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DEVELOPMENT OF GUIDELINES AND PERFORMANCE FOR ASPHALT CONCRETE CONTAINING RECYCLED RUBBER

by

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16. Abstract:

The primary objective of this study was to investigate the feasibility of implementation of the crumb rubber technology in Kentucky. The impetus for this study was provided by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

This study included an overview of existing literature on the subject from an implementation point of view for Kentucky's conditions. Upon completion of this phase of the study, guidelines were developed by the KTC research team and were submitted to the Transportation Cabinet for field implementation of the crumb rubber modifier (CRM) technology in Kentucky. From the ease of implementation point of view, the Cabinet opted to construct a field trial section using the "wet process" which utilized a fine ground rubber (80 mesh) material. The rationale for this decision was based upon the fact that the fine ground CRM mix closely resembles the polymer modified HMA, and that both the Cabinet and Kentucky contractors have an extensive amount of experience with polymer modified asphalt.

In July 1993, a field trial project was constructed on a portion of the US 421, Franklin County, Kentucky. The project involved milling of nominally one inch of the wearing surface followed up by a nominally one-inch overlay. The four-lane trial project (two lanes in each direction) was divided into two approximately half-mile sections. This allowed for a comparison of performance between the CRM hot mix asphalt (HMA) and the conventional HMA.

In summary, the trial implementation of the CRM technology in Kentucky proved to be a success. The 177-micron (80-mesh) fine ground rubber at 7.5% by weight of asphalt cement provided a material similar to polymer modified asphalt. Construction of the field project was possible with existing specifications and practices in Kentucky. The non-intrusive nature of the fine ground technology was most desirable from the ease of implementation point of view.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

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In July 1993, a field trial project was constructed on a portion of the US 421, Franklin County, Kentucky. The project involved milling of approximately 2.54 cm (one-inch) of the wearing surface followed up by a nominally 2.54 cm (one-inch) overlay. The four-lane trial project (two lanes in each direction) was divided into two approximately 0.8 km (half-mile) sections. This allowed for a comparison of performance between the CRM hot mix asphalt (HMA) and the conventional HMA.

The mix design was developed jointly by the contractor and the KTC research team. Construction of the trial section proceeded without difficulty. A documentation of key features of construction activities is presented in this report.

Post-construction interviews with the contractor revealed that the CRM hot mix construction was very similar to the conventional HMA construction.

In summary, the trial implementation of the CRM technology in Kentucky proved to be a success. The 177-micron (80-mesh) fine ground rubber at 7.5% by weight of total asphalt binder provided a material similar to polymer modified asphalt. Construction of the field project was possible with existing specifications and practices in Kentucky. The non-intrusive nature of the fine ground technology was most desirable from the ease of implementation point of view. Field performance of this project after 1.5 years in service revealed no major modes distress. Both the control section and the CRM section have been performing well. More time is needed to monitor manifestation of various modes of distress. It is recommended that long-term performance of this project be monitored.

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SCOPE OF THE STUDY

The overall objective of this study was to develop guidelines for utilization of crumb rubber in asphaltic concrete pavements. These guidelines were intended to cover areas dealing with materials characterization, mixture design, construction process control, and overall quality assurance/quality control (QA/QC) issues. New and innovative approaches to crumb rubber utilization as well as the traditional hot mix asphalt applications were investigated. General assessments of the economic and environmental impacts of the ISTEA mandate were also made.

The research study was conducted in accordance with a multi-phase approach: review of state-of-the-art, laboratory characterization of mixtures, construction of field trial sections, and performance evaluation.

Phase I of the research involved investigation of potential applications for recycled rubber and development of an experimental plan for an experimental field application.

1. Identify and study the feasibility of potential methods for utilizing recycled rubber in bituminous pavement mixtures.

2. Develop recommendations for utilization of rubber modified hot mix asphalt, and stress absorbing membrane interlayer (SAMI). Develop guidelines for design and construction of rubber modified hot mix asphalt with little or no modifications to the current design/construction practices in Kentucky.

3. Develop a plan for an experimental field application for the most promising potential utilization for recycled rubber in pavements.

Phase II of the research was designed to address the following long-term issues:

1. Evaluate performance of experimental sections in the field. Obviously, this will require funding commitment beyond the duration of this two-year study.

2. Develop guidelines for the long-term utilization of recycled rubber in pavements on the basis of the literature review and the experience with field studies in Kentucky. Again, this activity would require a continuation of efforts initiated during this study beyond the two-year duration of this study.

INTRODUCTION

U.S. motorists dispose of approximately 250 million automobile tires and about 25 million truck tires each year (SHRP 1991). Unofficial accounts indicate that in Kentucky we dispose of approximately 3.7 million tires per year which amounts to one tire/person/year (1990 Kentucky population: 3,685,268). It is estimated that there are presently 40 million scrap tires in Kentucky, in one location alone (Alexandria, Kentucky) there is a pile of 10 million tires. Clearly, this poses a variety of environmental concerns, ranging from insect control, fire hazard, to air and water quality issues. All trends indicate that waste disposal is "out", and waste utilization is "in" (California Health Department, 1990).

The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) has mandated the use of scrap tire rubber in asphalt pavements based on the tonnage on federal-aid funded projects in accordance with the following schedule:

a- 5 percent for the year 1994 (waived, section 325 of H.R. 2750, 1993);
b- 10 percent for the year 1995 (waived);
c- 15 percent for the year 1996; and
d- 20 percent for the year 1997 and each year thereafter.

There are unique features related to the design and construction of asphaltic concrete pavements containing crumb rubber which deserve special considerations. These considerations often involve adaptation and/or modification of conventional asphalt technology to rubber-modified materials.

SUMMARY OF LITERATURE REVIEW

Task 1 (Review of the State-of-the-Practice) of the work plan included a survey of literature and submittal of an interim report. To this end, an interim report was submitted to the Cabinet in January 1993 (Report KTC-93-2). This interim report was intended to provide an overview of the literature on the subject. In 1992, an FHWA report was released on the subject; this report provides an excellent source of information on the history, as well as the state-of-the-art of the asphalt rubber technology (Heitzman 1992). In the context of this final report, the intention is to provide a summary of key points that are important to successful implementation of the asphalt rubber technology in Kentucky in accordance with ISTEA, while realizing that more details may be found in references listed at the end of this report. Various asphalt rubber technologies are presented in this report along with their advantages and disadvantages. Issues related to structural design and construction are also discussed. A variety of environmental issues such as: emissions, leachate and issues related to future recyclability are presented. Finally, criteria are recommended to be used for selection of future asphalt rubber projects in Kentucky.

Terminology

Unfortunately, the misuse of asphalt rubber terms is common throughout the asphalt industry. This section is designed to establish a common ground for the asphalt rubber terminology in Kentucky. Terminology that is acceptable by ASTM, FHWA, and asphalt rubber producers is summarized and it is recommended for adoption by the Transportation Cabinet. The following summary of terminology and abbreviations was adopted from the report FHWA-SA-92-022 by Heitzman, 1992.

Asphalt Rubber (AR):

Asphalt cement modified with crumb rubber. Note that ASTM D-8 defines it as: "a blend of asphalt cement, reclaimed tire rubber and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles".

Buffing Waste:

High quality scrap tire rubber which is a by-product from the conditioning of tire carcasses in preparation for retreading.

Crackermill:

Process that tears apart scrap tire rubber by passing the material between rotating corrugated steel drums, reducing the size of the rubber to a crumb particle (generally 4.75 millimeter to 425 micron, No. 4 to No. 40 sieve).

Crumb Rubber Modifier (CRM):

A general term for scrap tire rubber that is reduced in size and is used as a modifier in asphalt paving materials.

Cryogenic:

Process that freezes the scrap tire rubber and crushes the rubber to desired particle size.

Diluent:

A lighter petroleum product (typically kerosene) added to asphalt rubber binder just before the binder is spray applied to the pavement surface.

Dry Process:

Any method that mixes the crumb rubber modifier with the aggregate before the mixture is charged with asphalt binder. This process only applies to hot mix asphalt (HMA) production.

Extender Oil:

An aromatic oil used to supplement the asphalt/crumb rubber modifier reaction.

Granulated CRM:

Cubical, uniformly shaped, cut crumb rubber particles having a low surface area which are generally produced by a granulator.

Granulator:

Process that shears apart the scrap tire rubber, cutting the rubber with revolving steel plates that pass at close tolerance, reducing the size of the rubber to a crumb particle (generally 9.5 millimeter to 2.0 millimeter, 3/8-inch to No. 10 sieve).

Ground CRM:

Irregularly shaped torn crumb rubber particles having a large surface area which are generally produced by a crackermill.

Micro-mill:

A process that further reduces a crumb rubber to a very fine ground particle, reducing the size of the crumb rubber below 425 micron (No. 40 sieve).

Reaction:

The interaction between asphalt cement and crumb rubber modifier when blended together. The reaction, more appropriately defined as polymer swell, is not a "chemical reaction". It is the absorption of aromatic oils from the asphalt cement into the polymer chains of the crumb rubber.

Rubber Aggregate:

Crumb rubber modifier added to HMA mixture using the dry process which retains its physical shape and rigidity.

Rubber Modified Hot Mix Asphalt (RUMAC):

Hot mix asphalt which incorporates crumb rubber modifier primarily as rubber aggregate.

Shredding:

Process that reduces scrap tires to pieces 0.15 meter (6 inches) square and smaller.

Stress Absorbing Membrane (SAM):

A surface treatment using an asphalt rubber spray and cover aggregate.

Stress Absorbing Membrane Interlayer (SAMI):

A membrane beneath an overlay designed to resist the stress/strain of reflective cracks and delay the propagation of the crack through the new overlay. The membrane is often a spray application of asphalt rubber and cover aggregate.

Wet Process:

Any method that blends crumb rubber modifier with the asphalt cement prior to incorporating the binder in the asphalt paving project.

NOTE:

According to the Asphalt-Rubber Producers Group (ARPG), the term Asphalt Rubber should be used when referring to the material derived from the wet process, while the term Rubberized Asphalt should be used for the material produced via the dry process (Roads and Bridges Magazine, December 1992).

Major Applications of the CRM Technology

Wet Process

This process is basically an asphalt binder modification process. The crumb rubber modifier (CRM) is added to the asphalt binder prior to its paving application. A reaction takes place between the asphalt and the CRM at high temperatures ranging from 177°C to 204°C (350°F to 400°F) and after 45 minutes to 1 hour of mixing and agitation. This reaction, which is called polymer swell, is often enhanced by the addition of extender oils such as kerosene.

Advantages

1. The crumb rubber modified asphalt produced via the wet process exhibits higher viscosity and less temperature susceptibility compared to the original unmodified asphalt. This is similar to polymer modified asphalts.

2. Because the process deals with the binder alone, it lends itself to both hot mix and spray applications. It may also be produced in emulsion form (Terry Industries product marketing brochures, 1992).

3. In hot mix applications, the CRM asphalt binder may be used in batch plants as well as drum plants without any operational complications.

4. Mix design may be accomplished with minor modifications to the conventional hot mix design practices. These modifications are very similar to binder rich polymer modified mixes.

5. Experienced suppliers operate under the umbrella of the Asphalt-Rubber Producers Group (ARPG, sometimes referred to as the "Arizona Group"). These suppliers have the experience and the capability of engaging in a partnering relationship with the state DOTs and producing a custom made product.

Disadvantages

1. The crumb rubber modified binder produced via the wet process has a short shelf life; it must be used within hours of its production.

2. Special pumps and tanks (reaction tanks with a mechanical agitator system) are needed.

3. Frequent monitoring of the reaction is necessary.

4. Long-term performance characteristics are unknown.

5. The cost of conventional HMA on this project was $32.63 per metric ton ($29.60 per ton), while the CRM-HMA cost was $51.00 per metric ton ($46.26 per ton) -- i.e. CRM-HMA on this project was more expensive than the conventional HMA by 56%.

Dry Process

The term "dry" refers to the addition of granulated crumb rubber to the heated aggregate in dry form prior to becoming "wet" by asphalt. Due to the particular nature of this process, there is a slight reaction between the granulated rubber and asphalt cement during mixing.

Advantages

1. Application in the batch plant is simple. Bags of CRM may be delivered to the pugmill similar to certain polymers, fibers, etc.

2. Compared to the wet process, much larger quantities of scrap tire rubber may be disposed of in this manner.

3. The production cost of granulated rubber is less than the fine ground type. Additionally, the dry process HMA is less complicated and therefore, less expensive than the wet process. Hence, the overall cost of dry process is less than the wet process (dry process: 30% to 50% cost increase, compared to wet process: 60% to 100%, Roads and

Bridges Magazine, December 1992; Rouse Rubber Industries, Information Brochures, 1992; Estakhri et al., 1992; Heitzman, 1992).

4. In response to a patented gap graded dry process, called PlusRide, most states have developed their own versions, called generic dry technology, information on which is available to the public.

Disadvantages

1. The dry process is limited to HMA applications.

2. It is hypothesized that with time, the "unreacted" rubber particles in the asphalt pavement rob the asphalt from its lighter molecules and thereby induce premature aging, brittleness and stripping in the asphalt layer.

3. Application in the drum plant involves introducing the CRM at a point away from the flame in order to prevent emissions associated with combustion of rubber (i.e. blue smoke). This requires a drum plant having an opening designed for this purpose (such as the recycled asphalt opening) or double barrel drum plant. However, this may not be a major concern since most drum plants in Kentucky are outfitted with a recycled material feed capability.

4. Depending upon the size of rubber particles used, alterations in the aggregate gradations and the job-mix formula may be necessary. Also, achieving density may become a problem due to swell.
5. Long-term performance characteristics are unknown.

New Technologies

UltraFine™

Rouse Industries, of Vicksburg, Mississippi, developed a material which is very fine 177-micron (No. 80-mesh) - with a mean particle size of 74 micron (No. 200 mesh), Rouse Rubber Industries, Information Brochures, (1992). They have shown that by using their UltraFine™ material the "reaction time" may be significantly reduced (less than a minute instead of an hour). There have been a few test sections in place and data on long-term performance of this material are not available.

Advantages

1. Short reaction time.

2. Has potential to be produced at the terminal in a manner similar to conventional modified asphalt binders.

3. This process cost is higher than the conventional HMA.

Disadvantages

1. The material producer has been primarily focusing on selling the UltraFine™ material and not necessarily the associated paving technologies.

2. Long-term performance characteristics are unknown.

3. The cost of conventional HMA on this project was $32.63 per metric ton ($29.60 per ton), while the CRM-HMA cost was $51.00 per metric ton ($46.26 per ton) -- i.e. CRM-HMA on this project was more expensive than the conventional HMA by 56%.

Flexochape™

The French road contractor, Beugnet, developed a process by which the shelf life of the asphalt rubber increases to eight days; the binder is marketed under the trade name Flexochape™. Conventional asphalt rubber binders, produced by the wet process, must be used within a few hours of production. The Flexochape™ may viewed as a major breakthrough in implementation of asphalt rubber technology. At this time, there are no performance data available for this material.

Advantages

1. Extended shelf life (days instead of hours).

2. Has a long-term potential to be handled in a manner similar to conventional modified asphalts.

Disadvantages

1. It is expected to be very expensive.

2. It is not widely available in the U.S.

3. Long-term performance characteristics are unknown.

Chunk Rubber Asphalt Concrete

The Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Corps of Engineers was contracted by the Strategic Highway Research Program (SHRP) to study ice-debonding characteristics of paving materials. Initially, PlusRide was marketed as a very flexible asphalt having ice-debonding properties. As an extension of the PlusRide concept, CRREL developed a dense graded mix having a CRM gradation within 12.5 to 4.75 millimeter (1/2-inch to No. 4 sieve). Unfortunately, studies on this material have been limited to the laboratory only.

Other Applications

Surface Treatments

A surface treatment that involves a spray application of asphalt rubber followed by a layer of cover stone is called a stress absorbing membrane (SAM). Surface treatment is a very inexpensive means of providing a fresh pavement surface with good skid resistance. Sometimes, the membrane is sandwiched between two layers of a pavement structure, in which case the membrane is called a stress absorbing membrane interlayer (SAMI). Perhaps the most widespread application of SAMI is as a reflective crack retarder in asphalt overlays on top of aged portland cement concrete pavements or cracked asphalt pavements.

Asphalt rubber SAM or SAMI may be applied with minor modifications by use of conventional surface treatment equipment. However, these modifications are necessary to account for the harshness of the CRM asphalt binder and its excessive wear on the equipment and higher operating temperatures.

Finally, there are other uses for surface treatments and spray applications which include: tack coat, fog seal, cape seal, microsurfacing, and many others.

Advantages

1. Ease of application.
2. Low cost, compared to HMA applications.
3. Sealed cracks reduce water infiltration.

Disadvantages

1. It adds no structural benefit to the pavement.
2. Heavy-duty spray nozzles and pumps are required.
3. Relatively small amount of rubber is disposed in this fashion.
4. Long-term performance characteristics are unknown.

Joint and Crack Sealants

Perhaps the most unadvertised use of rubber in asphalt is in the form of products that are used for joint and crack sealing. The process for producing this material is identical to the wet process for asphalt rubber with a typical rubber content of approximately 18%.

Advantages

1. Ease of application.
2. Low cost.

Disadvantage

1. Relatively small amount of rubber is disposed in this fashion.
2. Long-term performance characteristics are unknown.

Structural Design Issues

There is a tendency to assign a higher structural coefficient to crumb rubber modified asphalt primarily on the basis of its higher stiffness/modulus as compared to conventional hot mix asphalt. Based upon studies in California and Arizona, Van Kirk (1992) concluded that CRM asphalt overlays may be designed 30%-50% thinner than the conventional HMA overlays having the same performance. It must be pointed out that Van Kirk's report reflects a limited database and the author cautions against unwarranted extrapolations.

As a result of lack of adequate information on structural behavior of CRM asphalt, state agencies are considering construction applications which would minimize exposure to traffic loads. This has led to applications in shoulders, base, and/or subbase courses. Base and subbase applications offer an added advantage of isolation from most environmental elements leading to a more durable pavement.

Construction Issues - - Wet and Dry Processes

Plant Type

The asphalt rubber technology lends itself to both spray and hot mix applications. At the same time, in spray applications, the harsh and viscous nature of the CRM asphalt binder requires heavy duty pumps and nozzles. Both dry and wet processes may be accomplished with the currently available plant technology in Kentucky. The drum plant, however, must have an opening, away from the flame, for introduction of rubber particles in the dry process. This may be easily accomplished through the opening for the recycled asphalt pavement (RAP) materials, which most drum plants in Kentucky presently have. Batch plants, on the other hand, offer a means for easier application and better quality control.

Compaction

Compaction of CRM hot mix asphalt (CRM-HMA) may be easily accomplished with conventional equipment. Some minor increase in the level of field compaction might be necessary due to the more viscous nature of CRM asphalt binder, which makes the mix somewhat harsh. Some rubber mixes containing coarse rubber particles have a tendency to exhibit "elastic rebound", which may make achieving the specified field densities more difficult.

Post-Compaction Cooling Prior to Exposure to Traffic

Rubber is known to increase the latent heat capacity of hot mix asphalt. Therefore, it might be necessary to provide a longer cooling time for the freshly laid asphalt pavement prior to exposure to traffic.

DESCRIPTION OF THE FIELD TRIAL PROJECT

A field project was identified for evaluation of various aspects of CRM-HMA in relation to construction and performance. The construction consisted of a series of control and modified asphalt sections on a segment of the US 421, in Franklin County, Kentucky, as depicted in Figure 1.

Field trial sections were constructed during July 1993. A nominal 2.54 cm (1-inch) surface layer was applied to both CRM-HMA and control HMA sections. The primary purpose of a surface course is to protect the structural layers from environmental effects. A 2.54 cm (1-inch) surface layer was neither intended nor provides any structural support. This field project, however, was selected for evaluation of feasibility and performance of CRM in Kentucky using the fine ground rubber material.

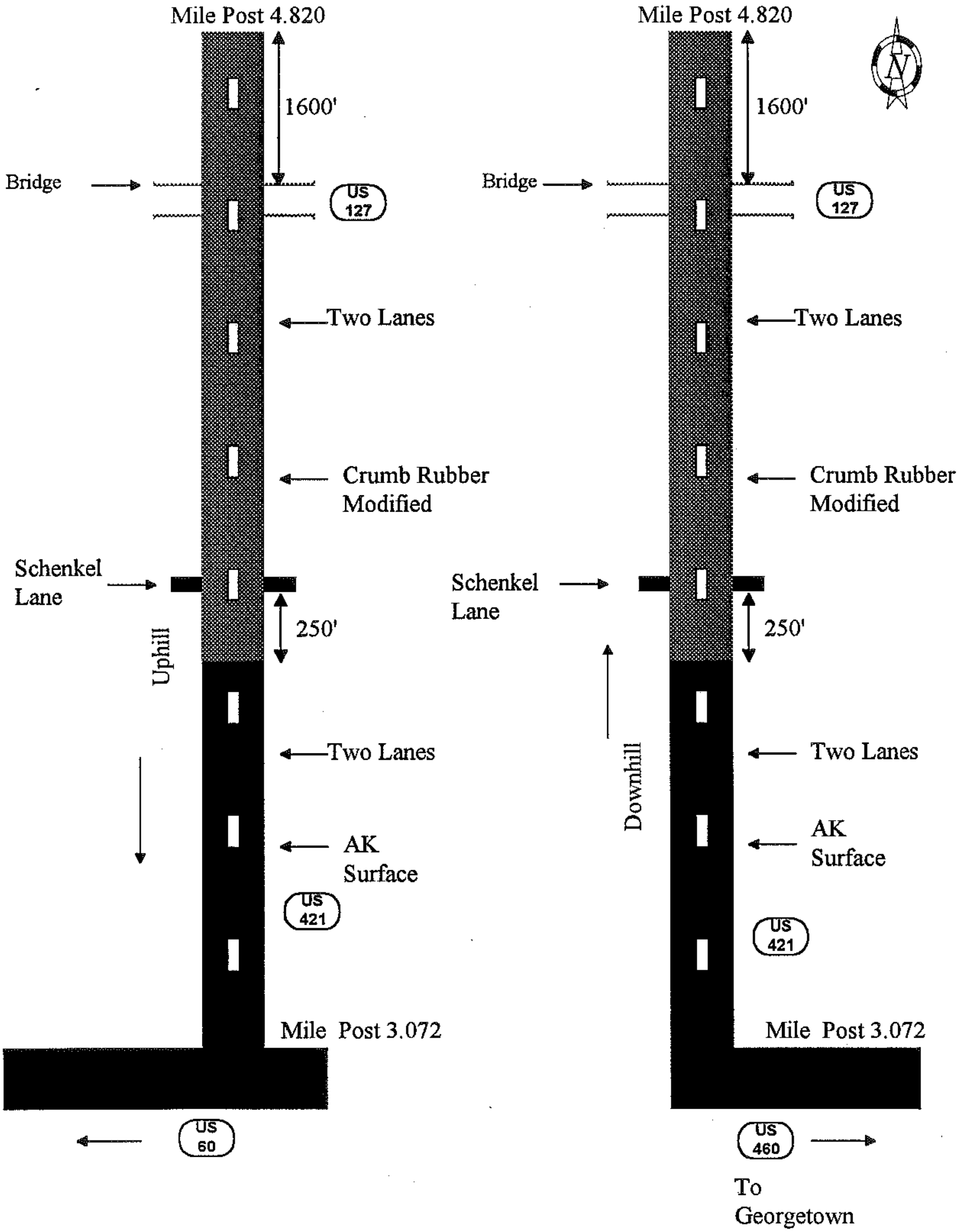


FIGURE 1. Project Layout, US 421, Franklin County, Kentucky.

PAVEMENT CONDITION SURVEY

Visual Inspection of US 421

On June 29, 1993, Kentucky Transportation personnel conducted a visual condition inspection of the pavement surface on US 421 prior to the milling and overlay operations. Transverse, longitudinal, and map cracking was observed in several areas throughout the project. Pumping and bleeding were also observed in several locations. Rut measurements were taken every 0.16 km (0.1 mile). The average rut depth was 0.81 cm (0.32 inch).

