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MUNICIPAL USE OF ASPHALT-RUBBER

BY

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BACKGROUND

The idea of using ground rubber in hot asphalt was first conceived by Mr. Charles McDonald in the early 1930's. As Materials Engineer with the City of Phoenix in 1969, Mr. McDonald had the opportunity to experimentally develop his ideas for a new paving material. While performing the initial experiments in the development of asphalt-rubber as a viable paving material, McDonald convinced the local industry to try it on the street. So began the history of asphalt-rubber in Phoenix.

The first use of asphalt-rubber on a city street was as a seal. The new asphalt-rubber was applied followed by a chip cover. This application became known as a stress absorbing membrane or SAM.

The early applications of asphalt-rubber were marked by some failures, as was to be expected. Improvements in equipment and mix designs over the past 18 years have now virtually eliminated failures. Observation of applications in Phoenix over time has helped in the development of asphalt-rubber application techniques. Applications which would be classified as failures have been of interest due to, 1) The lessons learned in regard to composition and application methods, and 2) The "forgiving" nature of this material. Pavements which exhibited early cracking with asphalt-rubber were found to deteriorate much more slowly than standard pavements. In some cases, time improved the pavement condition, as the asphalt-rubber flexed and worked with the pavement stresses. Asphalt-Rubber maintains pavement viscosity at near original levels. Standard asphalt hardens much more rapidly, becoming brittle as volatile components are lost.

Advancements made in the mechanics of application have greatly improved the quality of asphalt-rubber pavements over the years. In the 1981 national seminar on asphalt-rubber, specifications for Asphalt-Rubber Application developed by the City of Phoenix were adopted. Experience gained through years of experimentation have been incorporated into these specifications.

TYPES OF APPLICATION

Since 1968 Phoenix has placed over 700 lane miles of asphalt-rubber stress absorbent membrane (SAM). This method consists of the application of 0.6 gallons per square yard of hot asphalt-rubber directly on an existing stressed surface. A pre-coated cover aggregate at a rate of 25-30 pounds per square yard follows the asphalt-rubber. This application is used on streets with up to 55,000 ADT and was also used on Sky Harbor Airport in Phoenix.

In 1972 the City designed an economical residential street section. The pavement consisted of 4 1/2 inches of soil cement with 1 1/2 inches of asphaltic concrete followed by asphalt-rubber. This type of design was used from 1972 to 1974. There still are 37 miles of this design in use. The original design, intended to last five years, has lasted 14 years. Although, this type of design did not stop reflective cracking from the soil cement after eight years, with proper maintenance such as a chip seal, or another asphalt rubber application, this pavement should last for 20 years or more.

Perhaps the most astonishing pavement the City of Phoenix has is where asphalt rubber was applied directly on native soil. This pavement is now 16 years old with only two chip seals in the last 12 years. The last traffic count was 7,400 ADT. The pavement is just now failing and in need of reconstruction.

In 1982, a double application of asphalt-rubber on a major street was constructed. The total application rate was 1.25 gallons per square yard over an existing street. The existing surface was an asphaltic concrete roadway with portland cement concrete parking area. The street contained the remains of a street car track, including ties. The surface had up to two-inch cracks in the concrete with 1/4" to 1/2" crack throughout the roadway. This pavement was overlayed in 1983 to improve the ride. This type of design became known as a stress absorbant membrane interlayer (SAMI). The original pavement cracks have not reflected through except where the two-inch cracks existed in the concrete. These are indicated by hair line cracks only.

Phoenix has used asphalt-rubber in other ways that have created new industry and business. A partial listing follows:

1. Subgrade seal to retain a constant moisture content in swelling soils.
2. Crack filling prior to chip sealing, slurry sealing, and/or overlays.
3. Joint filler for portland cement concrete pavements.
4. Lake liners in parks and industry.
5. Roofing.

THE LATEST IN CITY STREET DESIGN USING ASPHALT-RUBBER

Today asphalt-rubber is being used as a SAMI for reconstruction of our major streets. As the city grew, it incorporated several miles of two lane roadways. To maintain the traffic demand these streets had to be widened from two to six lanes. The existing pavement was structurally adequate with an overlay. It was elected to keep the existing paved section by paving on each side to obtain the desired width. An asphalt rubber SAMI was then placed, followed by an overlay to obtain the desired grade and ride.

The SAMI system has saved materials, reduced utility relocations, and reduced inconvenience to the public. The current cost saving is estimated to be $250,000 to $300,000 per mile of major street.

The design of major streets requires alternatives that fit both the condition of the project and the politics. One of the design alternatives is to use a cement treated base followed by an aggregate base followed by asphaltic concrete. The intent of the aggregate base is to serve as a zone for crack absorption between the cement treated base and the surface. Also, the aggregate base serves as a curing blanket for the cement treated base when immediately applied.

