The NAPA disputes some of the data contained in the EPA report. The specific points are detailed in the "Evaluation of Stack Emissions from HMA Facility Operations, Special Report 166 (NAPA 1993)". These emission estimates provide insight into the composition of typical HMA drum plants across the United States. Knowing this composition matrix is crucial to understanding emission records of the plants.

NAPA has also compiled information regarding construction practices and mixing temperatures for HMA companies to reduce emissions. The NAPA emphasizes the importance of asphalt storage and HMA mixing temperatures. The recommended temperatures for PG grades are given in Table 6.

Internet search: A search was performed via Internet regarding the emissions generated from HMA drum plants. A list of applicable websites for obtaining and downloading information on the subject is included in the references. These websites contain a wide variety of information including proprietary information on specific brands, EPA findings, new uses, test results, as well as cost information. The readers are advised to visit these and other sites for information on particular products and applications. The available information, though useful, is too broad to be included in this report.

Agency requirements: The viability of PMA use in Alaska is dependent on the ability of the contractor to meet the regulations placed on them by the EPA / ADEC. The agencies have implemented a stack test to determine the amount of emissions produced by a hot mix plant. The requirements for hot mix asphalt plants found in the Code of Federal Regulations are lengthy. They can be found in 40 CFR Part 60 Subpart i, Standards of Performance for Hot Mix Asphalt Facilities.

Table 4. Estimated Annual Emissions for a Typical Drum Mix Plant (EPA, 2000)

Pollutant	Annual Emissions by Source, kg/yr (lb/yr)					
	Dryer	**Load-out**	**Silo filling**	**Asphalt Storage**	**Yard**	**Total**
Criteria air pollutants						
PM-10[1]	2,087 (4,600)	31 (69)	53 (117)			2,171 (4,790)
Volatile Organic Compounds (VOC)	2,903 (6,400)	350 (772)	1,107 (2,440)	29 (64)	100 (220)	4,489 (9,900)
Carbon Monoxide	12,701 (28,000)	123 (270)	107 (236)	3 (6)	33 (72)	12,966 (28,600)
Sulfur Dioxide	308 (680)					308 (680)
Nitrogen Oxides	2,631 (5,800)					2,631 (5,800)
Hazardous air pollutants (HAP)						
Polycyclic aromatic hydrocarbons (PAHs)	17 (38)	1 (2)	3 (1)			21 (46)
Phenol		0.2 (0.4)				0.2 (0.4)
Volatile HAPs	417 (920)	6 (12.4)	14 (31)	.4 (0.8)	1.5 (3.3)	439 (968)
Metal HAPs	7 (16)					7 (16)
Total HAPs	442 (974)	7 (14.7)	17 (37)	.4 (0.8)	1.5 (3.3)	468 (1,030)

1. Atmospheric fine particulates

Table 5. Specific Emission Quantities (EPA, 2000)

Pollutant	Emissions, kg/yr (lb/yr)	Pollutant	Emissions, kg/yr (lb/yr)
Criteria Pollutants		**Volatile HAPs**	
PM-10	2,086.5 (4,600)	Isooctane	3.6 (8)
VOC	2,903 (6,400)	Hexane	81.6 (180)
CO	12,700.6 (28,000)	Benzene	45.3 (100)
SO2	308.4 (680)	Ethylbenzene	21.8 (48)
NOX	2,630.8 (5,800)	Formaldehyde	226.8 (500)
PAHs		Methyl chloroform	4.35 (9.6)
2-Methylnapthhalene	6.7 (14.8)	Toluene	13.6 (30)
Acenaphthene	0.13 (0.28)	Xylene	18.1 (40)
Acenapthylene	0.78 (1.72)	**Metal HAPs**	
Anthracene	0.02 (0.044)	Lead	0.05 (0.12)
Benzo(a)anthracene	0.02 (0.042)	Mercury	0.022 (0.048)
Benzo(a)pyrene	0.001(0.002)	Antimony	0.016 (0.036)
Benzo(b)fluoranthene	0.01 (0.02)	Arsenic	0.05 (0.11)
Benzo(e)pyrene	0.01 (0.022)	Beryllium	0 (0)
Benzo(g,h,I)perylene	0.0036 (0.008)	Cadmium	0.037 (0.082)
Benzo(k)fluoranthene	0.0037 (0.0082)	Chromium	0.5 (1.1)
Chrysene	0.016 (0.036)	Manganese	0.7 (1.54)
Fluoranthene	0.054 (0.12)	Nickel	5.7 (12.6)
Fluorine	0.34 (0.76)	Selenium	0.03 (0.07)
Indeno(1,2,3-cd)pyrene	0.0006 (0.0014)		
Naphthalene	8.16 (18)		
Perylene	0.008 (0.0018)		
Phenanthrene	0.69 (1.52)		
Pyrene	0.05 (0.11)		

Table 6. Suggested Storage and Mixing Temperatures to Reduce Emissions (NAPA 2000)

Binder Grade[1]	HMA Asphalt Tank Storage Tank Temperature Range (C°)	HMA Plant Mixing Temperature Range (C°)
PG 46-28	127-143	116-146
PG 46-34	127-143	116-146
PG 46-40	127-143	116-146
PG 52-28	127-146	116-149
PG 52-34	127-146	116-149
PG 52-40	127-146	116-149
PG 52-46	127-146	116-149
PG 58-22	138-152	127-154
PG 58-28	138-152	127-154
PG 58-34	138-152	127-154
PG 64-22	141-157	129-160
PG 64-28	141-157	129-160
PG 64-34	141-157	129-160
PG 67-22	146-149	138-163
PG 70-22	149-163	135-166
PG 70-28	141-160	135-163
PG 76-22	157-166	141-168
PG 76-28	154-163	138-166
PG 82-22	157-168	143-171

[1] PG grades are not necessarily polymer modified.

4. References

Environmental Protection Agency, EPA (2000) "Hot Mix Asphalt Plants Emission Assessment Report (DRAFT)." EPA-454/R-00-0XX.

Code of Federal Regulations, 40 CFR Part 60 Subpart i, Standards of Performance for Hot Mix Asphalt Facilities.

Federal Highway Administration, "Hot Mix Asphalt for the Undergraduate," (1999), http://www.fhwa.dot.gov/asphtech/junior/lectures/block4/b4lect1.htm.

National Asphalt Pavement Association, Asphalt Institute, State Asphalt Pavement Associations (2000) "Best Management Practices to Minimize Emissions During HMA Construction." EC 101.

National Asphalt Pavement Association Task Force, NAPA (1993) "Evaluation of Stack Emissions from HMA Facility Operations." Special Report 166.

Zubeck, H. K., Raad, L., Ryer, J. (1999) "Constructability of Polymer-Modified-Asphalts and Asphalt-Aggregate Mixtures in Alaska.", FHWA-AK-RD-99-1, ftp://ftp.dot.state.ak.us/pub/nres/Research%20Reports/FHWA-AK-RD-99-1.pdf

4.1 Recommended Web Sites

- www.dupont.com/asphalt/H-81613.html
- www.fhwa.dot.gov/asphtech
- http://www.vti.se/nordic/
- www.heatec.com
- www.new-technologies.org/ECT/Civil/ar2000.htm
- www.rubberpavements.org
- www.utexas.edu/research/superpave/articles/
- www.arra.org/affil.htm
- http://www.mincad.com/
- www.hotmix.org/
- www.epa.gov/ttnemc01/asphalt.html