RUT MEASUREMENTS
NORTHBOUND, US 421

MILE POINT	RIGHT WHEEL PATH INSIDE LANE cm (in)	LEFT WHEEL PATH INSIDE LANE cm (in)	CRACKING CONDITION	
			INSIDE LANE	OUTSIDE LANE
3.1	0.48 (0.19)	0.15 (0.06)	Slight Longitudinal Cracking in Wheel Paths	None
3.2	0.64 (0.25)	0.48 (0.19)		
3.3	0.64 (0.25)	0.97 (0.38)		
3.4	0.79 (0.31)	0.79 (0.31)	Significant Longitudinal and Transverse Cracking	High Degree of Transverse and Longitudinal Cracking
3.5	0.97 (0.38)	1.12 (0.44)		
3.6	0.79 (0.31)	1.42 (0.56)		
3.7	0.48 (0.19)	1.27 (0.50)	Map Cracking	Map Cracking
3.8	0.64 (0.25)	2.24 (0.88)	None	Bleeding
3.9	1.12 (0.50)	0.97 (0.38)		None
4.0	0.97 (0.38)	0.79 (0.31)		
4.1	1.27 (0.50)	0.64 (0.25)	Mild Transverse and Longitudinal Cracking	Significant Transverse Cracking with Some Map Cracking
4.2	0.64 (0.25)	0.97 (0.38)		
4.3	0.48 (0.19)	0.15 (0.06)		
4.4	0.48 (0.19)	0.15 (0.06)		None

TABLE 1. Summary of visual condition survey prior to milling of surface wearing course.

The maximum rut depth recorded was 2.24 cm (0.88 inch) at Milepost 3.8, northbound, at intersection of US 421 and Schenkel Lane. The pavement had been overlaid from Milepost to 3.25, and from Milepost 3.8 to Milepost 4.2. Changes in pavement structure such as rlays were indicated on the condition sheets as pavement visual appearance change. More rmation is provided in Appendix A.

RUT MEASUREMENTS
SOUTHBOUND, US 421

MILE POINT	RIGHT WHEEL PATH INSIDE LANE cm (in)	LEFT WHEEL PATH INSIDE LANE cm (in)	CRACKING CONDITION	
			INSIDE LANE	OUTSIDE LANE
3.1	-	-	None	None
3.2	0.48 (0.19)	0.64 (0.25)		
3.3	1.12 (0.44)	0.97 (0.38)		
3.4	0.79 (0.31)	0.64 (0.25)	Mild Transverse And Longitudinal Cracking	Mild Transverse And Longitudinal Cracking
3.5	0.97 (0.38)	0.64 (0.25)		
3.6	1.60 (0.63)	1.42 (0.56)		
3.7	1.27 (0.50)	1.27 (0.50)		Significant Transverse Cracking
3.8	1.27 (0.50)	1.42 (0.56)		
3.9	0.48 (0.19)	0.48 (0.19)		Mild Transverse And Longitudinal Cracking
4.0	0.97 (0.38)	0.97 (0.38)		
4.1	0.48 (0.19)	0.64 (0.25)		
4.2	0.64 (0.25)	0.79 (0.31)		
4.3	0.48 (0.19)	0.64 (0.25)		
4.4	0.15 (0.06)	0.64 (0.25)		

TABLE 2. Summary of visual condition survey prior to milling of surface wearing course.

Video and Infrared Documentation of US 421

On July 1, 1993, Kentucky Transportation Center personnel videotaped the pavement surface prior to being overlaid with the CRM-HMA and control HMA surfaces. The video tapes and their associated distress survey sheets may be used in future to monitor reflective cracking in the CRM asphalt overlay. In addition to videotaping the surface, KTC personnel also used thermography equipment (infrared scanner) to scan the pavement surface for any large irregularities in surface temperature. This was the first attempt to use this equipment for this application in Kentucky. The results are often difficult to interpret, but the methodology appears to be promising.

The thermography equipment revealed several cool areas throughout the study area. Most of the cool areas detected were associated with areas of significant pavement distress (map cracking or staining due to pumping). It is apparent the pavement was cooler in these areas probably due to water being trapped in the pavement and subgrade. At milepost 4.27, significantly cooler pavement temperatures were observed between the two northbound lanes. Prior to milling, the surface showed severe cracking in several regions in this area .

At Milepost 4.18, a cool area was detected in the center of the southbound driving lane. No surface distress was apparent on the pavement surface. At Milepost 4.15, at the adjacent "on" ramp, significant cracking and pumping were observed.

Several hot spots were detected during the infrared survey. Hot spots were detected at Milepost 3.34 in the center of the northbound driving lane, and at Milepost 3.27 in the center of the southbound driving lane. No surface distress was observed at either location. Background literature indicates that these hot spots could be delaminations between layers.

NONDESTRUCTIVE PAVEMENT TESTING

Nondestructive deflection testing was conducted using a JILS-20 Falling Weight Deflectometer. Deflections were measured using a 30.48-m (12-inch) diameter loading plate and a dynamic load of 4082.4 kg (9,000 lbs). Deflections were measured at seven locations spaced at 30.48-cm (2-inch) centers from the center of the load plate.

Asphaltic concrete cores were obtained at four locations after overlay. These cores revealed considerable variability in both the asphaltic concrete and dense graded aggregate thicknesses. These thickness measurements are summarized in Table 3.

Milepost	Asphalt Layer Thickness cm (in.)	DGA Thickness cm (in.)
3.30 SB	21.6 (8.50)	27.9 (11.00)
3.60 SB	18.4 (7.25)	26.0 (10.25)
4.00 SB	19.1 (7.50)	29.2 (11.50)
4.225 SB	21.0 (8.25)	35.6 (14.00)
4.40 SB	23.5 (9.25)	35.6 (14.00)

TABLE 3. Asphaltic Core Thickness (Prior to Overlay), US 421, Franklin County, Kentucky.

Backcalculation of Layer Moduli

Falling Weight Deflectometer deflection measurements were obtained prior to the milling operation in July 1993. Deflection measurement were also obtained in October 1993 after placement of the asphaltic concrete overlay. Deflection measurements were obtained at 0.16-km (0.1-mile) increments. Layer moduli were backcalculated for each set of deflection measurements using Modulus Version 4.0. The backcalculated asphaltic concrete modulus was converted to an equivalent modulus at 21°C (70°F) using a relationship reported in KTC Research Report KTC-92-10.

Due to the large variation of material thicknesses given in Table 3, two different backcalculation scenarios were utilized. The first scenario was to use an average material thickness as determined from the field cores. These thicknesses were used as inputs into the MODULUS computer program and layer moduli were calculated. The average layer moduli for each layer in each direction for both sets of FWD measurements are given in Table 4. The actual test temperature is given in parentheses.

Table 4 reflects the results from average of five sites along the project. It may be seen in this table that there is a slight increase in asphaltic concrete modulus once the overlay was placed. However, the backcalculated asphaltic concrete layer moduli seem higher than might be expected; this may be due to asphaltic concrete aging. The pavement structure is approximately 20 years old, therefore it is possible that the material may have become brittle and age hardened. Due to the thin overlay thickness, it is not possible to backcalculate a modulus for the overlay itself. Hence, a modulus was calculated for a composite asphalt layer (surface plus base).

Test Date	Layer Moduli				
	Asphaltic Concrete Moduli	Test Temperature	Asphaltic Concrete (Adjusted for 21°C)	DGA	Subgrade
	MPa (ksi)	°C (°F)	MPa (ksi)	MPa (ksi)	MPa (ksi)
7/93, NB	4585 (665)	30 (86)	6647 (964)	427 (62)	145 (21)
10/93, NB	9039 (1311)	23 (74)	8143 (1181)	441 (64)	255 (37)
7/93, NB	3875 (562)	30 (86)	8570 (1243)	296 (43)	131 (19)
10/93, NB	8495 (1232)	23 (74)	9329 (1353)	448 (65)	214 (31)

TABLE 4. Backcalculated Layer Moduli, US 421, Franklin County, Kentucky.

The second scenario involved backcalculating layer moduli on a site specific basis where the asphaltic cores were obtained. Layer moduli were backcalculated for each site at the two sites adjacent to it. The results of this analysis are given in Table 5.

In Tables 4 and 5 , an increase in modulus is associated with decreases in temperature, and vice versa. Furthermore, changes in modulus are expected with asphalt aging.

It may be seen from Table 5 that at two locations the asphaltic concrete modulus increased after overlay, while in the remaining three locations the asphaltic concrete modulus slightly decreased or remained nearly the same.

General Comments about the FWD Analysis

There is a considerable amount of variability in the backcalculated layer moduli across the project. A portion of this variability may be due to the variation of the material thicknesses across the project. Similar trends in this variability are observed in both the July and October data. The changes in the average backcalculated DGA and subgrade moduli may be attributed to changes in their moisture content from July to October. This analysis will provide a good baseline of material information for future evaluations.

Test Date	Layer Moduli				
	Asphaltic Concrete Moduli	Test Temperature	Asphaltic Concrete (Adjusted for 21°C)	DGA	Subgrade
	MPa (ksi)	°C (°F)	MPa (ksi)	MPa (ksi)	MPa (ksi)
MP 3.3: 21.59-cm (8.5-in.) AC, 27.94-cm (11-in.) DGA					
7/93, NB	3592 (521)	30 (86)	4292 (695)	271 (39.3)	103 (15)
10/93, NB	6440 (934)	23 (74)	4675 (678)	469 (68)	117 (17)
7/93, SB	3503 (508)	40 (104)	7771 (1127)	296 (43)	117 (17)
10/93, SB	7412 (1075)	23 (74)	7509 (1089)	345 (50)	269 (39)
MP 3.6: 18.42-cm (7.25-in.) AC, 26.04-cm (10.25-in.) DGA					
7/93, NB	5475 (794)	30 (86)	7288 (1057)	359 (52)	152 (22)
10/93, NB	7984 (1158)	23 (74)	6281 (911)	434 (52)	152 (22)
7/93, SB	4275 (620)	40 (104)	9481 (1375)	131 (19)	193 (28)
10/93, SB	8812 (1278)	23 (74)	8908 (1292)	228 (33)	152 (22)
MP 4.225: 20.96-cm (8.25-in.) AC, 35.56-cm (14-in.) DGA					
7/93, NB	4337 (629)	30 (86)	5530 (802)	483 (70)	103 (15)
10/93, NB	10343 (1500)	23 (74	10591 (1536)	365 (53)	296 (43)
7/93, SB	4061 (589)	40 (104)	7943 (1152)	676 (98)	241 (35)
10/93, SB	9943 (1442)	23 (74)	10729 (1556)	386 (56)	248 (36)
MP 4.4: 23.5-cm (9.25-in.) AC, 35.56-cm (14-in.) DGA					
7/93, NB	4213 (611)	30 (86)	5378 (780)	669 (97)	269 (39)
10/93, NB	8915 (1293)	23 (74)	9136 (1325)	331 (48)	510 (74)
7/93, SB	5668 (822)	40 (104)	11073 (1606)	745 (108)	265 (38.5)
10/93, SB	10343 (1500)	23 (74)	11156 (1618)	531 (77)	531 (77)
MP 5.0: 19.05-cm (7.5-in.) AC, 29.21-cm (11.5-in.) DGA					
7/93, NB	4433 (643)	30 (86)	5654 (820)	579 (84)	117 (17)
10/93, NB	10343 (1500)	23 (74)	8798 (1276)	510 (74)	234 (34)
7/93, SB	5061 (734)	40 (104)	10542 (1529)	234 (34)	214 (31)
10/93, SB	10191 (1478)	23 (74)	10308 (1495)	407 (59)	393 (57)

TABLE 5. Site Specific Backcalculated Layer Moduli, US 421, Franklin County, Kentucky.

SUMMARY OF CONSTRUCTION ACTIVITIES

From the ease of implementation point of view, the Cabinet opted to build a field trial section using the "wet process" which utilized a fine ground rubber -- 177-micron (80-mesh) material. The rationale for this decision was based upon the fact that the fine ground CRM mix resembles closely the polymer modified HMA, and that both the Cabinet and Kentucky contractors have an extensive amount of experience with polymer modified asphalt.

In July 1993, a field trial project was constructed on a portion of the US 421, Franklin County, Kentucky. The project involved milling of one inch of the old wearing surface followed up by an approximately 2.54-cm (1-inch) overlay. The four-lane trial project (two lanes in each direction) was divided into two approximately 0.8 km sections (half-mile). This allowed for a comparison of performance between the CRM hot mix asphalt (HMA) and the conventional HMA.

The following is a summary of key features of the construction activities. The contractor was H.G. Mays of Frankfort, Kentucky.

- The fine ground rubber -- 177-micron (80-mesh, Rouse) was mixed with the AC-20 binder at 7.5% rate by the weight of the total binder. The rubber was fed via an auger system into a blending unit where it was mixed with the hot AC-20. The auger speed may be adjusted to produce any rubber content in the asphalt.

- The contractor used an asphalt transport unit as a temporary delivery facility feeding hot AC-20 into the CRM blending unit. The temperature of the CRM blending unit was 171°C-177°C (340°F-350°F).

- The contractor used a drum plant at a production rate of 159-181 metric tons/hour (175-200 tons/hour), depending upon the progression of the job.

- At the beginning of the job, two 0.150-km (500-foot) test strips were constructed to check the in-place properties. Two test strips were constructed to accommodate the change in the CRM binder content (from 5.3% to 5.1%). Each test strip was constructed with approximately 454-544 metric tons (500-600 tons) of HMA. The conventional HMA also included a test strip.

- The contractor used conventional laydown equipment. The paver machine was a model 561 Cedar Rapids. The paver had a 3-m (10-foot) screed plus 0.6 m (2-foot) extensions. Also, a 12.2 m (40-foot) ski rode on the mat for level control purposes.

- The breakdown roll of the 2.54-cm (1-inch) surface lift was accomplished by a DD-110 Ingersoll-Rand (9-11 metric tons, 10-12 tons) steel drum roller, operating in the vibratory mode moving toward the paver and in the static mode moving away from the paver. The compaction was finished using a DA-40 Ingersoll-Rand (7-9 metric tons, 8-10 tons).

- Desirable field densities (desirable limits: 92% to 94% of solid density) were accomplished in accordance with the following rolling pattern:

  one vibratory pass and 3 flat passes (9-11 metric ton roller, 10-12 ton);
  four flat passes (7-9 metric ton roller, 8-10 ton).

- There were a few "fat spots" along the CRM-HMA sections. Although no conclusive cause has been determined, these spots correspond to locations where the paver was approaching a stop.

- The entire project included 2,325 metric tons (2,563 tons) of class AK surface HMA for control sections, and 2,902 metric tons (3,199 tons) of class AK surface CRM-HMA. The entire project was paved in six days.

POST-CONSTRUCTION INTERVIEWS

On July 21, 1993, a post-construction interview was held with the contractor. The following is a summary of key comments made during that meeting.

- The contractor indicated that the various people in charge of production and laydown would not have known the difference between the control Class AK and the CRM Class AK if they were not told. This is a positive sign that the CRM-HMA material selected for this project behaved similar to conventional HMA.

- As a result of CRM binder over-production, approximately 5,678 liters (1500 gallons) of CRM-AC-20 remained in the hot storage tank.. In order to prevent any phase separation, the contractor recirculated the hot binder inside the storage tank for the duration of that night. There were no problems associated with using this binder for mix production the following day.

- The contractor felt that overall QA/QC was improved because of the partnering relationship between his company, the Transportation Cabinet, and the KTC research team.

- The contractor was concerned about some relatively low TSR values which were obtained for the CRM-HMA. He suggested that future research may focus on compatibility of various anti-stripping agents, including lime, with the CRM-

MATERIALS CHARACTERIZATION

Binder Viscosity Data

Generally, the CRM-AC-20 asphalt binder showed an increase in the viscosity which was comparable to an AC-40. This "jump" in the asphalt binder grade is similar to polymer modified asphalts. Hence, this is the best indication that fine ground -- 177-micron (80-mesh) CRM changes the viscosity characteristics of asphalt cement in a manner which is very similar to polymer asphalt modifiers.

For quality assurance and quality control (QA/QC) purposes several samples of the CRM asphalt binder were collected at various times during the production of the hot mix. Each sample can was allowed to cool for several hours and then sealed. These cans were then stored for two weeks before testing began.

Testing began by using a heated spatula to remove the top 3.81 cm (1-1/2 in.) of asphalt from the can so that a representative sample could be obtained. A small amount a CRM asphalt was removed from the can and placed into a preheated Brookfield plate and cone viscometer. Each sample was spread evenly over the plate and allowed 15 minutes to stabilize at the testing temperature of 60°C (166°F) before recording viscosity data. The viscometer was properly cleaned and recalibrated between each test. The testing procedure was then rerun on several samples per can in order to verify that original test data were accurate. Table 6 contains summary information from binder viscosity data. The average viscosities for the binder samples are graphed in Figure 2 along with the average for all the samples .

Can No.	Speed RPM	Average Torque %	Average Viscosity cP	Avg. Shear Stress (D/Cm2)	Shear Rate 1/Sec	Time Sec.
1	2.5	54.5	446,437	42,858	9.6	15
2	2.5	62.8	514,567	49,398	9.6	15
3	2.5	50.6	414,188	39,762	9.6	15
4	2.5	53.1	434,968	41,757	9.6	15
5	2.5	60.8	498,237	47,831	9.6	15
6	2.5	53.7	439,801	42,221	9.6	15
7	2.5	54.3	444,798	42,701	9.6	15

TABLE 6. Summary of data collected from binder viscosity tests.

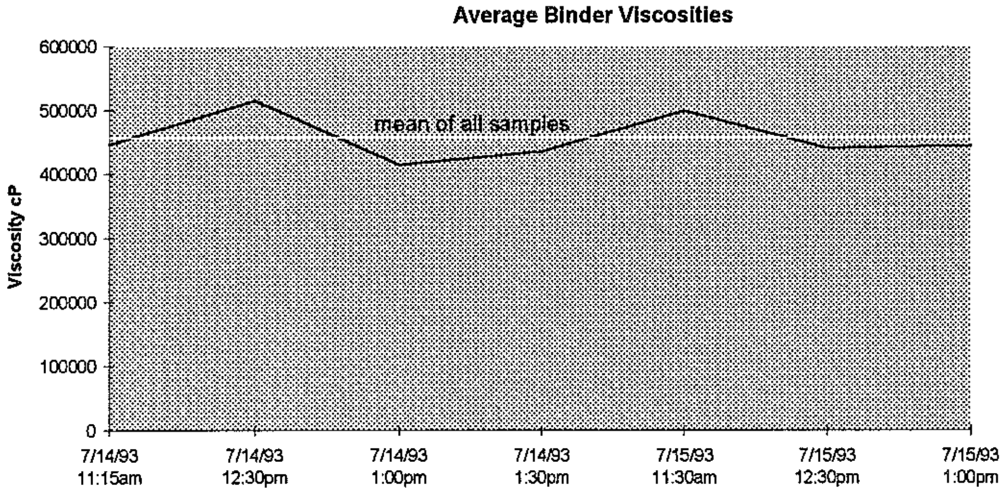


FIGURE 2. Average viscosities from 30 readings per can.

Statistical Modeling

Statistical analysis of viscosity data was performed using conventional analysis of variance (ANOVA) techniques. Both One-Way and Two-Way ANOVAs were used. The following equation represents the One-Way ANOVA model.

$$X_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

In this model the observations X_{ij} are assumed to be normally distributed about a mean μ with variance σ^2. The variance is assumed the same in all classes. This model is often called a fixed effects model because the effects of the treatments measured by α_i are regarded as fixed but unknown quantities to be estimated. The random element ε_{ij} is the experimental error. The model for the Two-Way ANOVA is the following:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \eta_{ij} + \varepsilon_{ijk}$$

The terms in the model are defined as follows:

X_{ijk} = the kth observation of the ith row of the jth column for all replicates

μ = the overall or grand mean of x_{ijk} values for all rows and columns

α_i = row effect of the ith row

β_j = column effect of the jth column

η_{ij} = interaction between the ith row and the jth column

ε_{ijk} = the experimental error in the kth observation in the ith row and the jth column and ε_{ijk} is independently and normally distributed with a mean of zero

Seven binder samples (in cans) were obtained during mixing operations. Binder viscosity readings were obtained 30 times for each can. Based on an analysis of variance where the null hypothesis is the means of the viscosities are equal, the F-test results in rejection of the null hypothesis. The average viscosities of all samples are not equal. Table 7 summarizes the One-Way ANOVA.

One-Way Analysis of Variance					
Source of Variation	df	S.S.	M.S.	F	Pr > F
Model	6	2.42191E+11	4.03651E+11	12.48	0.0001
Error	203	6.56528E+11	3.23413E+09		
Corrected Total	209	8.98719E+11			

TABLE 7. NOVA on viscosity data obtained from crumb rubber modified binder samples.

A better method of testing viscosities would have been to perform the testing on the sample as soon as it was removed from the mixing tank and allowed to stabilize at 60°C (166°F). This would have prevented the mix from cooling and possible settling of the crumb rubber. This also would have prevented the need for reheating of the sample before testing which may often cause viscosities to be slightly higher than the original material.

Another improvement that could have been made in testing the viscosities of the CRM asphalt would have been to use a viscometer other than the plate and cone type. One possible problem with the plate and cone viscometer is the fact that the rubber particles in the modified asphalt may clump under the cone or be forced from underneath the cone thus giving either a higher or lower viscosity reading than actually exists.

Impact of Rubber Concentration On Viscosity

Samples were prepared by blending asphalt cement and crumb rubber modifier at 3,000 RPM in approximately one-gallon quantities. Fine rubber samples were blended for one hour at 177°C (350°F). Coarse rubber samples were blended for one hour at 204°C (400°F). The samples were then allowed to cool before heating for hold times. Hold time is the period of time the asphalt cement and crumb rubber modifier were held in a hot condition prior to testing. Hold times were 1, 4, and 24 hours. Rotational viscosity according to ASTM D 4402 measures the viscosity of asphalts at elevated temperatures using a Brookfield apparatus. A bob is rotated in the asphalt sample at a designated temperature. Viscosity is defined as the ratio of shear stress to shear rate. In order to estimate temperature susceptibility, the viscosity was measured at 135°C and 150°C (275°F and 302°F). Figure 3 demonstrates the relationship between rotational viscosity and crumb rubber concentration in the AC-20 blend. As the crumb rubber concentration increases, the viscosity increases. However, the fine at 20% has a higher viscosity than the coarse at 20%. The highest viscosity appears in the fine at 20%. Statistical analysis was performed to determine whether rubber concentration effects rotational viscosity.

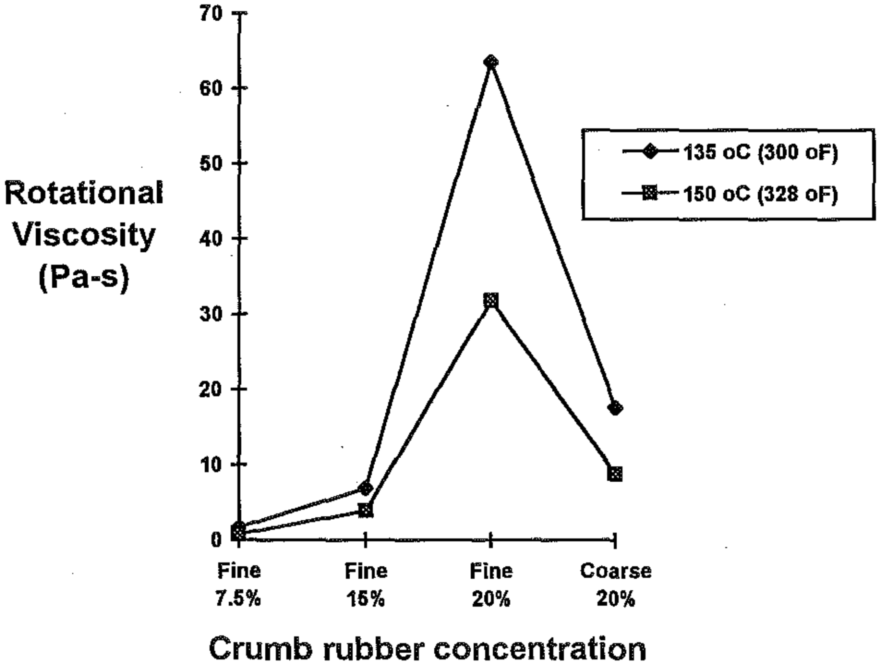


FIGURE 3. Effects of crumb rubber size/concentration on rotational viscosity in the AC-20 blend.

A One-Way ANOVA was performed on the viscosity data obtained at 135°C (300 °F) and 150°C (328 °F). The null hypothesis, noted as H_o, is that the mean for all treatments is equal or H_o: $\mu_i = \mu$. If the null hypothesis is accepted, different rubber concentrations do not have an effect on viscosity. A rejection of the null hypothesis results and rubber concentration is significant on viscosity at both temperatures. This is presented in Table 8.

<table>
<tr><th colspan="6">One-Way Analysis of Variance on Viscosity data at 135°C (300 °F)</th></tr>
<tr><td>Source of Variation</td><td>df</td><td>S.S.</td><td>M.S.</td><td>F</td><td>Pr > F</td></tr>
<tr><td>Model</td><td>3</td><td>7,128,460,724</td><td>2,376,153,575</td><td>66.57</td><td>0.0001</td></tr>
<tr><td>Error</td><td>8</td><td>285,565,795</td><td>35,695,724</td><td></td><td></td></tr>
<tr><td>Corrected Total</td><td>11</td><td>7,414,026,519</td><td></td><td></td><td></td></tr>
<tr><td colspan="6">One-Way Analysis of Variance on Viscosity data at 150°C (328 °F)</td></tr>
<tr><td>Source of Variation</td><td>df</td><td>S.S.</td><td>M.S.</td><td>F</td><td>Pr > F</td></tr>
<tr><td>Model</td><td>3</td><td>1,774,536,480</td><td>591,512,160</td><td>354.60</td><td>0.0001</td></tr>
<tr><td>Error</td><td>8</td><td>13,344,716</td><td>1,668,089</td><td></td><td></td></tr>
<tr><td>Corrected Total</td><td>11</td><td>1,787,881,196</td><td></td><td></td><td></td></tr>
</table>

TABLE 8. ANOVAs on viscosity data obtained from different crumb rubber concentrations at 135°C (300 °F) and 150°C (328 °F).

Impact of Hold Time On Viscosity

When comparing the effects of hold time and rubber concentration on viscosity, the hold time was significant at every level except the 7.5% fine rubber in the AC-20 blend. Figures 4 and 5 show the effects of hold time on rotational viscosity for the AC-20 blend. Higher concentrations of rubber yielded higher viscosities in both AC-20 and AC-30.

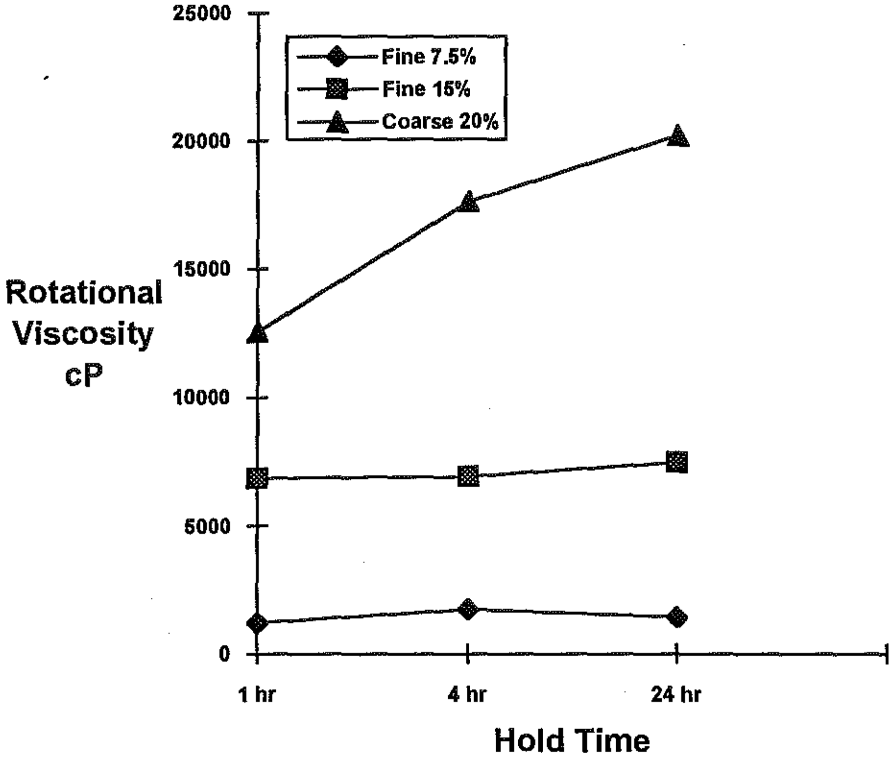


FIGURE 4. Effects of hold time on rotational viscosity in the AC-20 blend at 135°C (300 °F).

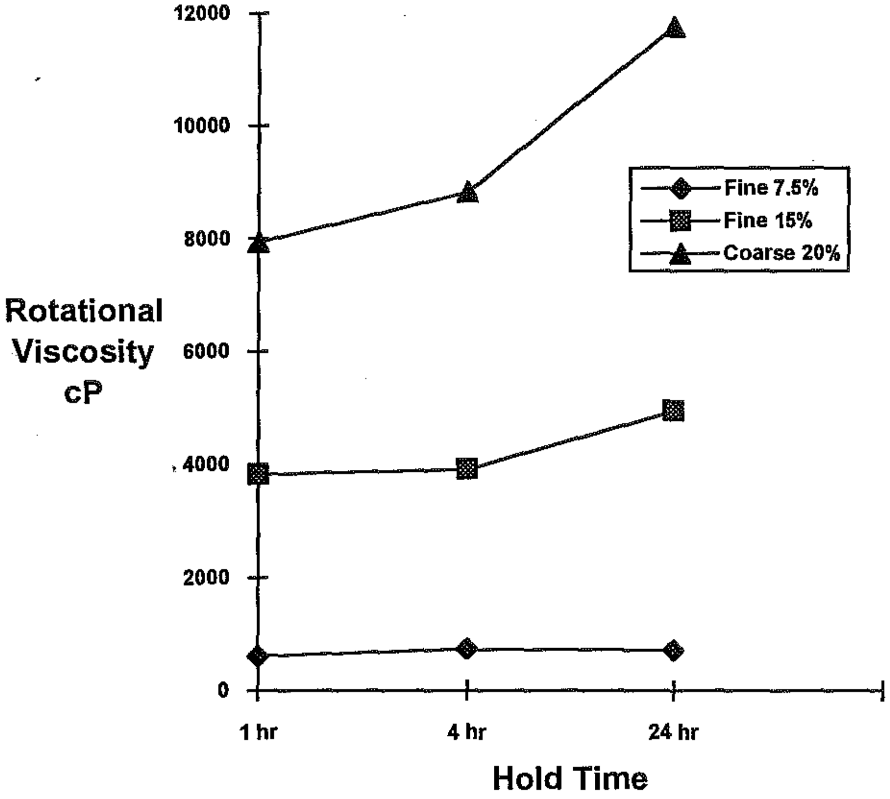


FIGURE 5. Effects of hold time on rotational viscosity in the AC-20 blend at 150°C.

A Two-Way ANOVA was performed on the viscosity data at 135°C and 150°C. Table 9, below, summarizes the results.

Two-Way ANOVA on viscosity data at 135°C (300 °F)					
Source of Variation	df	S. S.	M.S.	F	Pr > F
Hour	2	37,564,380	18,782,190	5.88	0.0108
Concentration	2	1,082,219,315	541,109,658	169.53	0.001
Interaction	4	54,550,723	13,637,681	4.27	0.0132
Error	18	57,451,888	3,191,772		
Two-Way ANOVA on viscosity data at 150°C (328 °F)					
Source of Variation	df	S. S.	M.S.	F	Pr > F
Hour	2	14,073,268	7,036,634	19.48	0.0001
Concentration	2	354,676,613	177,338,307	490.95	0.0001
Interaction	4	12,334,785	3,083,696	8.54	0.0005
Error	18	6,501,802	361,211		

TABLE 9. ANOVAs on viscosity data obtained with varying crumb rubber concentrations and varying hold times at 135°C (300 °F) and 150°C (328 °F).

The viscosities at both temperatures were affected by hold time. Viscosity was also affected by concentration (Table 10). Interactions are significant so the combined effect of concentration and hold time effects viscosity (Asphalt Institute 1993).

Significance of hold time on rotational viscosity	
Fine 7.5%	No
Fine 15%	Yes
Coarse 20%	Yes

TABLE 10. Significance of hold time for various crumb rubber concentrations in the AC-20 blend for 135°C (300 °F) and 150°C (328 °F).

Aggregate Data

The aggregate gradation was a typical Kentucky Class AK surface material with a nominal top size of 12.7 mm to 9.53 mm (1/2 inch to 3/8 inch). The aggregate consisted of the following components: 42% Nugent No. 8, 23% Harrod Limestone Sand, 19% Nugent Natural Sand, and 16% Nugent Crushed Gravel Sand. Details of aggregate gradations and job-mix formula are presented in the Appendix.

Marshall Mix Design

Marshall stability and flow are standard parameters for the evaluation of rutting resistance of asphalt mixtures. This methodology is being increasingly criticized within many circles, including the Asphalt Aggregate Mixture Analysis System, NCHRP 338 (Von Quintus et. al. 1991) and Strategic Highway Research Program, SHRP (Sousa 1991) for its weak correlation to field performance.

Mix design for this project was jointly conducted by the contractor and the KTC research team. The contractor (H.G. Mays Corporation, Frankfort, Kentucky) reported an optimum binder content of 5.1%, by weight of the mix, for both conventional and CRM mixes. The Transportation Cabinet's Materials Central Laboratory and the KTC research team verified the 5.1% binder content for the conventional HMA. However, the KTC research team reported 5.3% optimum binder content for the CRM-HMA. However, based upon visual observations of the mix and quality control checks on plant produced mix during construction of the first 0.15-km (500-foot) test strip, the binder content for the CRM-HMA was dropped back to 5.1%. Details on mix design information generated by various parties and quality control checks on plant mix material are given in Appendix B.

In summary, the 5.1% binder content was based upon 3%-4% voids based upon 75 blows Marshall design. This binder content led to an average voids in mineral aggregate (VMA) of 15.5%, and an average percent voids filled with asphalt (VFA) of 65%.

Finally, an inventory of all HMA compacted specimens along with the identification numbers which were used in this study are given in Appendix B.

Indirect Tensile Strength

Diametral indirect tensile strength (ASTM D4123) tests were conducted in order to determine the cracking susceptibility of different mixtures. These tests were conducted at room temperature (21°C,70°F) and loading rate of 5.08 cm/min (2 in/min).

- Tensile strength characteristics of class AK-surface revealed that there was not a significant change due to addition of the crumb rubber. Average tensile strength for conventional HMA was 994.12 kPa (144.18 psi), as compared to 953.85 kPa (138.34 psi) for the CRM-HMA. This information was used to develop the tensile strength ratio (TSR) for moisture susceptibility analysis.

Moisture Damage Susceptibility

Stripping is the cause of many premature failures in asphaltic pavements. An accelerated moisture damage test, commonly known as the Root-Tunnicliff Moisture Damage Susceptibility Test (Tunnicliff and Root 1984) was employed in this study in accordance with the procedures outlined in Kentucky Method 64-428-85. The test calls for measuring tensile strength before and after a moisture conditioning procedure which is patterned after the Lottman procedure (Lottman 1978). The tensile strength ratio, TSR, which is presented in Appendix B, represents a remaining strength factor. This ratio was determined by computing the ratio of each mixture's tensile strength after the moisture treatment to the tensile strength before the treatment.

- Moisture damage susceptibility analysis was conducted based upon tensile strength ratio (TSR). The TSR for conventional HMA was 87.26% as reported by the KTC research team, and 81% as reported by the contractor. The TSR for the CRM-HMA was 86.5% as reported by the KTC research team, and 71% as reported by the contractor. The discrepancies in the TSR data may be attributed to the nature of this test which often leads to variable outcomes.

- Generally, the contractor compacted the fresh plant-produced mix at approximately the same temperature as the mix exited the plant (i.e. 149°C, 300 °F). On the other hand, the reheated plant-produced mix at the KTC laboratory was compacted at 129°C (265°F), which is Kentucky's specified compaction temperature for Marshall specimens. For the purpose of the TSR specimens, higher temperatures during compaction by the contractor resulted in a lower number of blows to meet the target air voids of 7% +/-1%. This may have been another source of variation between the TSR results reported by the contractor and the KTC research team.

Resilient Modulus

In pavement technology, the resilient modulus has long been used in lieu of the modulus of elasticity (AASHTO 1986). Generally, higher moduli indicate greater structural capacity. A high modulus asphaltic layer adds to the structural capacity of the pavement by protecting the base, subbase, and subgrade layers from being overstressed, and therefore it will reduce the probability of premature structural failure. However, a high modulus also coincides with higher brittleness, and such material will crack prematurely in fatigue and/or low temperature cracking modes of distress (Yoder and Witczak 1975). The relationship between higher cracking life (both low temperature cracking and fatigue cracking) and lower modulus is reported by several researchers (Goodrich 1988, and McLean and Monismith 1974). Therefore, in addition to serving as a characterization tool for structural capacity of pavement, the resilient modulus offers insight into cracking performance potential of asphalt mixtures.

Testing procedures were in accordance with the SHRP Protocol P07 for SHRP Test Designation AC07 (SHRP 1993). Table 3 shows significance between sample means for conventional HMA versus CRM-HMA at different testing temperatures.

In the SHRP Protocol P07 (SHRP Test Designation A07) for the determination of the resilient modulus (M_R) of hot mix asphalt concrete, stress levels for testing specimens are based on the tensile strength of the materials and the test temperature (SHRP 1993). The resilient modulus is a measure of elastic modulus of the HMA materials taking into account certain nonlinear characteristics. During the actual test procedure, a cyclic stress of some fixed value is applied for a duration of 0.1 sec. while the cycle duration is 1.0 sec. The specimen is subjected to a dynamic cyclic stress (90% of the total load) and a constant stress (10% of the total load). M_{Ri} and M_{Rt} (the instantaneous and total resilient modulus) are calculated from the measured instantaneous and total resilient vertical and horizontal deformation responses..

Specimens are tested at three temperatures: initially at 5 ± 1°C (41 ± 2°F), and intermediately at 25 ± 1°C (77 ± 2°F) and finally at 40 ± 1°C (104 ± 2°F). Three samples were tested per test temperature. The computer generated wave form will match as closely as possible by adjusting the gains and preconditioning will continue until the horizontal deformations appear stable and uniform. The number of load applications is dependent on the test temperature. Tables 11 and 12 provide a summaries of resilient modulus data.

Average M_{Ri} kPa (psi)		
TEMP °C (°F)	Control	CR-Modified
5 (67)	2,532,203 (367,252)	1,980,285 (287,206)
25 (103)	2,048,167 (297,051)	1,962,331 (284,602)
40 (130)	880,416 (127,689)	925,985 (134,298)

TABLE 11. Average instantaneous resilient modulus values for the control and modified mix.

Average M_{Rt} kPa (psi)		
TEMP °C (°F)	Control	CR-Modified
5 (67)	2,426,164 (351,873)	1,925,132 (279,207)
25 (103)	1,978,327 (286,922)	1,853,872 (268,872)
40 (130)	757,829 (109,910)	807,625 (117,132)

TABLE 12. Average total resilient modulus values for the control and modified mix.

The following equations will be used in determining the resilient modulus (ASTM D 4123). For the instantaneous resilient modulus:

$$\mu_{Ri} = 3.59 \text{ x } \frac{\Delta H_i}{\Delta V_i} - 0.27$$

$$M_{Ri} = P \text{ x } \frac{(\mu_{Ri} + 0.27)}{(t \text{ x } \Delta H_i)}$$

μ_{Ri} = instantaneous resilient Poisson's ratio

ΔH_i = instantaneous recoverable horizontal deformation, mm (or in.)

ΔV_i = instantaneous recoverable vertical deformation, mm (or in.)

M_{Ri} = instantaneous resilient modulus of elasticity, Mpa (or psi)

P = repeated load, N (or lbf.)

t = thickness of specimen, mm (or in.)

$$\mu_{Rt} = 3.59 \text{ x } \frac{\Delta H_t}{\Delta V_t} - 0.27$$

$$M_{Rt} = P \text{ x } \frac{(\mu_{Rt} + 0.27)}{t \text{ x } \Delta H_t}$$

μ_{Rt} = total resilient Poisson's ratio

ΔH_t= total recoverable horizontal deformation, mm (or in.)

ΔV_t = total recoverable vertical deformation, mm (or in.)

M_{Rt}= total resilient modulus of elasticity, Mpa (or psi)

P = repeated load, N

t = thickness of specimen, mm (or in.)

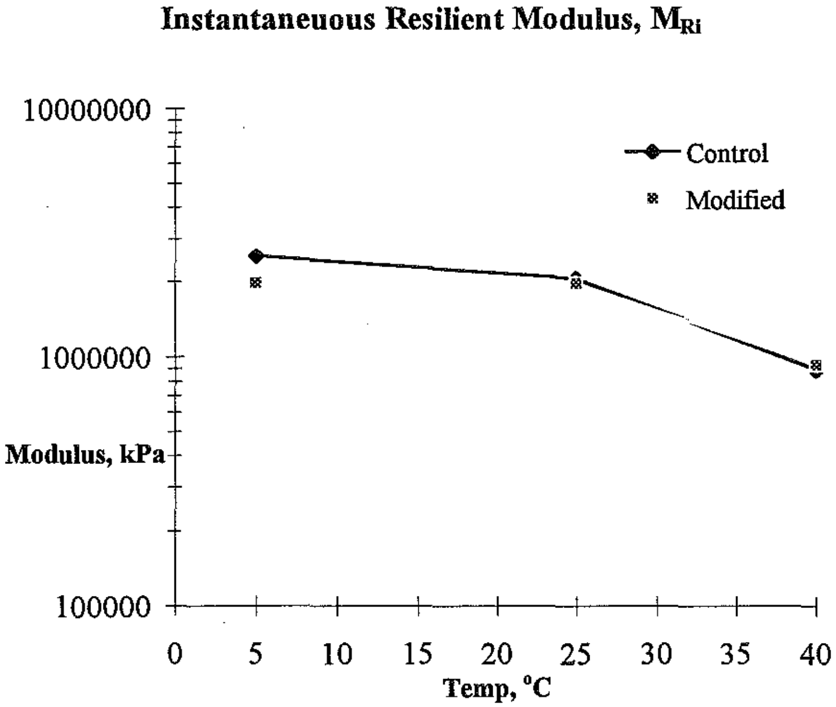


FIGURE 6. Instantaneous resilient modulus for both the control and modified mix.

Figures 6 and 7 show a comparison between the resilient modulus for the control mix and the modified mix. Statistical analysis comparing the means of the instantaneous modulus, M_{Ri}, for the control mix and the modified mix (CRM-HMA) indicated no significant difference between the moduli. In theory, the addition of rubber to a HMA should increase the resilient modulus. However, that is not evident in this case.

Temperature °C (°F)	Total M_R	Instantaneous M_R
5 (67)	Significant Difference:No P=0.1831	Significant Difference:No P=0.1828
25 (103)	Significant Difference:No P=0.6200	Significant Difference:No P=0.7157
40 (130)	Significant Difference:No P=0.4097	Significant Difference:No P=0.6394

TABLE 13. Statistical analysis between resilient moduli for control and modified mix.

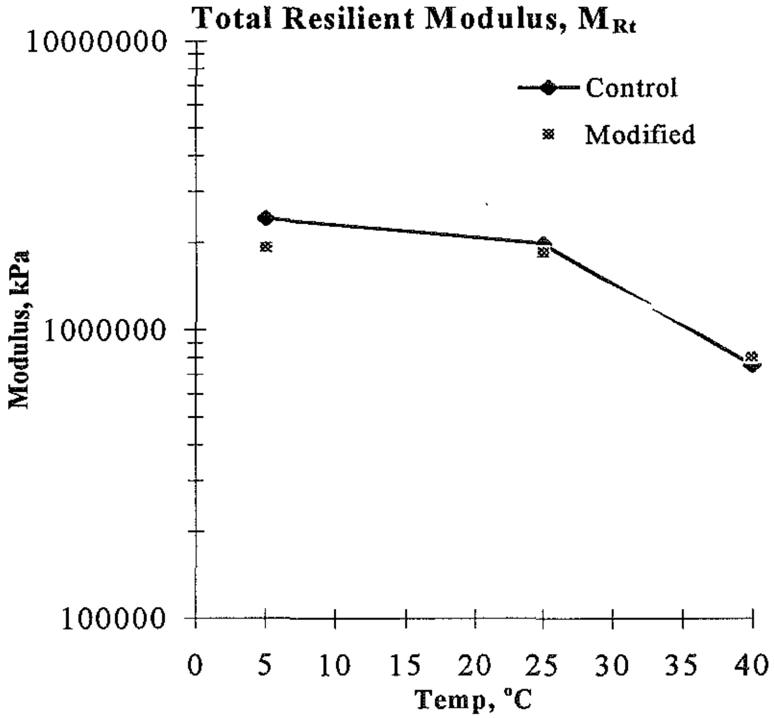


FIGURE 7. Total resilient modulus for both the control and modified mix.

FIELD PERFORMANCE DATA

This project was important for Kentucky to begin building a database and gain experience with asphalt rubber pavements to determine whether implementation would be easy with current construction procedures.

The trial sections have been in service for less than two years. A comprehensive pavement performance analysis would require a long-term performance record. It is therefore recommended that monitoring of these experimental sections be continued on a semi-annual basis for the next five years. At this time, visual observations indicate that the experimental pavement sections have not yet demonstrated any major modes of pavement distress.

Field performance of this project after 1.5 years in service revealed no major modes distress. Both the control section and the CRM section have been performing well; this is considering a harsh winter (for Kentucky) in January 1994. More time is needed to monitor manifestation of various modes of distress. It is recommended that long-term performance of this project be monitored.

QA/QC ISSUES

The following are issues that need to be considered in order to maintain a high level of quality assurance and quality control throughout the CRM projects.

- Construction of a valid control section is a must.
- Routine collection of binder and mixture specimens for testing at least twice a day.

- Independent materials testing by the contractor, the Transportation Cabinet, and perhaps a third party is essential to remove any potential biases.

- The metering system for addition of CRM to asphalt cement is the only direct way by which the quantity of CRM added can be controlled. Indirect checks may be conduced through the viscosity of the CRM-binder.

- The parameters that proved to be effective in determining the quality of the CRM material produced were: binder viscosity, mixture density and voids, mixture strength characteristics (Stability, Flow, TSR), and in place density. It is also very important to adhere to the prescribed temperatures during the following activities: CRM blending with the AC, mixture production, and mixture laydown and compaction.

- In-place HMA properties must be checked through construction of at least one 0.15-km (500-foot) test strip. If changes occur in the production of the mix at the plant, a new test strip may be warranted.

- The partnership relationship between the contractor, the Cabinet, and KTC, proved to be a success on this project and it is recommended for future CRM projects.

- Mix quality control parameters are given in the following table.

Type of Mix	Testing Agency	Mix Parameter					
		Stability kN (lb)	Flow mm (.001in)	AC %	Air %	VMA %	TSR %
Conventional HMA	KTC	10.25 (2305)	2.34 (9.2)	5.3	5.8	14.8	87.3 (35 blows)
	Contractor	11.34 (2550)	2.67 (10.5)	5.3	3.7	13.8	81.0 (27 blows)
CRM-HMA	KTC	11.32 (2544)	2.59 (10.2)	5.3*	5.4	16.2	86.5 (35 blows)
	Contractor	10.01 (2250)	2.49 (9.8)	5.3*	5.0	14.7	71.0 (27 blows)

(* the AC % was later changed to 5.1% based upon the test strip compaction results)

TABLE 14. Summary of mix control parameters (Average).

ENVIRONMENTAL ISSUES

In compliance with the Section 1038(b) of the 1991 ISTEA, the U.S. Department of Transportation and the Environmental Protection Agency submitted a report in June 1993 addressing environmental and performance issues related to the use of CRM in HMA pavements (DOT-EPA Report, June 1993). The following sections are direct excerpts of the DOT-EPA report.

Excerpts From U.S. DOT - EPA Report (pages 26-27)

A. Health/Environmental Assessment

The weight-of-evidence from the currently available information shows that the emissions from any asphalt plant, either producing conventional HMA or CRM HMA, can vary widely, both in the profile or emissions observed and in the levels of each contaminant released. Based on the findings from seven projects in the United States and Canada, the currently available data collectively indicate that no obvious trends of significantly increased or decreased emissions can be attributed to the use of CRM in HMA pavement production.

The finding of MIBK (methyl isobutyl ketone) in CRM asphalt pavement mixtures in three out of seven studies may warrant further investigation. An evaluation of the most exposed human population, workers involved in the production and construction of asphalt pavements containing CRM, indicates no obvious basis for concern of increased risk to this population, based principally on an analysis of emission data.

In summary, using the currently available information, we find 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. The findings are based on the limited available data from a few studies. These conclusions are subject to revisions as additional information is obtained and evaluated.

B. Recycling

Based on the results of two projects where asphalt pavements containing CRM were recycled, the available literature, and an evaluation of variability in plant configurations and operations, this technology appears to be constructible as a recycled pavement. To date, these two recycled pavements are performing comparably to existing hot mix asphalt pavement. However, sufficient information regarding long-term performance and economics is not available. These two project represent an extremely limited perspective of the variability of in-service pavement properties, environmental conditions, varying asphalt cements and mixtures, and asphalt plant configurations and operations. However, there is no reliable evidence that asphalt pavements containing recycled rubber cannot be recycled to substantially the same degree as conventional HMA pavements.

Additional evaluations are contemplated and will be required to develop further criteria for recycling CRM asphalt pavements. A national pooled-funds study has been initiated. Thirty-three states will participate with FHWA and EPA to further evaluate recycling CRM pavements. Requests for proposals for this pooled-fund research effort will be solicited this fiscal year (1993).

C. Performance

While pavements containing CRM have been constructed and have been in service for as many as 29 years in Arizona, California, and a few other states and based on an extensive review of available literature and project data, only limited information on engineering and economic performance is available. This is due to limited documentation, experimental evaluation, and a resulting incomplete data base upon which to complete long-term performance evaluations. While other states have conducted limited experimental research with CRM technologies, the performance of asphalt pavements containing recycled rubber has received only limited evaluations under varied climatic and use conditions.

In order to develop a reliable cost and economic evaluation of pavements containing CRM, comparable information must be developed on the construction of CRM asphalt paving projects of typical size rather then experimental applications. The performance to date on the CRM projects has been mixed, some experiencing early failure, others performing comparably to conventional asphalt pavements, and some CRM pavements have performed better than conventional mixes. Due to limited documentation, the exact cause of the premature distress in CRM pavements has not been established. However, when properly designed and constructed, there is no reliable evidence to show that pavements containing recycled rubber will not perform adequately as a paving material.

We will continue national research on CRM technologies to develop reliable engineering and economic criteria for the CRM pavements. Additionally, many states are conducting coordinated research to evaluate the effects of local conditions and materials. The results of these studies will be included in long-term performance evaluations.

Other Miscellaneous Issues

It appears that the jury will be out on various issues related to the utilization of scrap tire rubber in asphalt for some time. The following sections summarize various issues which might be of concern to Transportation Cabinet officials.

Potential for leachate of CRM asphalt pavements is another concern. One may hypothesize that local conditions such as soil conditions, surface runoff chemistry, and other factors which influence the pH of surface and ground water may influence the chemistry of the leachate. More data are expected to be generated by the EPA in this area.

There is a major concern for recycling potential of the asphalt pavements containing rubber. Currently, the Kentucky Transportation Cabinet does not use recycled asphalt pavement (RAP) in hot mix. Use of RAP materials by the Cabinet is almost exclusively limited to base and subbase construction. Local governmental agencies, however, use a significant amount of RAP in their hot mix projects. There is potential for state legislation to mandate more usage of RAP in a manner similar to California, where landfill disposal of milled pavement surfaces is prohibited and RAP usage is as high as 80% in hot mix recycling projects. Obviously, as more RAP containing rubber is incorporated into the hot mix, the concern for recyclability of the RAP material becomes greater. The limited experience in California, Arizona, and Canada reflects that the problem of "blue smoke" in hot mix plants may be overcome when the RAP material containing rubber is applied away from the flame. Generally, for hot recycling applications, the double barrel drum plant offers the best quality material with little or no adverse environmental impact (ASTEC 1992).

On another note, one should remember that scrap tire recycling in asphalt pavements is often advertised as a major landfill relief factor. However, realistic estimates of sound asphalt applications reveal that only a small portion of waste tires may be incorporated into hot mix asphalt. Additionally, most rubber vendors would like to use clean tires in their shredding and grinding operations, which eliminates the use of tires recovered from dump sites. As a result, it is becoming more obvious that other uses of scrap tires (such as: geocomposite, light weight fill, crash cushion, fuel source in power plants and cement plant, etc.) must be promoted if we are to make a significant change in the tire waste dilemma.

One major issue concerning the use of scrap tires is documentation of the sources of tires. This is primarily an accounting issue that vendors wishing to conduct business with the Transportation Cabinet must provide clear tire import-export equivalencies if the source of their rubber is outside Kentucky.

Finally, Transportation Cabinet officials are genuinely interested in engaging in a partnering relationship with contractors on a case by case basis. This offers a unique opportunity for successful implementation of the crumb rubber technology within the time constraints of the ISTEA mandate.

GUIDELINES FOR IMPLEMENTATION OF CRM TECHNOLOGY IN KENTUCKY

Performance

It is clear from the ISTEA mandate that the CRM asphalt must meet the performance requirements of the conventional HMA applications.

Ease of Implementation

Obviously, from the implementation point of view, Transportation Cabinet officials would prefer a technology which is least disruptive to current practices and costs. The fine ground rubber -- 177-micron (80-mesh) technology proved to be easily implementable for Kentucky's conditions without a need for altering current HMA practices and/or specifications in Kentucky. This is particularly true at rubber content of 7.5%, by weight of total binder, which results in a material similar to polymer modified asphalt.

Potential for Being Cost Effective in the Long Term

Although the primary thrust behind the implementation of the CRM asphalt technology in Kentucky appears to be the ISTEA mandate, this should not diminish the focus on engineering and cost aspects of the technology. Hopefully, wider availability of the technology and its associated market competition will reduce the cost of this technology. At the same time, more experience with the CRM asphalt and its performance will allow cost and performance comparisons to be based on engineering principles.

FHWA Equation for CRM-HMA Quantity

$$R = U \times (10M + 150S)$$

R= The kilograms of recycled rubber required to satisfy the minimum utilization.

U = The required utilization percentage expressed as a decimal.

M = The total contract metric tons of Federal-aid Hot Mix awarded during the fiscal year.

S = The total contract metric tons of Federal-aid Hot Spray Applied Binder awarded during the fiscal year.

Environmental Impact

Coordination with environmental agencies is recommended. The cost of monitoring plant emissions could be as high as $10,000 to $50,000 per day. At this time, it appears advisable to consult the EPA officials before developing plans for monitoring asphalt plant emissions in Kentucky.

CONCLUSIONS AND RECOMMENDATIONS

Based upon information presented in this report, the following conclusions are made. These conclusions are based upon statistical analysis of laboratory and field data. However, conclusions based upon the field data may have been premature due to the short service time, less than one year, of the US 421, Franklin County, Kentucky project.

- Mixture design and analysis of the CRM-HMA using the fine ground rubber -- 177-micron (80-mesh) was possible with the existing Kentucky specifications and practices.

- Construction of the CRM-HMA using the fine ground rubber -- 177-micron (80-mesh) was possible with the existing Kentucky specifications and practices.

- As expected, cost of the CRM-HMA ($46.26/ton) was higher than the conventional HMA ($29.60/ton). At this point, it is not clear whether the additional cost of the CRM-HMA is justifiable from a performance point of view. For this purpose, long-term performance monitoring of all CRM projects in Kentucky is recommended.

- Long-term field performance data are needed for evaluation of the performance. It is recommended that funds be made available for semi-annual monitoring of performance of the field trial project for the period of five (5) years.

- The US 421, Franklin County, Kentucky, field trial project focused on the "wet process", and specifically fine ground rubber from ease of implementation point of view. However, other CRM technologies are recommended to be investigated for possible implementation in Kentucky, including SAMI technology, for which an interim implementation guideline is included in Appendix C of this report.

- The contractor expressed willingness to implementing various CRM technologies for future projects.
- The partnership arrangement between the contractor, Transportation Cabinet, and the KTC research team proved to be a success. All parties genuinely cooperated toward a successful project.

REFERENCES

AASHTO (1986). GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

Asphalt Institute, Research Report (1993). 'Effect of Crumb Rubber on Properties of Asphalt Materials", Applied research for Rouse Rubber Industries, Inc., March 1993, Lexington, Kentucky.

ASTEC (1992), The Stationary Asphalt Facility, ASTEC Industries, Chattanooga, Tennessee.

Estakhri, C.K., Button, J.W., Fernando, E. (1992). "Use, Availability, and Cost-Effectiveness of Asphalt Rubber in Texas". TRR 1339, TRB.

California Health Department (1990). Draft Plan for Recycling of Hazardous Waste in Pavements. Sacramento, California.

Goodrich, J.L. (1988). "Asphalt and Polymer Modified Asphalt Properties Related to the Performance of Asphalt Concrete Mixes". Association of Asphalt Paving Technologists Proceedings, Volume 57.

Heitzman, M.A. (1992). "State of the Practice - Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier". FHWA-SA-92-022.

Lottman, R.P. (1978). "Predicting Moisture-Induced Damage to Asphalt Concrete". Report 192, National Cooperative Highway Research Program, Washington, D.C., 1986.

McLean, D.B., and Monismith, C.L. (1974). "Estimation of Permanent Deformation in Asphalt Concrete Layers Due to Repeated Traffic Load". Transportation Research Record 510, Transportation Research Board, Washington, D.C.

Road Bridges Magazine (1992). "Jury Remains Out on Asphalt-Rubber Use". December 1992.

SHRP (1991). *FOCUS*, Strategic Highway Research Program Newsletter, Washington, D.C., July Issue.

Sousa, J.B., Craus, J., and Monismith, C.L. (1991). Summary report on Permanent Deformation in Asphalt Concrete, Strategic Highway Research Board. SHRP-A/IR-91-104.

Tunnicliff, D.G., and Root, R.E. (1984). "Use of Antistripping Additives in Asphaltic Concrete Mixtures". Report 274, National Cooperative Highway Research Program, Washington, D.C.

Von Quintus, H.L., Scherocman, J.A., Hughes C.S., and Kennedy, T.W. (1991). "Asphalt-Aggregate Mixture Analysis System - AAMAS". NCHRP Report 338, Transportation Research Board.

Yoder, E.J., and Witczak, M.W. (1975). PRINCIPLES OF PAVEMENT DESIGN. John Wiley and Sons.

APPENDIX A - Pavement Condition Data

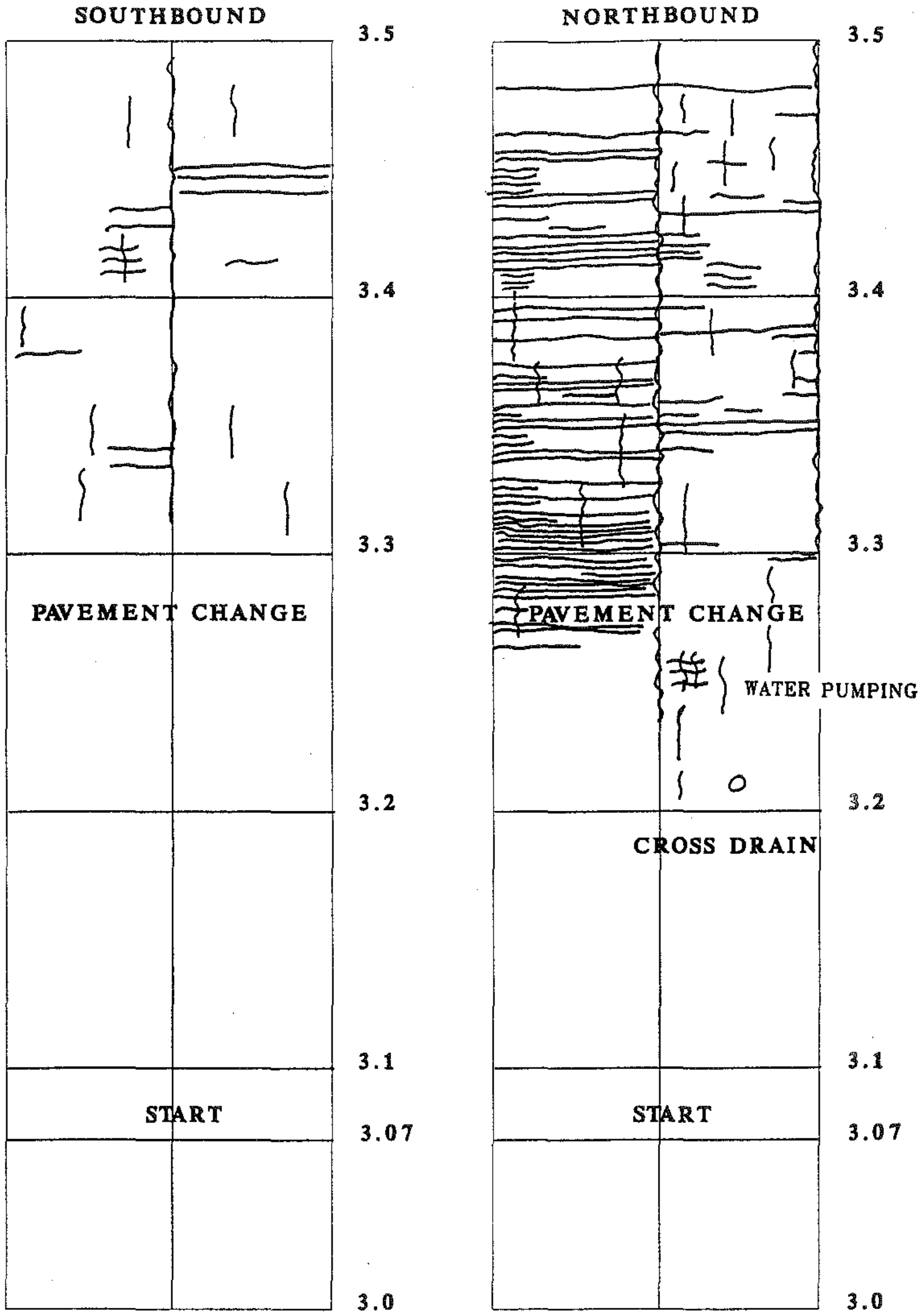
HMA. More information is provided under the "moisture susceptibility" section of this report.

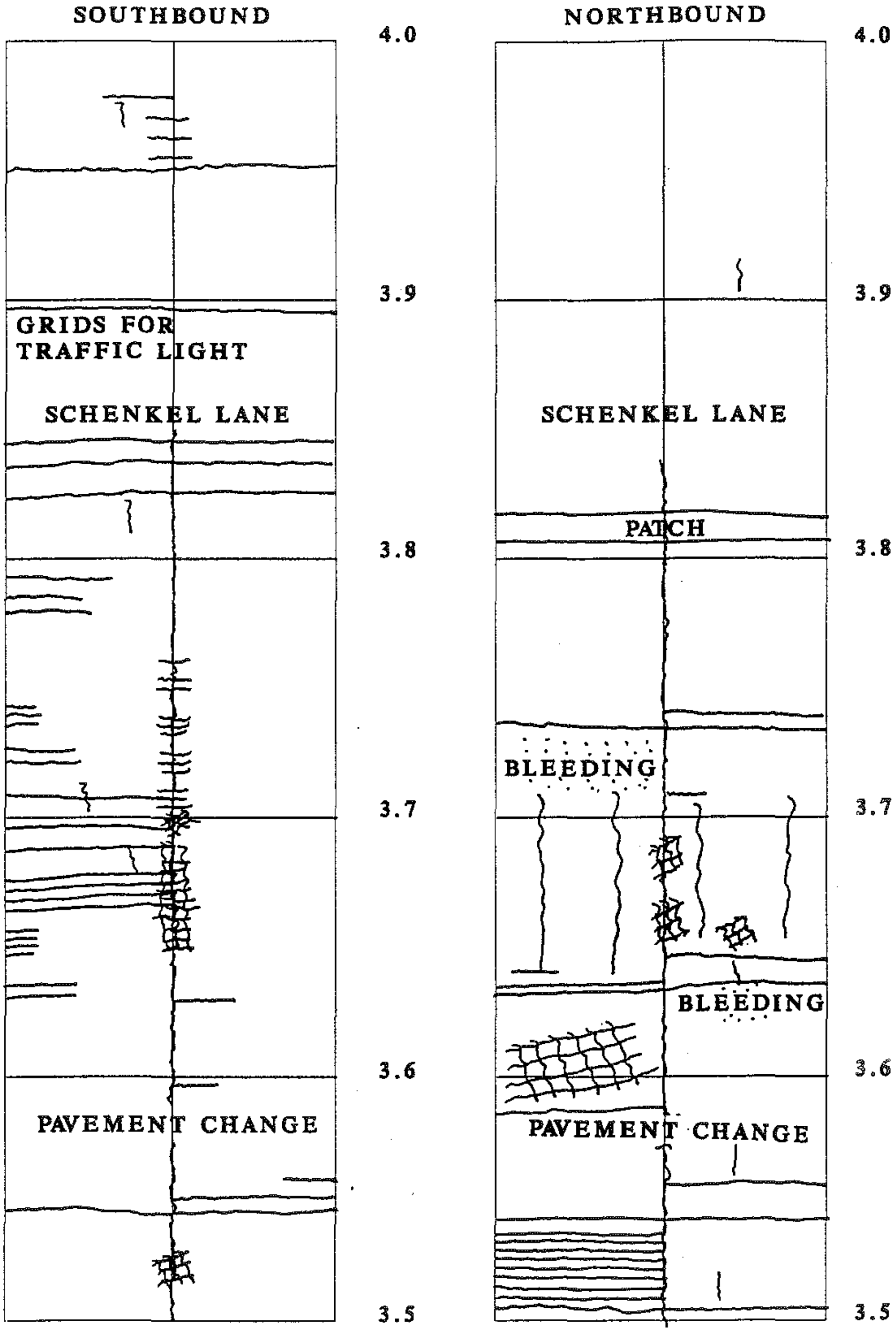
◆ No unusual wear on the plant equipment was observed. Plant modifications were very minor.

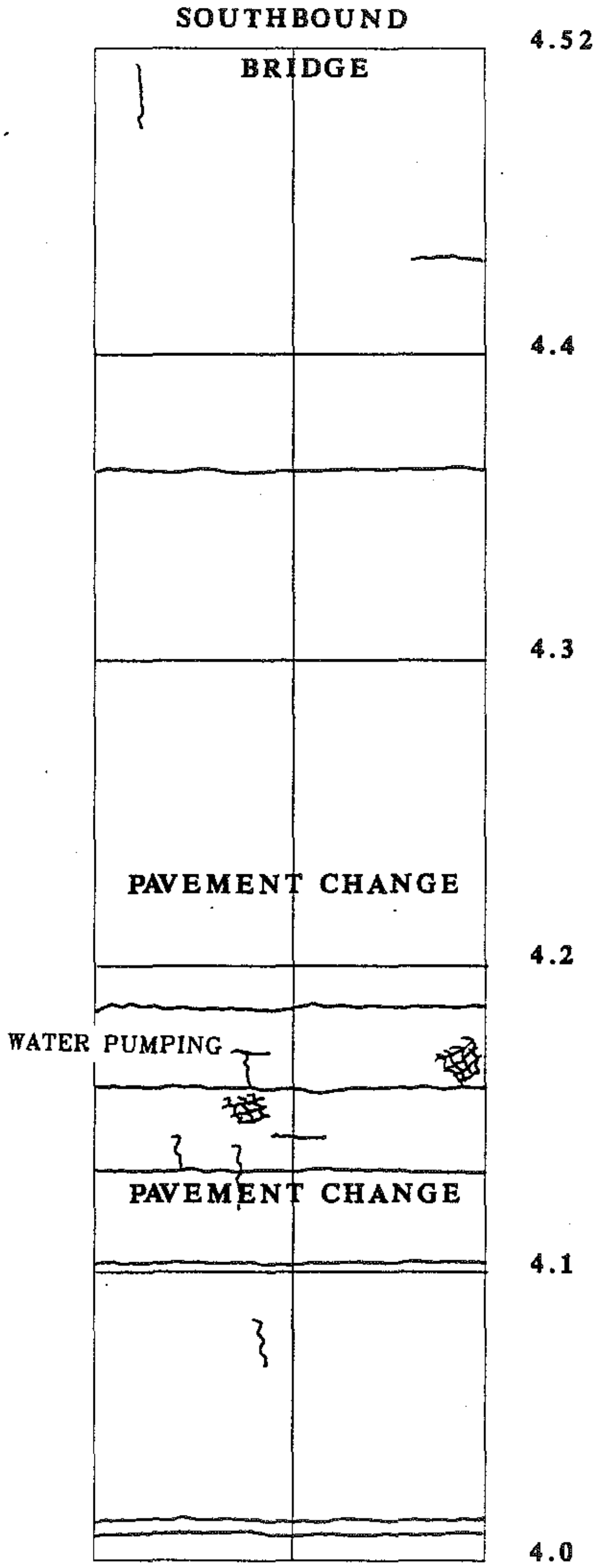
◆ Simple observations indicated no difference in human perception of CRM-HMA versus conventional HMA on this project. Visual inspections revealed no difference between the finished surfaces of CRM-HMA and that of conventional HMA.

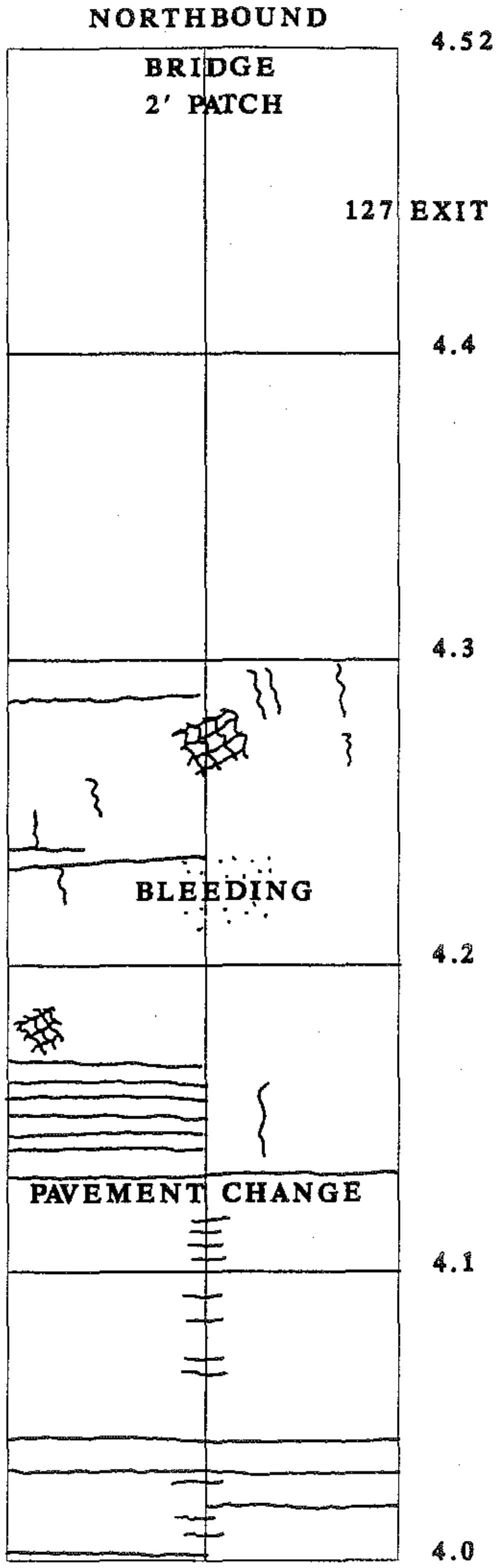
◆ The cost of conventional HMA on this project was $32.63 per metric ton ($29.60 per ton), while the CRM-HMA cost was $51.00 per metric ton ($46.26 per ton) -- i.e. CRM-HMA on this project was more expensive than the conventional HMA by 56%.

◆ In summary, the construction was a success. The contractor felt comfortable implementing this technology with existing Kentucky specifications and practices.


SOUTHBOUND
NORTHBOUND
3.5
3.4
3.3
PAVEMENT CHANGE
PAVEMENT CHANGE
WATER PUMPING
3.2
CROSS DRAIN
3.1
START
START
3.07
3.0


SOUTHBOUND
4.0
3.9
GRIDS FOR
TRAFFIC LIGHT
SCHENKEL LANE
3.8
3.7
3.6
PAVEMENT CHANGE
3.5
NORTHBOUND
4.0
3.9
SCHENKEL LANE
PATCH
3.8
BLEEDING
3.7
BLEEDING
3.6
PAVEMENT CHANGE
3.5


SOUTHBOUND
4.52
BRIDGE
4.4
4.3
PAVEMENT CHANGE
4.2
WATER PUMPING
PAVEMENT CHANGE
4.1
4.0


NORTHBOUND
4.52
BRIDGE
2′ PATCH
127 EXIT
4.4
4.3
BLEEDING
4.2
PAVEMENT CHANGE
4.1
4.0

Transportation Cabinet
Department of Highways
Specialized Programs

TC 40-14
Rev. 2/91

Pavement Condition Evaluation Form

68

District: 1
County: FRANKLIN
Route No: US421
Road Name: THORN HILL BY-PASS
From: (MP 3.072) US60
To: (MP 4.820) 1600' N of US127 BC.
Length: 1.748
Width: 2 X 24'
Project No: MP-037-0421-003-005
System: SP

I. CONDITION SURVEY

	EXTENT							SEVERITY					POINTS
		Few		Intermediate		Extensive		Slight		Moderate		Severe	
Cracking	1	2	[✓ 3]	4	5	6		1	1.5	2	[✓ 3]	4	6
Base Failures (Faulting)		1	1.5	2	2.5	3	1.5	1	1.5	2	2.5	3	1.5
Raveling (Spalling)		.6	.9	1.3	[✓ 1.6]	2		.6	.9	1.3	[✓ 1.6]	2	3.2
Edge Failures		.6	.9	1.3	1.6	2	0	.3	.4	.6	.8	1	0
Out of Section		1	[✓ 1.5]	2	2.5	3		1	[✓ 1.5]	2	2.5	3	3
Appearance			Fair - [✓ 1.5] 2			Poor - 3 4			Very Poor - 5				1.5
												Subtotal	15.2

II.	RIDEABILITY	N/E: 3.07 S/W: 3.02	RI 3.0	2.5
III.	RUTTING	N/E: S/W: up to 7/16"	Depth 3/8"	6
IV.	SKID RESISTANCE		SN No Points x Factor x	—
V.	TRAFFIC VOLUME TRAVEL SPEED		AADT 19810 MPH 55	12 5

Raters: Dade, P.E. / McCann P.E
Date: 7/2/93

Total 40.7
Points Ranking

ROADWAY CHARACTERISTICS

PCC [✓ AC] AC/PCC
Curbs & Gutters Manholes Inlet Boxes

Shoulders High ____ Low 1/2'
Width 10'
Type AC & Gravel
Industrial Haul Type ____
Patching (Percent) 30

CO RECOMMENDATIONS

Improvement Needed? [✓ Yes] Marginal No
Type [✓ Resurface (AC)] Other ____
Preparation: Leveling & Wedging (Percent) 20
Milling (in.) ____ Other Mill Parts of it
Other: ____

STATEWIDE RANKING:
DISTRICT RANKING:

Preparator: ____
DISTRICT RECOMMENDATIONS
Cost Estimate: ____
Treatment Code: ____
Remarks: ____

K.M.

Transportation Cabinet
Department of Highways
Specialized Programs

69

TC 40-1-
Rev. 2/9

Pavement Condition Evaluation Form

91
16
0

District: 5
County: FRANKLIN
Route No: US 421
Road Name: THORNHILL BY-PASS

From: (MP 3.072) US 60
To: (MP 4.520) US 127 BRIDGE

Length: 1.448
Width: 2X24'
Project No: MP-037-0421-003-005
System: SP

I. CONDITION SURVEY

MP 3.072- 3.600 77
MP 3.600- 4.520 70

	EXTENT							SEVERITY					POINTS
		Few		Inter-mediate		Exten-sive		Slight		Mod-erate		Severe	
Cracking	1	2	[✓ 3]	4	5	6		1	1.5	2	[✓ 3]	4	6.0
Base Failures (Faulting)		1	1.5	2	2.5	3	1.5	1	1.5	2	2.5	3	1.5
Raveling (Spalling)		.6	.9	1.3	[✓ 1.6]	2		.6	.9	[✓ 1.3]	1.6	2	2.9
Edge Failures		.6	.9	1.3	1.6	2	0	.3	.4	.6	.8	1	0
Out of Section		1	[✓ 1.5]	2	2.5	3		1	[✓ 1.5]	2	2.5	3	3.0
Appearance			[✓ Fair - 1.5] 2			Poor - 3 4			Very Poor - 5				1.5
												Subtotal	14.9

II.	RIDEABILITY	N/E: 3.07 S/W: 3.14	RI 3.1	1.0
III.	RUTTING	N/E: S/W: UP TO 7/16"	Depth 3/8	6.0
IV.	SKID RESISTANCE		SN ND Points x Factor x	0
V.	TRAFFIC VOLUME TRAVEL SPEED		AADT 19810 MPH 55	12 5

Raters: ~~RIZENBERGS, P.E., / GREENFIELD~~ Burchett P.E. / Hollinger
Date: 6 / 11 / 1992

Total 38.9
Points Ranking - ~~30~~ 23

ROADWAY CHARACTERISTICS

PCC [✓ AC] AC/PCC
Curbs & Gutters Manholes Inlet Boxes

Shoulders
High ____ Low 1/2
Width 10'
Type Gravel /AC
Industrial Haul Type ____
Patching (Percent) 20

CO RECOMMENDATIONS

Improvement Needed? [✓ Yes] Marginal No
Type: [✓ Resurface (AC)] Other ____
Preparation: Leveling & Wedging (Percent) 25
Milling (in.) ____ Other ____
Other: ____

STATEWIDE RANKING:
DISTRICT RANKING: ~~29~~ 30

Preparator: Cal
Cost Estimate: $198,200
Treatment Code: [1, 3] - D - II, I
Remarks: Milling will be essential
1 Bridge

DISTRICT RECOMMENDATIONS

APPENDIX B - Material Properties

APPENDIX B1 - Inventory of HMA Specimens Compacted by KTC

Regular AK-Surface Mix (4"pills) Project: P-150
(compacted at 265 F unless otherwise noted)

Pill #	OD	Sat.	SSD	Spec. Grav. (Bulk)	% Air Voids	Compaction (# Blows)	Test Performed on Sample
1	1199.3	689.1	1200.1	2.3470	6.0838	75	STABILITY
2	1194.9	688.6	1195.7	2.3563	5.7087	75	STABILITY
3	1214.5	700.6	1215.4	2.3592	5.5955	75	STABILITY
4	1193.7	683.5	1195.1	2.3333	6.6319	75	
5	1195.1	686.2	1196.5	2.3420	6.2843	75	
6	1202.7	687.1	1205.5	2.3200	7.1619	75	PRACTICE (Mr)
7	1196.5	684.2	1199.1	2.3238	7.0127	75	PRACTICE (Mr)
8	1194.9	684.2	1196.3	2.3333	6.6293	75	
9	1208.8	693.0	1210.5	2.3358	6.5288	75	
10	1179.5	674.7	1181.8	2.3260	6.9239	75	PRACTICE (Mr)
11	1175.0	674.6	1177.0	2.3388	6.4116	75	
12	1187.9	680.9	1189.5	2.3356	6.5375	75	
13	1213.3	692.6	1216.3	2.3168	7.2915	75	PRACTICE (Mr)
14	1174.5	667.4	1178.1	2.2998	7.9718	75	PRACTICE (Mr)
15	1212.6	694.1	1215.8	2.3243	6.9898	75	PRACTICE (Mr)
16	1190.6	680.9	1194.0	2.3204	7.1466	75	PRACTICE (Mr)
A1	1202.1	692.8	1205.5	2.3446	6.1766	75	RES. MOD. (77F)
A2	1202.8	692.9	1203.4	2.3561	5.7174	75	RES. MOD. (77F)
A3	1204.9	694.1	1205.8	2.3547	5.7743	75	RES. MOD. (77F)
A4	1213.6	697.4	1214.4	2.3474	6.0669	75	RES. MOD. (77F)
A5	1203.9	693.1	1204.8	2.3527	5.8525	75	RES. MOD. (104F)
A6	1222.6	701.3	1223.8	2.3399	6.3664	75	RES. MOD. (104F)
P1	1208.5	694.8	1209.7	2.3471	5.8918	75	RES. MOD. (32F)
P2	1200.1	690.1	1201.2	2.3481	5.8511	75	RES. MOD. (32F)
P3	1208.9	696.3	1210.3	2.3519	5.6958	75	RES. MOD. (32F)
P4	1206.5	695.4	1207.7	2.3551	5.5708	75	RES. MOD. (104F)

Regular AK-Surface Mix (4"pills) Continued

Pill #	OD	Sat.	SSD	Spec. Grav. (Bulk)	% Air Voids	Compaction (# Blows)	Test Performed on Sample
N1	1201.1	685.7	1204.0	2.3174	7.0816	50	TSR (SAT.)
N2	1207.7	689.2	1210.5	2.3167	7.1087	50	
N3	1200.1	685.3	1202.0	2.3226	6.8715	50	TSR (DRY)
N4	1199.7	684.4	1201.2	2.3214	6.9206	50	TSR (SAT.)
N5	1192.9	681.1	1195.0	2.3213	6.9259	50	
N6	1197.8	682.6	1199.0	2.3195	6.9960	50	
N7	1200.5	685.4	1202.1	2.3234	6.8405	50	
N8	1206.0	687.3	1207.9	2.3166	7.1148	50	TSR (DRY)
N9	1210.9	691.9	1214.5	2.3171	7.0943	50	
O1	1217.1	695.7	1221.0	2.3170	7.0986	50	
O2	1198.9	684.2	1200.8	2.3208	6.9466	50	TSR (DRY)
O3	1214.8	693.3	1216.8	2.3205	6.9553	50	TSR (SAT.)
1 (7-16)	1202.0	702.9	1202.5	2.4059	3.6860	PLANT MADE	RES. MOD. (ALL)
2 (7-16)	1199.7	702.5	1200.3	2.4100	3.5227	PLANT MADE	RES. MOD. (ALL)
3 (7-16)	1198.8	698.8	1199.3	2.3952	4.1151	PLANT MADE	RES. MOD. (ALL)
I1I	1191.1	679.9	1192.3	2.3246	6.9435	75 @ 240F	
I2I	1195.5	677.9	1198.1	2.2982	8.0002	75 @ 240F	
I3I	1197.4	682.9	1200.1	2.3152	7.3195	75 @ 240F	
75-1	1198.1	681.0	1211.8	2.2572	9.6414	75 @ 240F	
75-2	1187.6	680.7	1193.1	2.3177	7.2170	75 @ 240F	
75-3	1218.8	697.0	1227.3	2.2983	7.9935	75 @ 240F	
55-1	1206.5	688.7	1216.4	2.2863	8.4733	55 @ 240F	
55-2	1198.8	681.1	1207.9	2.2756	8.9021	55 @ 240F	
50-1	1189.7	678.5	1201.1	2.2765	8.8670	50 @ 240F	
50-2	1187.9	676.3	1205.7	2.2439	10.1737	50 @ 240F	
50-3	1216.3	694.0	1227.6	2.2794	8.7501	50 @ 240F	
45-1	1162.5	661.5	1172.5	2.2750	8.9291	50 @ 240F	
45-2	1217.0	693.7	1227.2	2.2812	8.6805	50 @ 240F	
45-3	1173.9	671.6	1193.9	2.2476	10.0257	50 @ 240F	

AK-Surface Mix w/Rouse GF-80A (4" pills) Project: P-150
(compacted at 265 F unless otherwise noted)

Pill #	OD	Sat.	SSD	Spec. Grav. (Bulk)	% Air Voids	Compaction (# Blows)	Test Performed on Sample
1 am	1202.0	697.5	1202.6	2.3797	3.8106	PLANT MADE	
2 am	1200.1	697.3	1200.6	2.3845	3.6191	PLANT MADE	
3 am	1199.5	695.7	1200.5	2.3762	3.9536	PLANT MADE	
4 am	1201.1	694.9	1201.9	2.3690	4.2428	PLANT MADE	
5 am	1204.3	696.3	1205.3	2.3660	4.3649	PLANT MADE	
1 noon	1201.7	694.1	1202.4	2.3642	4.7863	PLANT MADE	RES. MOD. (32F)
2 noon	1202.3	693.5	1203.9	2.3556	5.1308	PLANT MADE	RES. MOD. (77F)
3 noon	1204.6	694.6	1205.4	2.3583	5.0237	PLANT MADE	RES. MOD. (104F)
4 noon	1202.6	694.5	1203.4	2.3631	4.8274	PLANT MADE	
1 (7-14)	1200.2	691.4	1201.0	2.3552	5.0330	PLANT MADE	RES. MOD. (32F)
2 (7-14)	1174.9	680.7	1175.5	2.3745	4.2542	PLANT MADE	RES. MOD. (77F)
3 (7-14)	1166.0	674.7	1166.5	2.3709	4.3999	PLANT MADE	RES. MOD. (104F)
1 (2:00)	1199.9	697.3	1200.4	2.3850	3.9850	PLANT MADE	RES. MOD. (32F)
2 (2:00)	1199.7	696.8	1200.4	2.3822	4.0963	PLANT MADE	RES. MOD. (77F)
3 (2:00)	1197.2	694.7	1197.9	2.3792	4.2201	PLANT MADE	RES. MOD. (104F)
K1	1202.1	691.2	1203.0	2.3488	5.4441	75	RES. MOD. (77F)
K2	1199.2	689.2	1200.0	2.3477	5.4875	75	RES. MOD. (77F)
K3	1104.3	636.8	1105.6	2.3556	5.1695	75	RES. MOD. (77F)
K4	1208.4	695.4	1209.4	2.3510	5.3554	75	STABILITY
K5	1203.2	692.6	1204.8	2.3491	5.4315	75	RES. MOD. (104F)
K6	1200.3	693.3	1201.3	2.3628	4.8794	75	RES. MOD. (104F)
K7	1193.2	686.4	1194.3	2.3493	5.4235	75	STABILITY
K8	1202.5	692.7	1203.9	2.3523	5.3016	75	STABILITY
K9	1230.7	708.7	1231.9	2.3523	5.3037	75	RES. MOD. (32F)

AK-Surface Mix w/Rouse GF-80A (4" pills) Continued

Pill #	OD	Sat.	SSD	Spec. Grav. (Bulk)	% Air Voids	Compaction (# Blows)	Test Performed on Sample
11/12 1	1212	697.4	1213.1	2.3502	5.3863	75	RES. MOD. (32F)
11/12 2	1162.7	669.5	1163.8	2.3522	5.3053	75	RES. MOD. (32F)
11/12 3	1220.2	700.8	1221.5	2.3434	5.6609	75	RES. MOD. (104F)
11/12 4	1181.5	679.6	1184.1	2.3419	5.7197	75	
11/12 5	1195.5	687.4	1199.2	2.3359	5.9632	75	
11/12 6	1194.6	688.5	1196.8	2.3502	5.3870	75	
11/12 7	1166.8	673.9	1169	2.3567	5.1250	75	
H1	1202.7	688.5	1208.4	2.3133	7.0952	50	
H2	1205.4	689.0	1209.5	2.3159	6.9940	50	TSR (DRY)
H3	1204.4	687.7	1207.3	2.3179	6.9102	50	TSR (SAT.)
I1	1203.3	688.9	1207.0	2.3225	6.7259	50	TSR (DRY)
I2	1201.8	686.7	1204.8	2.3196	6.8422	50	
I3	1206.7	692.0	1211.1	2.3246	6.6426	50	TSR (DRY)
I4	1203.2	689.5	1207.6	2.3223	6.7337	50	TSR (SAT.)
I5	1206.3	691.1	1210.0	2.3247	6.6375	50	TSR (SAT.)
I6	1200.7	687.4	1204.7	2.3211	6.7835	50	
L1	1251.6	715.9	1255.3	2.3204	6.5879	50	
L2	1209.6	691.5	1212.9	2.3199	6.6060	50	TSR (DRY)
L3	1201.9	688.2	1206.3	2.3198	6.6094	50	TSR (SAT.)
L4	1200.3	684.0	1205.1	2.3034	7.2707	50	
B1	1153.9	662.8	1154.7	2.3458	5.6774	70	PRACTICE (Mr)
B2	1197.1	681.2	1200.3	2.3061	7.2736	70	
B3	1206.2	691.7	1207.5	2.3385	5.9709	70	PRACTICE (Mr)
C1	1204.3	689.4	1206.7	2.3280	6.3913	65	
C2	1201.2	686.9	1204.6	2.3203	6.7044	65	
C3	1194.0	683.4	1196.4	2.3275	6.4139	65	
D1	1211.6	694.5	1216.8	2.3197	6.7254	60	
D2	1195.2	684.2	1198.5	2.3239	6.5567	60	
D3	1208.6	691.6	1211.9	2.3229	6.5987	60	
D4	1203.3	689.0	1206.4	2.3257	6.4871	60	
D5	1204.6	689.1	1202.5	2.3463	5.6567	60	
D6	1210.5	693.4	1213.3	2.3283	6.3799	60	

AK-Surface Mix w/Rouse GF-80A (4" pills) Continued

Pill #	OD	Sat.	SSD	Spec. Grav. (Bulk)	% Air Voids	Compaction (# Blows)	Test Performed on Sample
E1	1209.8	694.1	1212.2	2.3351	6.1089	65	
E2	1192.9	683.6	1195.4	2.3308	6.2809	65	
E3	1201.6	690.7	1203.9	2.3414	5.8550	65	
E4	1211.3	694.5	1215.0	2.3272	6.4260	65	
E5	1210.0	693.2	1213.7	2.3247	6.5264	65	
E6	1206.3	688.3	1219.0	2.2730	8.6033	65	
F1	1197.3	686.3	1199.3	2.3339	6.2683	60	
F2	1197.7	686.7	1199.5	2.3356	6.2005	60	
F3	1210.3	692.4	1213.4	2.3230	6.7055	60	
G1	1198.8	688.0	1202.8	2.3287	6.4791	55	
G2	1197.3	684.0	1201.5	2.3136	7.0834	55	
G3	1199.8	687.2	1204.0	2.3216	6.7633	55	
J1	1201.1	688.0	1204.8	2.3241	6.6623	45	
J2	1205.2	687.2	1214.1	2.2873	8.1389	45	
J3	1198.5	686.6	1204.3	2.3150	7.0262	45	
J4	1197.5	682.1	1206.3	2.2844	8.2557	45	

APPENDIX B2 - Mixture Analysis Data

ASTM D 4867: Effect of Moisture on Asphalt Concrete Paving Mixtures

AK Surface Mix w/ 7.5% Rouse GF-80A

PROJECT: P-150
DATE: 10-1-93
TECH: R. Bosley and P. Massie
COMPACTION: 50 blows at 265 F

SAMPLE			H2	I1	I3	L2	H3	I4	L3
Diameter		D	4	4	4	4	4	4	4
Thickness		t	2.5885	2.5675	2.5735	2.5920	2.5815	2.5755	2.5625
Dry mass in Air		A	1205.4	1203.3	1206.7	1209.6	1204.4	1203.2	1201.9
SSD mass		B	1209.5	1207.0	1211.1	1212.9	1207.3	1207.6	1206.3
Mass in Water		C	689.0	688.9	692.0	691.5	687.7	689.5	688.2
Volume	(B-C)	E	520.5	518.1	519.1	521.4	519.6	518.1	518.1
Bulk Sp Gravity	(A/E)	F	2.316	2.320	2.325	2.320	2.318	2.322	2.320
Max Sp Gravity		G	2.490	2.490	2.490	2.484	2.490	2.490	2.484
% Air Voids	(100(G-F)/G)	H	6.99	6.84	6.64	6.61	6.91	6.73	6.61
Vol Air Voids	(HE/100)	I	36.39	35.46	34.48	34.45	35.91	34.89	34.25
Load		P	2100	2390	2300	2180			
SATURATED									
SSD mass		B'					1229.2	1227.1	1225.8
Mass in Water		C'					712.3	712.2	708.3
Volume	(B'-C')	E'					516.9	514.9	517.5
Vol Abs Water	(B'-A)	J'					24.8	23.9	23.9
% Saturation	(100J'/I)						69.06	68.49	69.79
% Swell	(100(E'-E)/E)						-0.5196	-0.6176	-0.1158
CONDITIONED									
Thickness		t"					2.5819	2.5936	2.5719
SSD mass		B"					1238.8	1236.2	1233.7
Mass in Water		C"					716.0	714.9	713.0
Volume	(B"-C")	E"					522.8	521.3	520.7
Vol Abs Water	(B"-A)	J"					34.4	33.0	31.8
% Saturation	(100J"/I)						95.79	94.57	92.85
% Swell	(100(E"-E)/E)						0.6159	0.6176	0.5018
Load		P"					1900	1975	1950
Dry Strength	2P/(3.14tD)	Std	129.12	148.15	142.24	133.86			
Avg. Dry Strength			138.34						
Wet Strength	2P"/(3.14t"D)	Stm					117.12	121.19	120.67
Avg. Dry Strength							138.34		
TSR							84.66	87.61	87.23
AVERAGE TSR (KTC lab compacted using 35 blows)									86.50%
AVERAGE TSR (Plant compacted using 27 blows)									71.00%

ASTM D 4867: Effect of Moisture on Asphalt Concrete Paving Mixtures

Regular AK-Surface Mix

PROJECT: P-150 TECH: R. Bosley and P. Massie
DATE: 10-8-93 COMPACTION: 50 blows at 265 F

SAMPLE			N8	O2	N3	O3	N1	N4
Diameter		D	4	4	4	4	4	4
Thickness		t	2.5850	2.5665	2.5750	2.6000	2.5680	2.5525
Dry mass in Air		A	1206.0	1198.9	1200.1	1214.8	1201.1	1199.7
SSD mass		B	1207.9	1200.8	1202.0	1216.8	1204.0	1201.2
Mass in Water		C	687.3	684.2	685.3	693.3	685.7	684.4
Volume	(B-C)	E	520.6	516.6	516.7	523.5	518.3	516.8
Bulk Sp Gravity	(A/E)	F	2.317	2.321	2.323	2.321	2.317	2.321
Max Sp Gravity		G	2.494	2.494	2.494	2.494	2.494	2.494
% Air Voids	(100(G-F)/G)	H	7.11	6.95	6.87	6.96	7.08	6.92
Vol Air Voids	(HE/100)	I	37.04	35.89	35.51	36.41	36.70	35.77
Load		P	2385	2290	2325			
SATURATED								
SSD mass		B'				1240.8	1225.6	1223.0
Mass in Water		C'				717.4	707.6	706.2
Volume	(B'-C')	E'				523.4	518.0	516.8
Vol Abs Water	(B'-A)	J'				26.0	24.5	23.3
% Saturation	(100J'/I)					71.41	66.75	65.15
% Swell	(100(E'-E)/E)					-0.0191	-0.0579	-0.0000
CONDITIONED								
Thickness		t"				2.5978	2.5840	2.5611
SSD mass		B"				1244.9	1229.0	1228.3
Mass in Water		C"				721.2	710.6	710.1
Volume	(B"-C")	E"				523.7	518.4	518.2
Vol Abs Water	(B"-A)	J"				30.1	27.9	28.6
% Saturation	(100J"/I)					82.67	76.01	79.97
% Swell	(100(E"-E)/E)					0.0382	0.0193	0.2709
Load		P"				1910	2200	2010
Dry Strength	2P/(3.14tD)	Std	146.84	142.01	143.70			
Avg. Dry Strength				144.18				
Wet Strength	2P"/(3.14t"D)	Stm				117.02	135.50	124.91
Avg. Dry Strength							144.18	
TSR						81.16	93.98	86.63
AVERAGE TSR (KTC lab compacted using 35 blows)								87.26%
AVERAGE TSR (Plant compacted using 27 blows)								81.00%

Marshall Stability and Flow

AK Surface

Sample #	Corrected Stability (lbs)	Flow (1/100")
1	2225	8.5
2	2336	9.5
3	2352	9.5
Average	2304	9.2

AK Surface w/GF-80A

Sample #	Corrected Stability (lbs)	Flow (1/100")
K4	2512	10.0
K7	2416	9.5
K8	2703	11.0
Average	2544	10.2

APPENDIX B3 - Mixture Design Data Generated by KTC

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                         GRADATION COMBINATION PROGRAM
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DATE:          5-28-93

PROJECT:       CLASS AK SURFACE/ THORNHILL BYPASS

AGGREGATE TYPES:                                       SIEVES  % PASS  CUMULAT.  MASTER   RANGE   JMF
       (1)-    NUGENT #8           (BIN1 %):   42.0                     % RETAIN. (LOWER)  (UPPER)  SET @
               --------------------------             ------------------------------------------------
       (2)-    HARROD LSS          (BIN2 %):   23.0     1/2"-   100.0     0.0     100      100     100
               --------------------------               3/8"-    95.0     5.0      75       97      92
       (3)-    NUGENT MS           (BIN3 %):   19.0      #4-     65.8    34.2      48       72      66
               --------------------------                #8-     39.8    60.2      30       54      40
       (4)-    NUGENT 1/4"CHIPS    (BIN4 %):   16.0     #16-     27.5    72.5      18       40      28
               --------------------------               #30-     18.3    81.7       9       28      19
       (5)-                        (BIN5 %):    0.0     #50-      9.4    90.6       5       18      10
               --------------------------              #100-      5.4     0.0       2       10       6
       (6)-                        (BIN6 %):    0.0    #200-      4.2    95.8       1        5     4.5
               --------------------------
       (7)                         (BIN7 %):    0.0
               --------------------------


---------------------------------------------------------------------------------------------------------
 SIEVE  AGG. (1) AGG. (1) AGG. (2) AGG. (2) AGG. (3) AGG. (3) AGG. (4) AGG. (4) AGG. (5)  AGG (5) AGG. (6) AGG. (6)
 SIZE   % PASS    BIN %   % PASS    BIN %   % PASS    BIN %   % PASS    BIN %   % PASS    BIN %   % PASS    BIN %
                   42.0              23.0              19.0              16.0               0.0               0.0

---------------------------------------------------------------------------------------------------------
 1/2"-   100.0     42.0    100.0     23.0    100.0     19.0    100.0     16.0      0.0      0.0      0.0      0.0
 3/8"-    88.3     37.1    100.0     23.0    100.0     19.0     99.2     15.9      0.0      0.0      0.0      0.0
  #4-     21.6      9.1     97.3     22.4     99.6     18.9     96.2     15.4      0.0      0.0      0.0      0.0
  #8-      2.3      1.0     69.7     16.0     87.8     16.7     38.3      6.1      0.0      0.0      0.0      0.0
 #16-      1.0      0.4     43.1      9.9     68.5     13.0     26.1      4.2      0.0      0.0      0.0      0.0
 #30-      0.9      0.4     29.1      6.7     48.9      9.3     12.1      1.9      0.0      0.0      0.0      0.0
 #50-      0.8      0.3     21.4      4.9     17.6      3.3      5.0      0.8      0.0      0.0      0.0      0.0
 #100-     0.7      0.3     16.7      3.8      4.2      0.8      2.7      0.4      0.0      0.0      0.0      0.0
 #200-     0.6      0.3     13.6      3.1      2.7      0.5      2.2      0.4      0.0      0.0      0.0      0.0
```

APPENDIX B4 - Mixture Design Data Generated by the Contractor

Summary of Mix Design Data KY-421

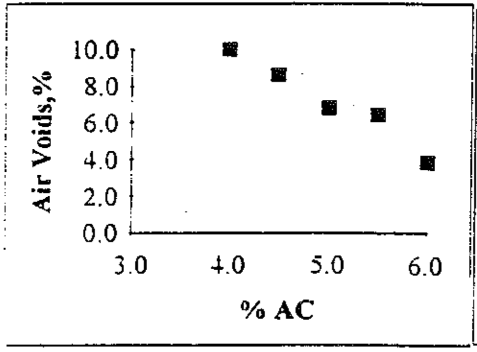
Material

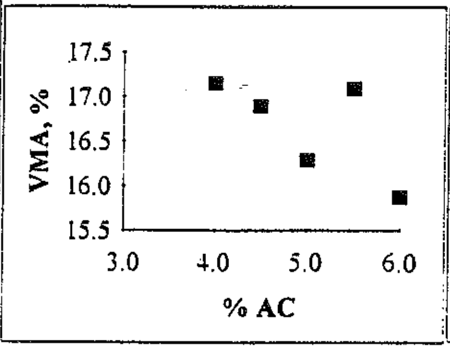
Aggregate	**Binder**
1. Nugent #8	AC-20 Ashland
2. Harrod LSS	7.5% Rouse GF-80
3. Nugent NS	(by weight of total binder)
4. 1/4" Chips	

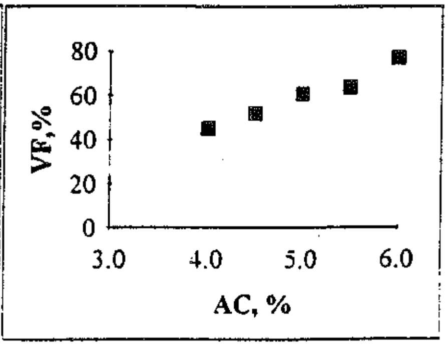
Optimum %AC = 5.4%

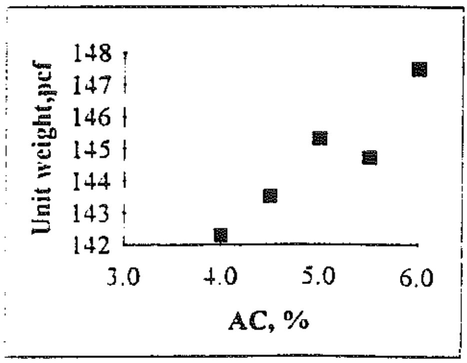
AC.%	Theoretical S.G.	Bulk S.G.	Air Voids.%	VMA.%
4.0	2.534	2.280	10.0	17.2
4.5	2.515	2.299	8.6	16.9
5.0	2.496	2.328	6.8	16.3
5.5	2.478	2.318	6.5	17.1
6.0	2.460	2.364	3.9	15.9

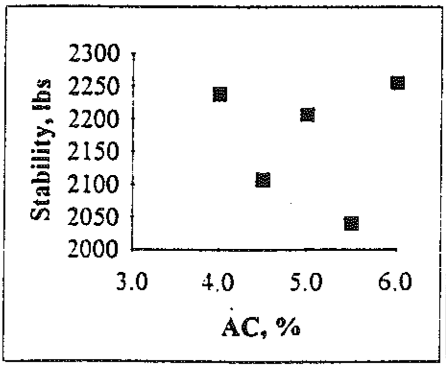
VF.%	Unit Weight	Stability. lbs	Flow(0.01in)
45	142.3	2238	8
52	143.5	2107	7
61	145.3	2206	8
64	144.7	2040	7
77	147.5	2254	7

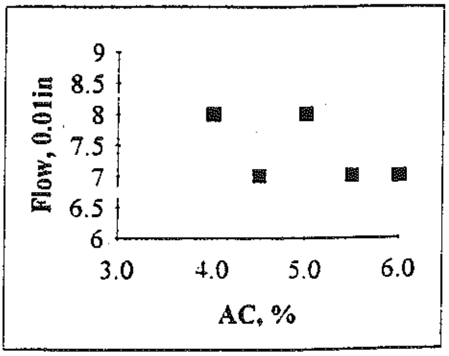


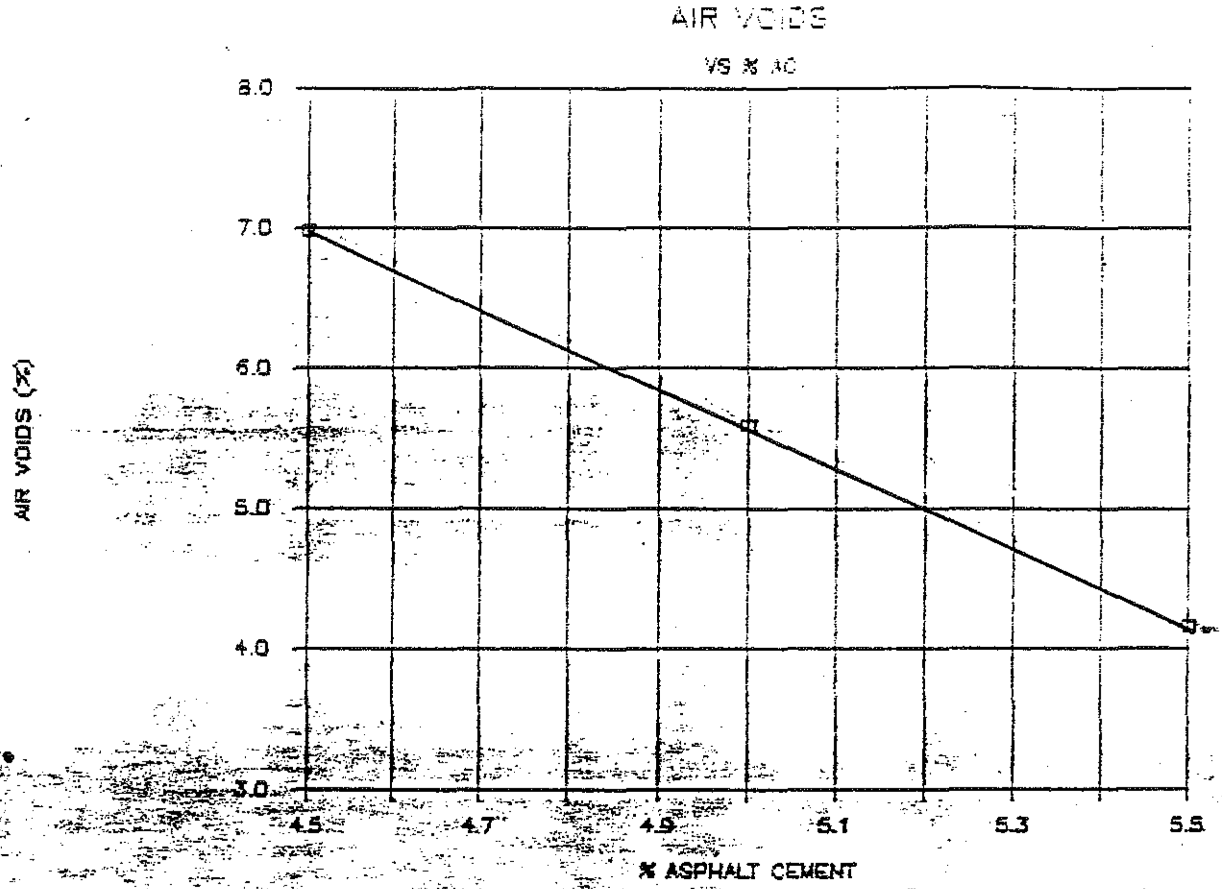


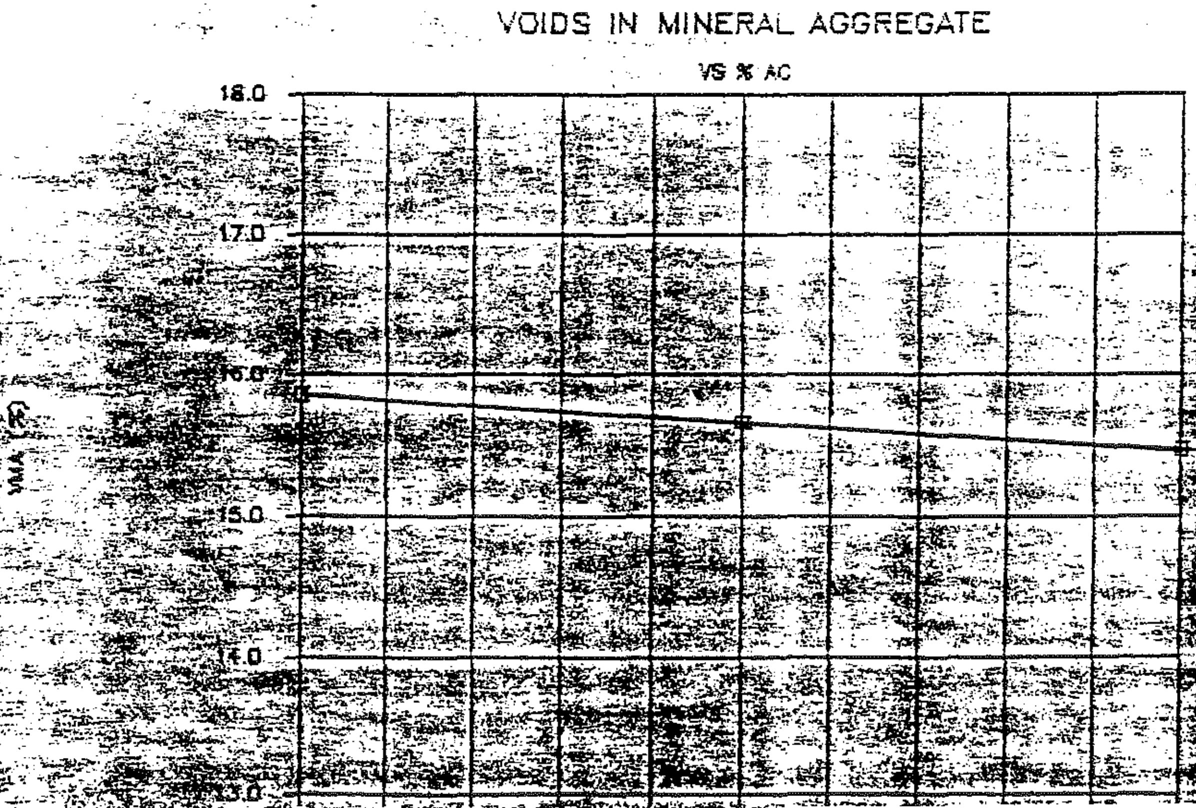









AIR VOIDS
VS % AC
AIR VOIDS (%)
8.0
7.0
6.0
5.0
4.0
3.0
4.5
4.7
4.9
5.1
5.3
5.5
% ASPHALT CEMENT


VOIDS IN MINERAL AGGREGATE
VS % AC
VMA (%)
18.0
17.0
16.0
15.0
14.0
13.0

VOIDS ANALYSIS

MPACTIVE EFFORT: 75 (blows/side)
MBINED BULK AGG. SP. GRAVITY(Gsb): 2.644
PHALT CEMENT SP. GRAVITY(Gb): 1.03

EFFECTIVE SPECIFIC GRAVITY(Gse): 2.686

AC (%)	SPEC. #	W/AIR (GRAMS)	W/WATER (GRAMS)	W/SSD (GRAMS)	BULK VOL.	BULK SP. GRAVITY	UNIT WEIGHT (pcf)	MAX. SP. GRAVITY	VOIDS (%)	VMA (%)	VFWA (%)	ABSORBED AC (%)	EFFECTIVE AC (%)
		(A)	(B)	(C)	(C-B)	A/(C-B) or (G)	(G*62.4)	(D)	100(D-G) / (D)	100 - (G)(100-AC) /Gsb	100(VMA-VOID) / VMA	100*Gb* (Gse-Gsb) /(GsbGse)	AC-ABS. (100-AC)
4.5	1	1182.0	680.0	1187.4	507.4	2.330	145.4	2.505	7.0	15.9	55.9		
	2	1182.2	680.3	1187.8	507.5	2.329	145.4	2.505	7.0	15.9	55.9		
	3	1181.8	679.6	1187.0	507.4	2.329	145.3	2.505	7.0	15.9	55.9		
AVE.						2.329	145.4		7.0	15.9	55.9	0.60	3.92
5.0	4	1187.9	686.2	1191.7	505.5	2.350	146.6	2.486	5.5	15.6	64.9		
	5	1185.4	684.1	1189.1	505.0	2.347	146.5	2.486	5.6	15.7	64.4		
	6	1188.9	685.3	1192.5	507.2	2.344	146.3	2.486	5.7	15.8	63.8		
AVE.						2.347	146.5		5.6	15.7	64.4	0.60	4.43
5.5	7	1195.1	692.3	1196.7	504.4	2.369	147.8	2.468	4.0	15.3	74.0		
	8	1194.0	690.2	1195.9	505.7	2.361	147.3	2.468	4.3	15.6	72.4		
AVE.						2.365	147.6		4.1	15.5	73.2	0.60	4.93

```
                          MAXIMUM SPECIFIC GRAVITY
                          ------------------------
--------------------------------------------------------------------------
ASPHALT CONTENT:                     5.0            5.0
--------------------------------------------------------------------------
WEIGHT OF SAMPLE + CONTAINER:       3186.7         3188.1
WEIGHT OF CONTAINER:                1995.3         1995.3
--------------------------------------------------------------------------
WEIGHT OF SAMPLE (A):               1191.4         1192.8
CALIBRATION (D):                    7234.8         7234.8
SUM (A+D):                          8426.2         8427.6
FINAL WEIGHT (E):                   7947.3         7949.3
DIFFERENCE (A+D-E):                  478.9          478.3
VOLUME ABSORBED WATER (G):             0.9            1.0
CORRECTED DIFFERENCE (A+D-E+G):      479.8          479.3
--------------------------------------------------------------------------
MAXIMUM SPECIFIC      (A)
GRAVITY :          ---------         2.483          2.489
                   (A+D-E+G)
--------------------------------------------------------------------------
AVERAGE MAXIMUM SPECIFIC GRAVITY(Gmm):        2.486
--------------------------------------------------------------------------
EFFECTIVE SPECIFIC GRAVITY(Gse):              2.686
--------------------------------------------------------------------------
CALCULATED MAXIMUM SPECIFIC GRAVITY:

                                   % AC          MAX. SP. GRAVITY
                                 ---------------------------------
                                    4.5            2.505

                                    5.0            2.486

                                    5.5            2.468
```

MARSHALL STABILITY FLOW ANALYSIS

ASPHALT CEMENT (%)	SPECIMEN #	SPECIMEN HEIGHT (inches)	CORRECTION FACTOR	UNCORRECTED MARSHALL STABILIT (lbs.)	CORRECTED MARSHALL STABILITY (lbs.)	FLOW (inches)
4.5	1	2.512	0.99	2090	2072	0.070
	2	2.514	0.99	2230	2208	0.070
	3	2.511	0.99	2090	2074	0.070
AVERAGE					2118	0.070
5.0	4	2.487	1.01	2070	2086	0.077
	5	2.487	1.01	2050	2066	0.074
	6	2.481	1.01	2090	2115	0.070
AVERAGE					2089	0.074
5.5	7	2.464	1.02	1980	2026	0.074
	8	2.474	1.02	2110	2145	0.080
AVERAGE					2086	0.077
0.0	0	0.000	4.94	0	0	0.000
	0	0.000	4.94	0	0	0.000
	0	0.000	4.94	0	0	0.000
AVERAGE					0	0.000

Contractor: H. G. Mays Corp. @ FrankFort, KY

Project: Franklin Co., US 421
(Thornhill Bypass)

GRADATION COMBINATION PROGRAM

DATE: [illegible]

PROJECT: CLASS AK SURFACE THORNHILL BYPASS

AGGREGATE TYPES:

(1) - NUGENT #8 (BIN1 %): 42.0 %
(2) - HARROD LSS (BIN2 %): 23.0 %
(3) - NUGENT NS (BIN3 %): 19.0 %
(4) - NUGENT 1/4"CHIPS (BIN4 %): 16.0 %
(crushed gravel sand)
(5) - (BIN5 %): 0.0
(6) - (BIN6 %): 0.0
(7) (BIN7 %): 0.0

Job Mix Formula

SIEVES	% PASS	CUMULAT. % RETAIN.	MASTER (LOWER)	RANGE (UPPER)	JMF SET %	Wet Sieve Analysis
1/2"-	100.0	0.0	100	100	100	100
3/8"-	95.0	5.0	75	97	92	92
#4-	65.9	34.2	48	72	66	66
#8-	39.8	60.2	30	54	40	39
#16-	27.5	72.5	18	40	28	27
#30-	18.3	81.7	9	28	19	18
#50-	9.4	90.6	5	18	10	9
#100-	5.4	0.0	2	10	6	5
#200-	4.2	95.8	1	5	4.5	2.5

	Nugent #8		Harrod Limestone Sand		Nugent natural sand		Nugent Crushed Gravel Sand					
SIEVE SIZE	AGG. (1) % PASS	AGG. (1) BIN %	AGG. (2) % PASS	AGG. (2) BIN %	AGG. (3) % PASS	AGG. (3) BIN %	AGG. (4) % PASS	AGG. (4) BIN %	AGG. (5) % PASS	AGG (5) BIN %	AGG. (6) % PASS	AGG. (6) BIN %
		42.0		23.0		19.0		16.0		0.0		0.0
1/2"-	100.0	42.0	100.0	23.0	100.0	19.0	100.0	16.0	0.0	0.0	0.0	0.0
3/8"-	88.3	37.1	100.0	23.0	100.0	19.0	99.2	15.9	0.0	0.0	0.0	0.0
#4-	21.6	9.1	97.3	22.4	99.6	18.9	96.2	15.4	0.0	0.0	0.0	0.0
#8-	2.3	1.0	69.7	16.0	87.8	16.7	38.3	6.1	0.0	0.0	0.0	0.0
#16-	1.0	0.4	43.1	9.9	68.5	13.0	26.1	4.2	0.0	0.0	0.0	0.0
#30-	0.9	0.4	29.1	6.7	48.9	9.3	12.1	1.9	0.0	0.0	0.0	0.0
#50-	0.8	0.3	21.4	4.9	17.6	3.3	5.0	0.8	0.0	0.0	0.0	0.0
#100-	0.7	0.3	16.7	3.8	4.2	0.8	2.7	0.4	0.0	0.0	0.0	0.0
#200-	0.6	0.3	13.6	3.1	2.7	0.5	2.2	0.4	0.0	0.0	0.0	0.0

Design Mixture Properties of Conventional Class AK Surface

- Design Asphalt Content: 5.1 %
- Tensile Strength Retained (per KM 64-428): 82 % (without anti-stripping additive) ASTM-D-4867
- Stability: 2680 lbs.
- Flow: 0.08 inches
- Air Voids: 4.3 %
- VMA: 14.8 %
- VFWA: 72 %
- Maximum Specific Gravity: 2.476
- Compaction: 75 blows (using Mechanical Hammer)
- Bulk Specific Gravity of Combined Aggregate: 2.642
- [illegible] Asphalt Cement: 1.03

APPENDIX B5 - Mixture Quality Control / Quality Assurance

MEMORANDUM

TO: Files

FROM: Danny Young
Field Operations Section
Division of Materials

DATE: July 28, 1993

SUBJECT: Franklin County, SSP 037 0421 003-005 074 H
AK Surface Mixtures

Attached is information obtained juring field verification testing performed on plant produced material.

The information consists of volumetric analysis for the AK surface mixture containing Rubberized Asphalt Cement and the control mixture containing AC-20.

Also attached is data from the cores taken from the control strips which were constructed for the various mixtures and asphalt contents.

Each days production is listed with the values for testing by Materials Central Lab personnel and by the contractor when he performed Marshall testing. Also on file within the Field Operations Section is data from which the summary sheets were documented.

It should be noted that when extraction testing was performed in the MCL, evidence of the rubber fines were in the fine fractions of the aggregate. Also, the effluent contained rubber fines which shows that the rubber was not completely dissolved into the asphalt cement.

Samples were also obtained for testing on the Loaded Wheel Tester. At this point testing has not been completed.

DY:tc

JUL 29 1993

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. = (FHWA) ______ UPN) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK SURFACE MIX ID # w/Rubberized

SUPPLIER H.G MAYS CORP. LOCATION FRANKFORT

DATE VERIFIED 7-13-93 AM VERIFIED BY MATERIALS CENTRAL LAB Personnel

RESULTS:

PROPERTY	MCL F/V	CONTR	ACCEPTABLE LIMITS	DESIGN
STAB., lbs.	2200	—	1800 (min)	2150
FLOW, 0.01"	10	—	8-16	7
MSG	2.466	2.474		2.485
UW, PCF	147.0	148.8		145.5
AV, %	4.5	3.6	3.5-6.5	5.8
VMA, %	15.6	14.2	14.5 (min)	16.4
TSR, %	—	—	65 (min.)	—
AC, %	5.2 (EXTR.)	5.3 (back calc.)	5.0 — 5.6	5.3

GRADATION - P 200, % 5.5 OTHER SIGNIFICANT VALUES NACG

PAN #1 = 5.3% % AC by NACG using master calibration, % AC by extraction performed by the contractor: 5.3 and 5.1%.

REMARKS:

Design values based on Mix Design data provided by UK. Research Personnel.

Limited Production of approximately 550 tons was performed at 5.3% AC. Based on values obtained + the contractors (air voids and % VMA of the plant produced mixture) the % AC was reduced to 5.1%.

This material was placed on the inside lane from the concrete section uphill to approximately the turn lanes at 421 & sckenkel lane.

MSG RPTD to DME 2.474 Confirmed ____ Revised Yes.

cc:

DME #- 5 COMPILED BY DY DATE 7/15/93

FILES RVD BY: DY ______ DW ______.

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. # (FHWA) ______ (UPN) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK Surface MIX ID # W/Rubberized AC

SUPPLIER H.G. Mays Corp. LOCATION FRANKFORT

DATE VERIFIED 7/13/93 PM VERIFIED BY MATERIALS CENTRAL LAB PERSONNEL

RESULTS:

PROPERTY	MCL F/V	CONTR	ACCEPTABLE LIMITS	DESIGN *
STAB., lbs.	2275	–	1800 (min)	2175
FLOW, 0.01"	9	–	8-16	7
MSG	2.491	2.483		2.493
UW, PCF	146.4	147.8		145.0
AV, %	5.8	4.6	3.5-6.5	6.5
VMA, %	15.7	15.0	14.5 (min.)	16.5
TSR, %	58	–	65 (min.)	–
AC, %	5.2 NACG	(5.1 back calc)	4.8 – 5.4	5.1

GRADATION – P 200, % ______ OTHER SIGNIFICANT VALUES ______

% AC by NACG using master calibration.

REMARKS:

MSG was revised for 5.1% AC, also at this point a new control strip was constructed in order to establish a target for the 5.1% mixture which utilized rubberized asphalt cement.

* Design values based on Marshall data supplied by UK Research Personnel.

MSG RPTD to DME 2.483 Confirmed ____ Revised Yes.

cc:

DME #- 5 COMPILED BY DY DATE ______

FILES RVD BY: DY ______ DW ______.

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. # (FHWA) ________ (UPN) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK Surface MIX ID # w/Rubberized AC

SUPPLIER H.G. Mays Corp LOCATION FRANKFORT

DATE VERIFIED 7-14-93 (AM&PM) VERIFIED BY Materials Central Lab Personnel

RESULTS:

PROPERTY	MCL F/V Pan #1	CONTR. F/V Pan #1	ACCEPTABLE LIMITS	DESIGN *
STAB., lbs.	2375	—	1800 (min)	2175
FLOW, 0.01"	9	—	8-16	7
MSG	2.485	2.480		2.493
UW, PCF	147.5	147.9		145.0
AV, %	4.9	4.4	3.5-6.5	6.5
VMA, %	15.1	14.8	14.5 (min.)	16.5
TSR, %	71	—	65 (min)	—
AC, %	5.2 NACG	—	4.8 - 5.4	5.1

GRADATION - P 200, % ________ OTHER SIGNIFICANT VALUES ________

% AC by NACG using master calibration. Extraction by contractor 5.1 and 5.1%.

REMARKS:

Both AM and PM samples were taken this date. As noted above the AM sample (pan #1) was compacted by both MCL and the Contractor for comparison purposes. Pan #2 (PM sample) results are on the attachment.

* Design data based on Mix Design supplied by UK Research Personnel.

MSG RPTD to DME 2.483 Confirmed ____ Revised ____.

cc:
DME #- 5 COMPILED BY DY DATE ____
FILES RVD BY: DY DW

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. # (FHWA) ____________ (. ON) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK Surface MIX ID.# w/Rubberized AC

SUPPLIER H.G. MAYS CORP. LOCATION FRANKFORT

DATE VERIFIED 7/15/83 VERIFIED BY MATERIALS CENTRAL LAB PERSONNEL

RESULTS:

PROPERTY	F/V	ACCEPTABLE LIMITS	DESIGN *
STAB., lbs.	2150	1800 (min.)	2175
FLOW, 0.01"	11	8-16	7
MSG	2.484		2.493
UW, PCF	147.8		145.0
AV, %	4.6	3.5-6.5	6.5
VMA, %	14.9	14.5 (min.)	16.5
TSR, %	—	65 (min.)	—
AC, %	5.2(EXTR)	4.8-5.4	5.1

GRADATION - P 200, % — OTHER SIGNIFICANT VALUES ______

REMARKS:

Extraction Results by contractor this date: 4.9 and 5.2%. P200 content by contractor testing 5.0 and 5.0%.

Final days production for mixture using Rubberized AC.

*Design data based on Mix Design supplied by UK Research Personnel.

MSG RPTD to DME 2.483 Confirmed ____ Revised ____.

cc:

DME #- 5 COMPILED BY DY DATE ______

FILES RVD BY: DY ______ DW ______.

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. # (F-WA) ______ (-FN) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK Surface MIX ID # w/ AC-20

SUPPLIER H.G. MAYS CORP. LOCATION Frankfort

DATE VERIFIED 7/15/93 VERIFIED BY MATERIALS CENTRAL LAB PERSONNEL

RESULTS:

PROPERTY	F/V	ACCEPTABLE LIMITS	DESIGN
STAB., lbs.	2700	1800 (min.)	*2675
FLOW, 0.01"	11	8-16	8
MSG	2.486		2.4
UW, PCF	150.7		148.1
AV, %	2.9	3.5-6.5	4.3
VMA, %	13.2	14.5 (min.)	14.8
TSR, %	81	65 (min.)	82
AC, %	5.4 (EXTR)	4.8-5.4	5.1

GRADATION - P 200, % 7.0 OTHER SIGNIFICANT VALUES ______

% AC by NACG using master calibration 5.5% for Pan #1.

REMARKS: *Design values from Marshall testing performed by MCL.

1st days production for mixture with AC-20.

% AC by NACG using 4" pills 4.9% using calibration performed by MCL.

The air voids and % VMA are below the minimum specified minimums. It should be noted that this sample was taken from the last load of material produced this date and so deviation in the production would be expected. A follow up verification will be performed on 7/16/93.

MSG RPTD to DME 2.486 Confirmed ____ Revised No.

CC:

DME #- 5 COMPILED BY DY DATE ______

FILES RVD BY: DY ______ DW ______.

SUMMARY OF PLANT-PRODUCED BITUMINOUS MIXTURE'S PROPERTIES
(FVSUMFRM)

PROJ. # (FHWA) ____________ (CON) (#211) SSP 037 0421 003-005 074 H

COUNTY FRANKLIN MIX TYPE AK Surface MIX ID # W/AC-20

SUPPLIER H.G. Mays Corp. LOCATION Frankfort

DATE VERIFIED 7-16-93 VERIFIED BY Materials Central Lab Personnel

RESULTS:

PROPERTY	F/V	ACCEPTABLE LIMITS	DESIGN *
STAB., lbs.	2400	1800 (min)	2675
FLOW, 0.01"	10	8-16	8
MSG	2.497		2.476
UW, PCF	148.8		148.1
AV, %	4.5	3.5-6.5	4.3
VMA, %	14.4	14.5(min)	14.8
TSR, %	—	65 (min)	82
AC, %	5.2(EXTR)	4.8-5.4	5.1

GRADATION — P 200, % 6.0 OTHER SIGNIFICANT VALUES ______

REMARKS:

*Design values from Marshall testing performed by MCL

% AC by extraction performed by contractor: 5.0 and 4.9%.

P200 content from testing by contractor 5.0 and 5.0%.

MSG RPTD to DME 2.497 Confirmed ____ Revised No.

cc:

DME #- 5 COMPILED BY DY DATE ______

FILES RVD BY: DY ______ DW ______.

FRANKLIN Co.
98
(#211) SSP 037 050
AK Surface

BITUMINOUS MIXTURES FIELD VERIFICATION REPORT
COMMENTS & RECOMMENDATIONS

Attached are results of core density testing performed by MCL. The cores were supplied by the Resident Engineer. They were taken from the control strips which were constructed on the project.

	5.3% Rubberized AC (2.474 solid density 154.4)		5.1% Rubberized AC (2.483 solid density 154.9)		5.1% AC-20 (2.483 solid density 154.9)	
Core #	5.1 - 1	(142.6)	5.3-1	(143.7)	1	(146.3)
	5.1 - 2	(142.2)	5.3-2	(146.3)	2	(146.2)
	5.1 - 3	(143.7)	5.3-3	(145.8)	3	(146.4)
	5.1 - 4	(144.7)	5.3-4	(144.7)	4	(142.9)
		143.3 pcf average		145.1 pcf average	5	(144.8)
						145.3 pcf averag

$\frac{143.3}{154.4}$ = 92.5% of solid (93%)

$\frac{145.1}{154.9}$ = 93.97% of Solid (94%)

$\frac{145.3}{154.9}$ = 93.8% of Soli (94%)

The actual location from which the nuclear density testing was performed and subsequent coring locations are on file at the Resident Engineer's office.

34-404
2-A)

CONTRACTORS JOB-MIX FORMULA & ASPHALT PLANT ([redacted] DRUM) MIX DESIGN

3-3-99

No 00930 2650

County Franklin
SPECTOR SSN 317-26-298E
Name R. Simmons Crew Contr.
TE SAMPLED 02-08-93
Sample Sequence No. 4
PE OF INSPECTION INF
Original Ident
ODUCER NO. P1182001
Name Frankfort Materials Loc Frankfort
TERIAL CODE 050125
Description Class AK Surface (Exp.)
SPECTED QUANTITY 9999999.9
Units Tons
ESPONSIBLE LOC C5 LAB 0C5
Name Materials Central Lab
Test ☒ Distribution

Proj Code 072236
Project Number SSP 037 C421 003-C05 074H (#21)
QUANTITY 00000000.0
DATE ASSIGNED 03-~~25~~ 25-9

DATE REC. 02-10-93 DATE COM. PASS/FAIL UNPR Reason

	Aggregate Prod. CD	Prod. Name	Mat'l .CD	Size	Aggregate
Coarse	PC02302	Nugent Sand & Gravel	0010C8	Grav. #8's	42.C
Coarse					.
Fine	P002302	Nugent Sand & Gravel	001CGS	Grav. mfg. sd.	16.0
Fine	P002302	Nugent Sand & Gravel	001BFA	n. sd.	19.0
Filler	P005101	Harrod Stone	0C1BFA	Issand	23.C

Screens-Scalper

Extractions Mix Gradations

Rev JMF

JMF/Specs

Sieve Size	WET SIEVE Job-Mix
1/2	100
3/8	92
4	66
8	40
16	28
30	19
50	10
100	6
200	4.5

F.M.

Mix Approval Data

Approved Asph Cont 05.1%
Target Mix Temp 300
Mix Time (Dry) (Wet)
Approved by DMC Larry E Epley AHM Date
Approved by MTL Date March 25, 1993

[✓ Approved] ☒ As Proposed ☐ With Changes ☐ Disapproved (See Remarks)

Plant Data

Aggr/Batch Lbs
Total Batch Wt Lbs
Asph/Batch (Lbs.)
Gals of Asph/Batch (Fluidometer)

Bin 4 . Bin 3 . Bin 2 . Bin 1 . Filler . Totals
Pounds
Acc Wt

Asphalt Data
Temp. Bit. Mix AC-20
Type 030102 Producer P1509011 Ashland @ Louisville
Bitumen (By Design) 05.1 % Additive
Extraction Tests . . . .
Cold Feed Data % Natural Sand

Submitted By R. Simmons
Project Engineer
Date
MTLS Rep.

INSTRUCTIONS

It should be noted that the design asphalt content is established for this particular combination of materials and project characteristics and should not be used on other projects without evaluating the materials' source(s), gradation, and the project conditions.

"Minor-change" tolerances are permitted on the + #4 fraction of the mixture only. Adjustments on the - #4 fraction of the mixture, in particular the - #200 fraction, are contingent upon plant-produced mixture properties indicating adequate air voids. Bituminous mixtures of this nature have a potential for flushing and/or rutting. Significant revisions may require a new lab design. The design asphalt content is for the submitted JMF gradation. Deviations from the materials furnished the laboratory or in the actual project gradation may require an adjustment in the design asphalt content.

* Special Note for Bituminous Concrete Surface, Class AK, applies (75 blows).

* Compaction control strip from Special Note for Bituminous Concrete Surface, Class AK, applies.

* Laboratory Marshall density: 148.1 PCF @ 5.1 % AC.
  Laboratory maximum specific gravity: 2.476 @ 5.1 % AC.
  Laboratory solid density: 154.5 PCF @ 5.1 % AC.

* Special Note for Acceptance of Bituminous Mixtures applies.

* Job-mix formula (JMF) is based on wet-sieve analysis.

* All mix design values are from a Materials Central Lab (MCL) design.

* Contact Materials Central Lab (MCL) prior to the start of production.

* Cold feed checks are required twice daily.

* One sample consisting of the + #4 combined aggregate (from either all extractions, hot bin samples, or combining belt samples) to represent the job will be needed. This sample shall be submitted to the Materials Central Lab (MCL), Aggregate Section, for Insoluble Residue and/or Percent Crushed testing.

* It is recommended that mix design properties of plant-produced material be monitored by District personnel. The following information should be used during the performance of field verifications:

  Bulk Specific Gravity of Aggregate = 2.642

  Marshalls TSR's

INSTRUCTIONS (cont.)

- Although the percentage of voids-in-mineral aggregate (% VMA) is slightly low, the value is in reasonably close conformance with the specifications.

  The % VMA of this mixture is "borderline" at best. In fact, using some combinations of aggregate specific gravity values as tested by MCL results in unacceptable % VMA. For this reason, the contractor is strongly urged to maintain close control of the dust content of this mixture during production. Field verification analyses of this mixture may yield low % VMA values, thereby requiring some sort of mixture modification.

- The contractor submitted three Marshall specimens and one maximum specific gravity (MSG) sample to MCL for analysis, with the following results:

  UW = 147.1 pcf   Stab. = 2305 lbf   Flow = 0.09 "
  % AV = 5.1   MSG = 2.484   % AC = 5.1
  % VFWA = 67   % VMA = 15.3   % Eff. AC = 4.5
  % Abs. AC (Mix) = 0.63   Comp. = 75 blows

C64-711

MARSHALL TEST

Rev 12-9-

102

).No. 00930 2651 County FRANKLIN

.SPECTOR SSN 317-26-2988 Name R. Simmons Crew CONTR.

'ATE SAMPLED 02-08-93 Sample Sequence No. 14

YPE OF INSPECTION INF Original Ident

RODUCER NO./SUPP. NO. P1182001 Name FrankFort Materials Loc Frankfort

IATERIAL CODE 050125 Description CLASS AK SURFACE (EXP.)

VSPECTED QUANTITY 9999999.9 Units TONS

OT NO. 009302651

ampled From BIT PLANT STOCKPILES

ESPONSIBLE LOC 05 LAB 000 Name MATERIALS CENTRAL LAB

etail Test ☒ Distribution ~~☐☐~~

Proj Code	Project Number	QUANTITY	DATE ASSIGNED
022236	SSP 037 0421 003-005 074H (#21)	0000000.0	03-25-9
		.	- -

'ATE REC. 02-10-93 DATE COM. 03-25-93

ASS/FAIL COMP Reason

.osts

NO CHARGE

Design Results for CL AK SURF EXP-US421

'nit Weight PCF	148.1	Stability Lbs.	2680	Flow Ins.	0.08
'oids in Mix %	04.3	Max. Spec. Gr.	2.476	Asph. Content %	05.1
and Equivalent	80	VMA	14.8	Eff. AC%	04.6
/FWA	072	ABS.AC Mix	0.50	Compaction	075

INSTRUCTIONS

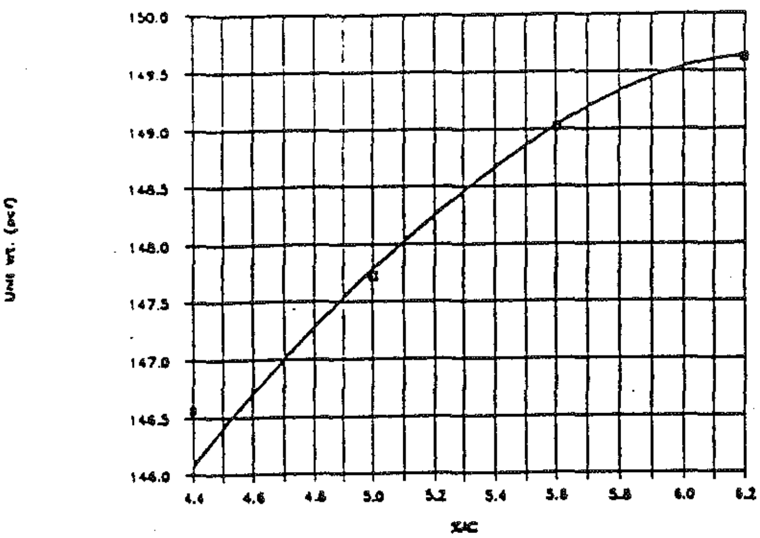
LABORATORY MIX DESIGN CRITERIA: STABILITY → 1800 LBF (MINIMUM); FLOW → 0.08"-0.16"; % AIR VOIDS → 4.0 ± 1.0; % VMA → 15.0 (MINIMUM); % TSR → 70 (MINIMUM). TSR WITHOUT ADDITI = 82%; no additive required. D/A = 0.9. Class AK, Acceptance notes apply. A mix design values are from MCL design. % Crushed (1 or more) = 98; % Crush (2 or more) = 92, and Insoluble Residue = 38% on gravel #8's. Bulk specific gravity of aggregate = 2.642. Although % VMA is slightly low, value is in reasonably close conformance with specifications. % VMA of this mix is "borderline" at best. Contractor is strongly urged to maintain close control

KENTUCKY DEPARTMENT OF HIGHWAYS
Laboratory Mix Design Report

Mix Identification: # 14, Franklin Class AK Surface (Exp.)
Project Number: SSP 037 0421 003-005 074H (#211)
Compaction: 75 blows

Contractor: Frankfort Materials
@ Frankfort

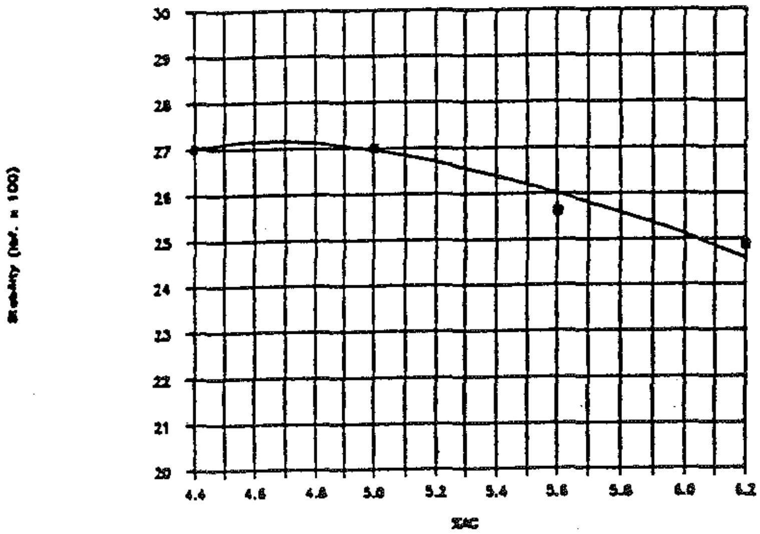
Unit Wt. vs. %AC



Design Results

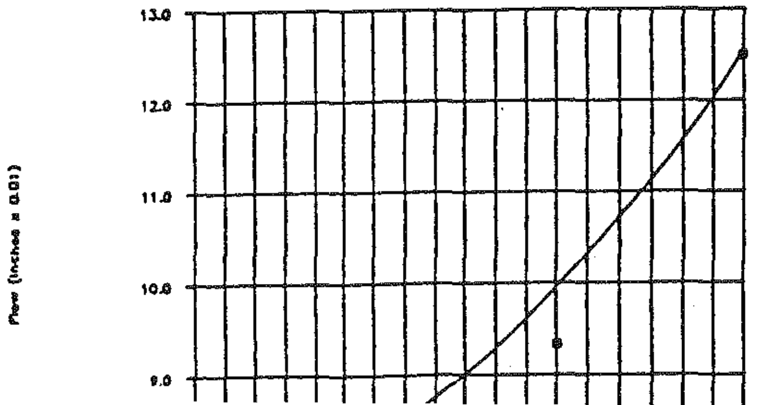
Asphalt Content, % 5.1
Unit Weight, pcf 148.1
Stability, lbf 2680
Flow, ins. 0.08

Stability vs. %AC



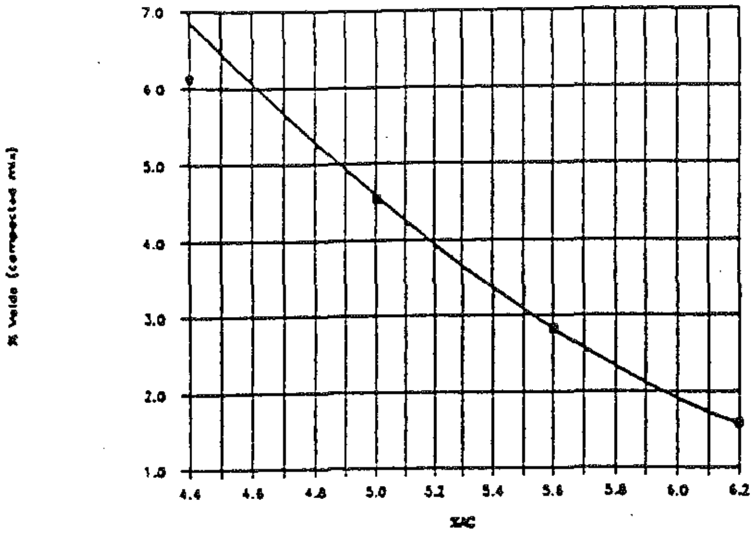
Remarks:

Flow vs. %AC

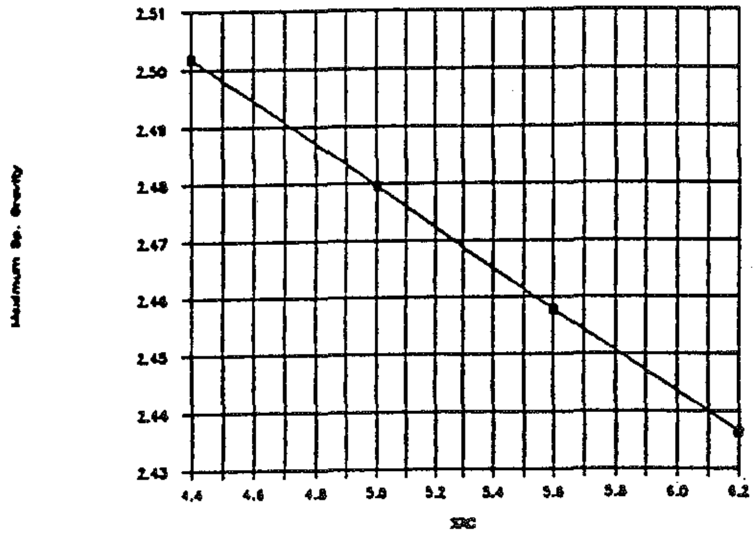


Mix Identification: # 14, Franklin Class AK Surface (Exp.)

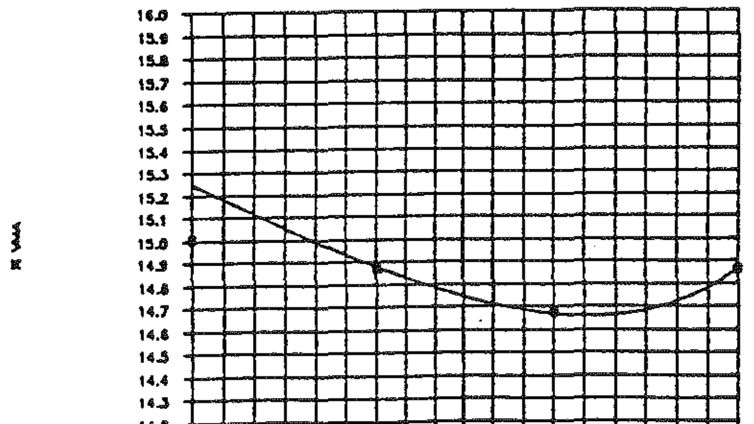
% Voids vs. %AC



Max Sp. Grav. vs. %AC



%VMA vs. %AC



<u>Design Results</u>

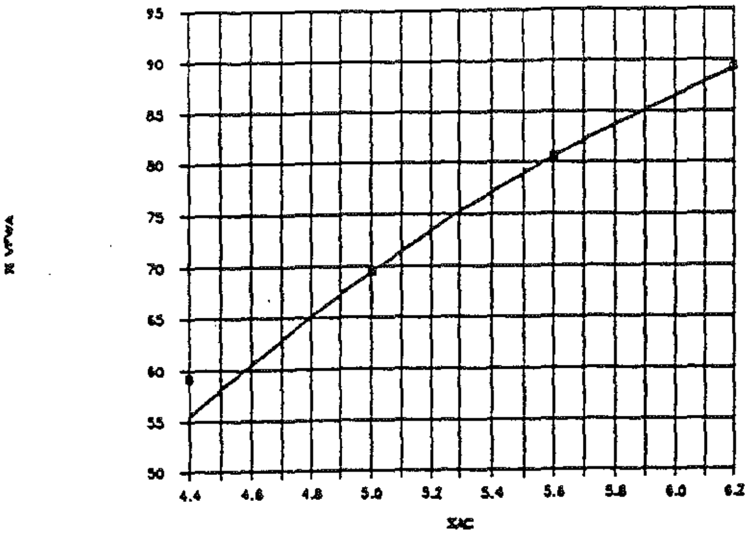
Asphalt Content, %	5.1
Voids in Mix, %	4.3
Max. Sp. Gravity	2.476
% VMA	14.8

<u>Remarks:</u>

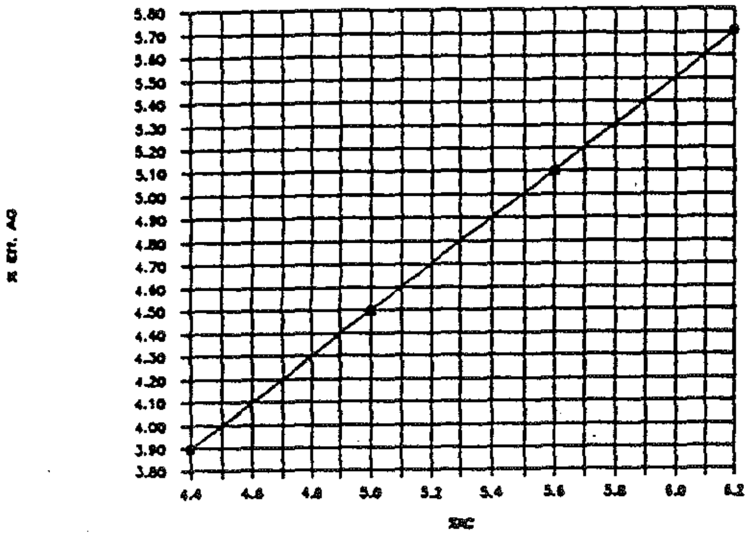
Although the percentage of void
in-mineral aggregate (% VMA
is slightly low, the value is
in reasonably close conforma
with the specifications.

Mix Identification: # 14, Franklin Class AK Surface (Exp.)

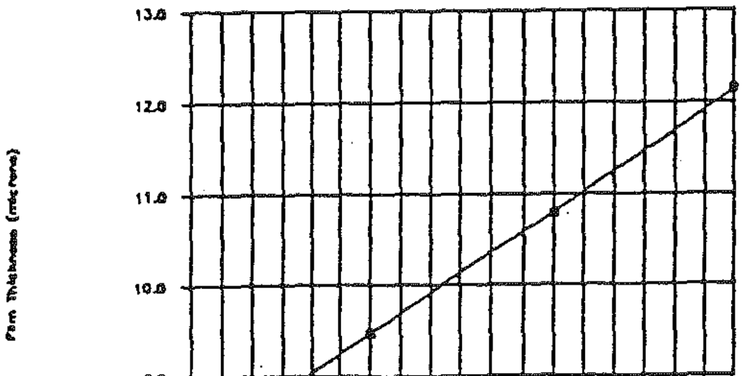
%VFWA vs. %AC



% Eff. AC vs. %AC



Film Thickness vs. %AC



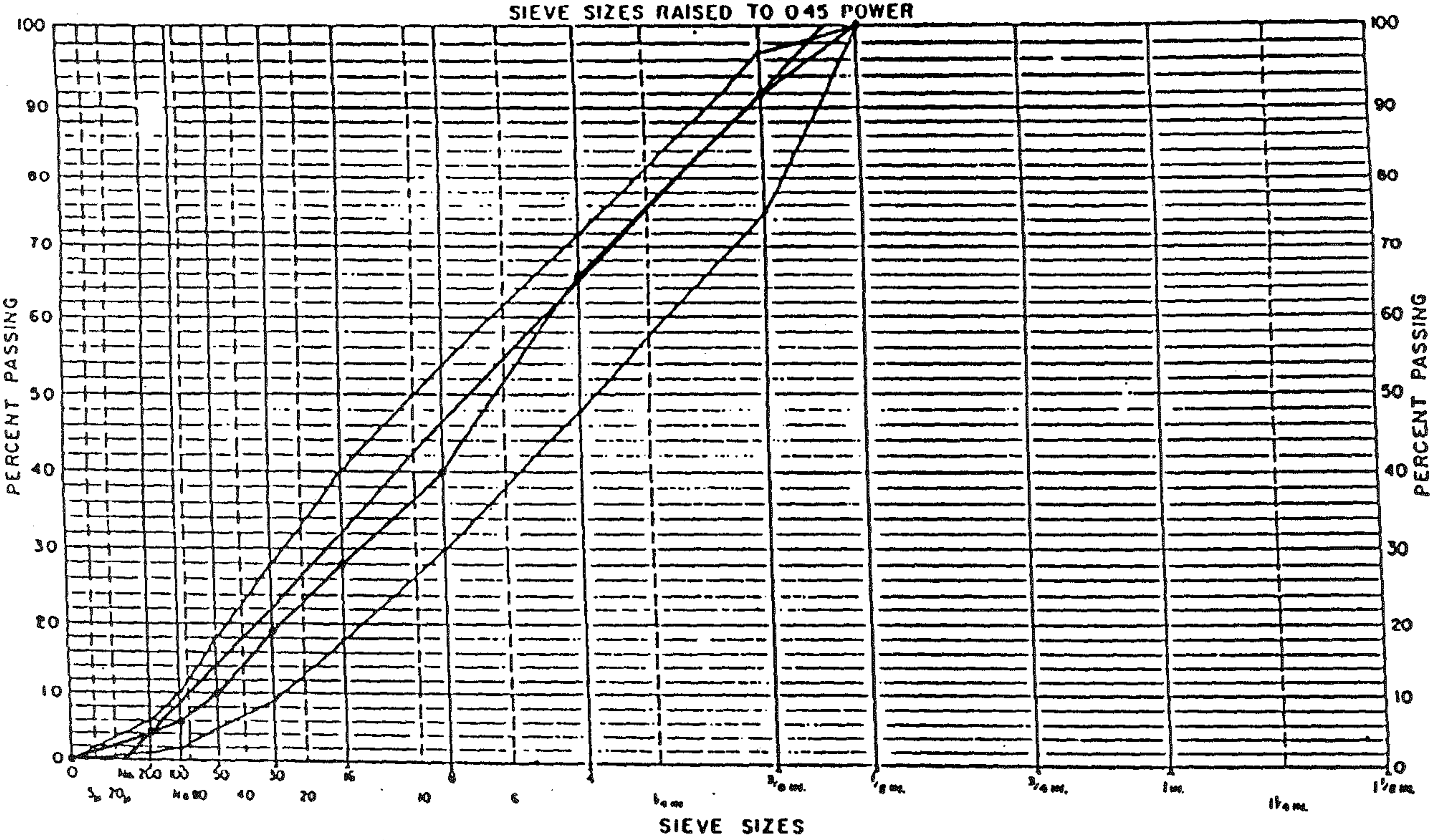
Design Results

Asphalt Content, %	5.1
% VFWA	72
% Eff. A.C.	4.6
Film Thickness	9.5

Remarks:

01 031 0421 003-005 014H (#211) @ Frankfort CLASS AK SURFACE (Exp.

UNITED STATES BUREAU OF PUBLIC ROADS 0.45 POWER GRADATION CHART



A THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations:

WET SIEVE

Sheet No.

Date 2-24-03

Form No. QC-3
THE ASPHALT INSTITUTE

Post-it™ brand Fax Transmittal Memo 7672

No. of Pages 1 | Today's Date 7-9-93 | Time 10:10 am

To R. S. Quire | From K. C. Mahboub

Company H. Mays | Company UK

Location | Location | Dept. Charge

Fax # | Telephone # | Fax # | Telephone #

Comments | Original Disposition: ☐ Destroy ☐ Return ☐ Call for pickup

---

TRANSPORTATION CABINET
DIVISION OF MATERIALS

Rev. 2-88

C64-404
(12-A)

CONTRACTORS JOB-MIX FORMULA & ASPHALT PLANT ~~(BATCH)~~ DRUM MIX DESIGN

).No.	009308539	County	Franklin
NSPECTOR SSN	402-98-0902	Name	R.Scott Quire Crew Contractor
ATE SAMPLED	06-28-93	Sample Sequence No.	
YPE OF INSPECTION	INF	Original Ident	
RODUCER NO.	P182001	Name	Frankfort Materials Loc Frankfort
MATERIAL CODE	050125	Description	Class AK Surface (Exp.)
NSPECTED QUANTITY	9999999.9	Units	Tons
ESPONSIBLE LOC	05 LAB 005	Name	
Detail Test	☐ Distribution		

Proj Code	Project Number	QUANTITY	DATE ASSIGNED
022236	SSP 037 0421 003-005 024H	0000000.0	- -

DATE REC. - - DATE COM. - - PASS/FAIL Reason

	Aggregate Prod. CD	Prod. Name	Mat'l .CD	Size	Aggregate %
Coarse	P002302	Nugent Sand & Gravel.	001008	Gravel #8	42.0
Coarse					.
Fine	P002302	Nugent Sand & Gravel	001CGS	Gravel mfg. sand	16.0
Fine	P002302	Nugent Sand & Gravel	001BFA	Natural Sand	19.0
Filler	P005101	Harrod Stone	001BFA	Limestone Sand	23.0

Screens-Scalper

Sieve Size	Job-Mix	Extractions Mix Gradations				Rev JMF	JMF/Specs
1/2	100						
3/8	92						
4	66						
8	40						
16	28						
30	19						
50	10						
100	6						
200	45						
	F.M.	.	.	.	.		.

Mix Approval Data

Approved Asph Cont 5.3%

Target Mix Temp 300

Mix Time (Dry) ______ (Wet) ______

Plant Data

Aggr/Batch ______ Lbs

Total Batch Wt ______ Lbs

Asph/Batch (Lbs.) ______

Gals of Asph/Batch (Fluidometer) ______

AK Surface
w/ Rubberized
Approved by K.
Mahboub
(UK Research)
at 5.3%
≈ 5
After
tons of produ
on 1st day
the
%AC wa
revised
to 5.1
by
Danny Y.
on 7/13

% Bin 4 ☐☐☐☐.☐ Bin 3 ☐☐☐☐.☐ Bin 2 ☐☐☐☐.☐ Bin 1 ☐☐☐☐.☐ Filler ☐☐☐.☐ Totals ______

Pounds ______ ______ ______ ______ ______

Acc Wt ______ ______ ______ ______ ______

Cold Feed Data Non Polishing Agg(s) A.M. ☐☐ Coarse P.M. ☐☐ Coarse

☐☐ Fine (N.S.) ☐☐ Fine (N.S.)

Type Additive Rouse GF-80 crumb rubber

Asphalt Data

Type 030102 AC-20

Producer P150901 Ashland @ Louisville

Bitumen (By Design) 5.3

% Additive 7.5

Extraction Tests ☐☐.☐ ☐☐.☐ ☐☐.☐ ☐☐.☐

Submitted By R. Scott Quire

Project Engineer 7-9-93 (UK.

Set up by Tech. ______

Date 6-29-93

MTLS Rep. ______

Plant Inspector ______

Remarks:

Copies:

MEMORANDUM

TO: BERNIE ROACH, P.E.,
D-5 MATERIALS ENGINEER

FROM: C. T. SMITH, C.T. Smith
RESIDENT ENGINEER C-312

DATE: AUGUST 11, 1993

SUBJECT: FRANKLIN COUNTY
SSP 037-0421-003-005
CONTROL STRIP RESULTS

PLEASE FIND ATTACHED THREE CONTROL STRIP FORMS TC63-49 FOR 7/13/93 & 7/16/93 CONCERNING AK SURFACE PLACED ON THE ABOVE SUBJECT PROJECT. ON JULY 13, 1993, TWO CONTROL STRIPS WERE CREATED TO ACCOMMODATE THE CHANGE IN ASPHALT CONTENT IN THE EXPERIMENTAL RUBBERIZED MODIFIED MIX. AS ONE CAN SEE THE IN PLACE DENSITIES FELL WELL WITHIN THE TARGET VALUES.

ATTACHMENTS

PC: D. WALKER, C.O. MATERIALS
K. C. MAHBOUB, U.K. RESEARCH

TC 63-49
Rev. 6/92

KENTUCKY TRANSPORTATION CABINET
Department of Highways
Division of Construction

In-place Density Using Control Strip

DIST. NO: 05
7-13-93
DATE:
METER NO:
MODEL NO:

PROJECT NO: SSP 037-0421-003-005
COUNTY: FRANKLIN
TYPE MAT'L: AK SURFACE
CONTRACTOR: H.G. MAYS CORPORATION
ROAD NAME: THORNHILL BY-PASS
ROUTE NO: (RUBBERIZED) (5.3)

ROLLERS

BRAND A: INGERSOLL RAND DESC: 2 WHEEL VIBRATORY WGT: 10-12 TON
BRAND B: INGERSOLL RAND DESC: 2 WHEEL VIBRATORY WGT: 8-10 TON
BRAND C: DESC: WGT:
REMARKS: PATTERN: 1 VIBRATORY & 3 FLAT PASSES WITH A AND 4 FLAT PASSESS WITH B

CONTROL STRIP

STA: 3+00 TO STA: 8+00 LENGTH: 500 FT: WIDTH: 12 FT.
REMARKS: SOUTH BOUND LANE: PASSING

3 DENSITY MEASUREMENTS

SITE 1 @ STA: 3+00 GEN. DESC: 3' RT CURB
SITE 2 @ STA: 6+00 GEN. DESC: 6' RT CURB
SITE 3 @ STA: 7+75 GEN. DESC: 6' RT CURB

DENSITIES:	TEST NO. 1		TEST NO. 2		TEST NO. 3		TEST NO. 4 COMMENTS
SITE 1:	131.6	lb/cf	139.3	lb/cf	138.7	lb/cf	138.7
SITE 2:	135.7	lb/cf	140.4	lb/cf	141.5	lb/cf	140.9
SITE 3:	139.1	lb/cf	140.9	lb/cf	143.2	lb/cf	144.7
AVG:		lb/cf		lb/cf		lb/cf	

REMARKS:

TARGET DENSITY

RANDUM LOCATIONS		FIELD DENSITY		CORE DENSITY		COMMENTS
NO. 1	@ STA. 3+00	139.5	lb/cf	143.7	lb/cf	(SEE ROLLERS)
NO. 2	@ STA. 5+00	141.8	lb/cf	146.3	lb/cf	141.8/154.4= 92.0%
NO. 3	@ STA. 6+00	142.1	lb/cf	145.8	lb/cf	145.1/154.4= 93.97%
NO. 4	@ STA. 6+75	140.9	lb/cf	144.7	lb/cf	
NO. 5	@ STA. 7+75	144.7	lb/cf		lb/cf	ADJUSTED TARGET DENSITY = lb/cf
	AVG DENSITY:	141.8	lb/cf	145.1	lb/cf	

REMARKS: STATIONS FOR CORES BASED ON EQ EXTENDING SOUTHERNLY STA. 0+00 = M.P. 4.820

TC 63-49
Rev. 6/92

KENTUCKY TRANSPORTATION CABINET
Department of Highways
Division of Construction

DIST. NO: 05 7-13-93

DATE:

METER NO: 620

MODEL NO:

In-place Density Using Control Strip

PROJECT NO: SSP 037-0421-003-005

COUNTY: FRANKLIN

TYPE MAT'L: AK SURFACE (RUBBERIZED)

CONTRACTOR: H. G. MAYS CORPORATION

ROAD NAME: THORNHILL BY-PASS

ROUTE NO: 5.1

ROLLERS

BRAND A: INGERSOLL RAND DESC: 2 WHEEL VIBRATORY WGT: 10-12 TON

BRAND B: INGERSOLL RAND DESC: 2 WHEEL VIBRATORY WGT: 8-10 TON

BRAND C: DESC: WGT:

REMARKS: PATTERN: 1 VIBRATORY AND 3 FLAT PASSES WITH A AND 4 FLAT PASSES WITH B

CONTROL STRIP

STA: 3+00 TO STA: 8+00 LENGTH: 500' FT: WIDTH: 12 FT.

REMARKS: SOUTH BOUND LANE: DRIVING

3 DENSITY MEASUREMENTS

SITE 1 @ STA: 3+00 GEN. DESC: 18' RT CURB

SITE 2 @ STA: 6+00 GEN. DESC: 16' RT CURB

SITE 3 @ STA: 7+50 GEN. DESC: 20' RT CURB

DENSITIES:	TEST NO. 1		TEST NO. 2		TEST NO. 3		TEST NO.4. COMMENTS
SITE 1:	133.2	lb/cf	136.5	lb/cf	138.3	lb/cf	137.2
SITE 2:	137.3	lb/cf	139.6	lb/cf	140.3	lb/cf	140.5
SITE 3:	142.7	lb/cf	142.3	lb/cf	141.5	lb/cf	141.5
AVG:		lb/cf		lb/cf		lb/cf	

REMARKS:

TARGET DENSITY

RANDUM LOCATIONS	FIELD DENSITY		CORE DENSITY		COMMENTS
NO. 1 @ STA. 3+00	139.0	lb/cf	142.6	lb/cf	(SEE ROLLERS)
NO. 2 @ STA. 5+00	138.3	lb/cf	142.2	lb/cf	
NO. 3 @ STA. 6+00	140.1	lb/cf	143.7	lb/cf	140.6/154.9=91.0%
NO. 4 @ STA. 6+75	143.3	lb/cf	144.7	lb/cf	143.3/154.9=92.5%
NO. 5 @ STA. 7+50	142.2	lb/cf		lb/cf	ADJUSTED TARGET DENSITY = lb/cf
AVG DENSITY:	140.6	lb/cf		lb/cf	

REMARKS: STATION FOR CORES BASED ON EQ EXTENDING SOUTHERNLY STA. 0+00 = M.P. 4.820

Procedures in accordance with KM 64-430-90

TC 63-49
Rev. 6/92
112

KENTUCKY TRANSPORTATION CABINET
Department of Highways
Division of Construction

In-place Density Using Control Strip

DIST. NO: 05
DATE: 7-16-93
METER NO: 620
MODEL NO:
PROJECT NO: SSP 037-0421-003-005
COUNTY: Franklin
TYPE MAT'L: AK Surface
CONTRACTOR: H. G. Mays Corporation
ROAD NAME: Thornhill By-Pass
ROUTE NO: U.S. 421

ROLLERS

BRAND A:	Ingersoll-Rand	DESC:	2 Wheel Vibratory	WGT:	10-12 TONS
BRAND B:	Ingersoll-Rand	DESC:	2 Wheet Vibratory	WGT:	8-10 TONS
BRAND C:		DESC:		WGT:	

REMARKS:

CONTROL STRIP

STA: 0+00
TO STA: 5+30
LENGTH: 530 FT:
WIDTH: 25 FT.
REMARKS: Off Ramp U.S. 421
LANE:

3 DENSITY MEASUREMENTS

SITE 1 @ STA: 0+00 GEN. DESC: OFF RAMP U.S. 421
SITE 2 @ STA: 0+80 GEN. DESC: OFF RAMP U.S. 421
SITE 3 @ STA: 2+30 GEN. DESC: OFF RAMP U.S. 421

DENSITIES:	TEST NO. 1		TEST NO. 2		TEST NO. 3		COMMENTS
SITE 1:	130.2	lb/cf	140.1	lb/cf	142.2	lb/cf	USED BELOW ROLLING PATTERN UNTIL
SITE 2:	138.1	lb/cf	139.9	lb/cf	141.5	lb/cf	DENSITIES BROKE OVER
SITE 3:	138.5	lb/cf	141.1	lb/cf	142.0	lb/cf	
AVG:	138.2	lb/cf		lb/cf		lb/cf	

REMARKS:

TARGET DENSITY

RANDUM LOCATIONS	FIELD DENSITY		CORE DENSITY		COMMENTS
NO. 1 @ STA. 0+00	141.7	lb/cf	146.3	lb/cf	ROLLING PATERN:
NO. 2 @ STA. 1+00	142.4	lb/cf	146.3	lb/cf	1 VIBRATORY PASS 3 FLAT PASSES(10-
NO. 3 @ STA. 2+00	142.9	lb/cf	146.4	lb/cf	4 FLAT PASSES(8-10 TON ROLLER)
NO. 4 @ STA. 3+00	140.5	lb/cf	142.9	lb/cf	141.7/154.9=91.5% 145.3/154.9=93.8
NO. 5 @ STA. 4+00	141.2	lb/cf	144.8	lb/cf	**ADJUSTED TARGET DENSITY = lb/cf**
AVG DENSITY:	141.7	lb/cf	145.3	lb/cf	

REMARKS:

Procedures in accordance with KM 64-432-92

INSPECTOR

APPENDIX C - Double Layer SAMI Guidelines

Recommended Guidelines for Application of a Double Seal Coat Using Crumb Rubber Modified Asphalt Technology - A Membrane Application

Project Specific Notes

Location: Bridge Approach, Mason County, Maysville Bridge.
Subgrade: Low CBR (approximately 2).
Other: Use crumb rubber modified asphalt for construction of a double seal coat membrane on top of the subgrade.

Recommended Construction Sequence and Materials Specifications

1. Subgrade compaction at or 2% below the optimum moisture content and tapered along the shoulders for drainage.

2. No prime coat application on the compacted subgrade.

3. Seal coat applications should include all taper areas (shoulder, etc.).

4. First seal coat application:

    a. Rapid set cationic emulsion, preferably CRS-2.
    b. Rubber modified asphalt in the emulsion with 30%-35% water.
    c. Rich spray rate of emulsion, 0.3-0.4 gallon per squared yard.
    d. Cover the emulsion surface immediately after the spray with clean #57 stone with 40%-50% surface coverage.
    e. After application of the #57 stone, cover the surface with the rubber chips. These particles (0.25-0.5 inch) shall fill the voids left on the surface of the emulsion after the #57 application.
    f. Compaction with static steel drum roller (5-7 tons). One pass, one direction coverage only. When rollers are 48-54 inches wide, three rollers in tandem, with a slight overlap, may be necessary to cover the entire echelon.

4. Second seal coat application:

    a. Rapid set cationic emulsion, preferably CRS-2.

b. Rubber modified asphalt in the emulsion with 30%-35% water.
c. Rich spray rate of emulsion, 0.3-0.4 gallon per squared yard.
d. Cover the emulsion surface immediately after the spray with clean #9-M or #8, or #11 stone with at least 80% surface coverage.
e. Compaction with static steel drum roller (5-7 tons). One pass, one direction coverage only. When rollers are 48-54 inches wide, three rollers in tandem, with a slight overlap, may be necessary to cover the entire echelon.

Special Notes

1. There should be no duplicate handling of the emulsion. The emulsion should be delivered from the transport tank to the distributor tank as needed.

2. Pavement thickness design should not include a structural value for the double seal layer.
3. Pavement edge drains are recommended.

4. Subgrade instrumentation for temperature and moisture is highly recommended. This type of instrumentation will provide scientific data for reasons behind the success or failure of this project.

5. Use of Special Provision No. 99(91) dealing with partnering is highly recommended.