Asphalt-rubber has been recently utilized in place of the aggregate base. The asphalt-rubber is applied to the cement treated base, serving as a curing cover and retarding reflective cracking from the base. The asphalt-rubber is applied at the rate 0.75 gallon per square yard followed by chips. The chips allow traffic and prevent the pickup of the asphalt-rubber during construction. This system has saved $10,000 per mile in materials alone, with additional savings from decreased utility relocations.

New portland cement concrete pavements have been overlayed with double applications of asphalt-rubber due to early cracking in the concrete. The cracks have not reflected through to date. This is not a recommended practice, however, the contractor lost the concrete while constructing it. The more he tried to save it, the more the pavement cracked.

Asphalt-rubber as a binder in asphaltic concrete has been placed on a city street. This concept was first tried in 1971 with questionable success. The Arizona Department of Transportation (ADOT) has used asphalt-rubber as a binder on surface materials with reasonable success. The City's most recent trial was in 1985 wherein 13% asphalt-rubber binder was used with a coarse graded aggregate. This segment was placed on a super elevated section. The super elevated section was developed by placing one-inch of A-R AC on the lower side with five-inches on the upper. This experiment offered the opportunity to observe how the variable thickness performed. The three to five-inch section was found to be unstable under high ambient temperatures. The less than two-inch section is performing very well.

After observing the performance under construction it was concluded that the AR-AC binder should be reduced to 9%. In addition, a maximum placement of two-inches is recommended. This design will be continually observed and reported on.

The reasons for selecting asphalt-rubber are the same as for selecting a standard seal:

1. Provides a low-cost all weather surface.
2. Waterproof paving.
3. Provides skid-resistant surface.
4. Gives new life to dry, weathered surfaces.
5. Reinforces pavement strength.
6. Guides traffic.
7. Improves visibility.

The asphalt-rubber, however, offers these added advantages:

1. Prevents crack reflection
2. Prevents spalling.
3. Provides a truly flexible surface.
4. Reduces maintenance for at least eight full years.
5. Increases life of pavement by a factor as large as two.
6. Delays need for reconstruction.

Asphalt-rubber was not considered a preventive maintenance material in new construction until the reported work done at Sky Harbor International airport. The asphalt-rubber sealed runway preserved the viscosity of the pavement and maintained much of the original flexibility of the asphalt-concrete, (refer to Figure1). This property adds a major advantage in the use of asphalt-rubber in new construction.

ECONOMICS

Does asphalt-rubber save money, time and inconvenience? Considering the additional pavement life gained by applying asphalt-rubber, the reduction of utility relocation and pavement sections, and the added in convenience to the public, yes. When asphalt-rubber was first used in 1969, the cost was three times that of a conventional asphalt. Today the cost is 1.5 times conventional asphalt in Phoenix. Figure 2 shows the costs comparisons for standard and asphalt-rubber chip seals in the past 15 years in Phoenix.

It must be pointed out that asphalt-rubber has historically been applied in situations where pavement reconstruction was indicated, but was not economically possible.It is difficult to measure the cost savings in maintenance alone. The hours spent on an asphalt-rubber treated surface has been minimal to non-existant.

Figure 3 shows the savings obtained by using asphalt-rubber instead of a standard chip seal. Maintenance costs are added to both seals which start with only their 1975 placement costs. While the asphalt-rubber shows only a slight increase due to maintenance starting in 1983, the standard chip seal has already been resurfaced in 1983. This second chip seal, combined with maintenance prior to the resurfacing, more than triples the initial cost.

Asphalt-rubber has given the engineer property values that have been proven in municipal work by:

1. Stopping reflective cracking in pavements with less than 0.25 inch (0.64 cm) cracks for over 3 to 12 years.
2. Stopping spalling of asphaltic concrete around pot holes and larger cracks.
3. Water-proofing the structure to obtain maximum stability.
4. Sealing and preserving the original quality of the asphalt cement and the asphaltic concrete pavement.
5. Reducing maintenance due to all of the above.
6. Sealing the subgrade to minimize the volume changes that take place due to moisture changes.
7. Serving as a stress absorbing interlayer to reduce future maintenance.
8. Offering a flexible property for streets and roads.
9. Performing as an excellent crack-filling material and joint sealer.

CONCLUSION:

Asphalt-rubber has performed very well in Phoenix. Several of the original installations in the past 15 years are still working. As pointed out asphalt-rubber was used in severe cases of disrepair and managed to save the roadway from major maintenance costs and reconstruction. The Material has delayed reconstruction by as much as 15 years.

The City of Phoenix is currently using asphalt-rubber for all crack filling. Over 20 miles of SAMI's have been completed with an average annual future use of ten miles per year. Over 500 lane miles of SAM's have been placed with an average future annual usage of 25 miles per year.

The municipalities surrounding Phoenix are using asphalt-rubber for maintenance along with the counties and the State of Arizona (ADOT). Asphalt-Rubber is no longer considered experimental, it is being used as a problem solving material. However there are experiments that are on going in using asphalt-rubber as reported here. We believe in keeping an open mind to any and all applications of asphalt-rubber. It is not a cure-all and needs engineering judgement for a successfull application.

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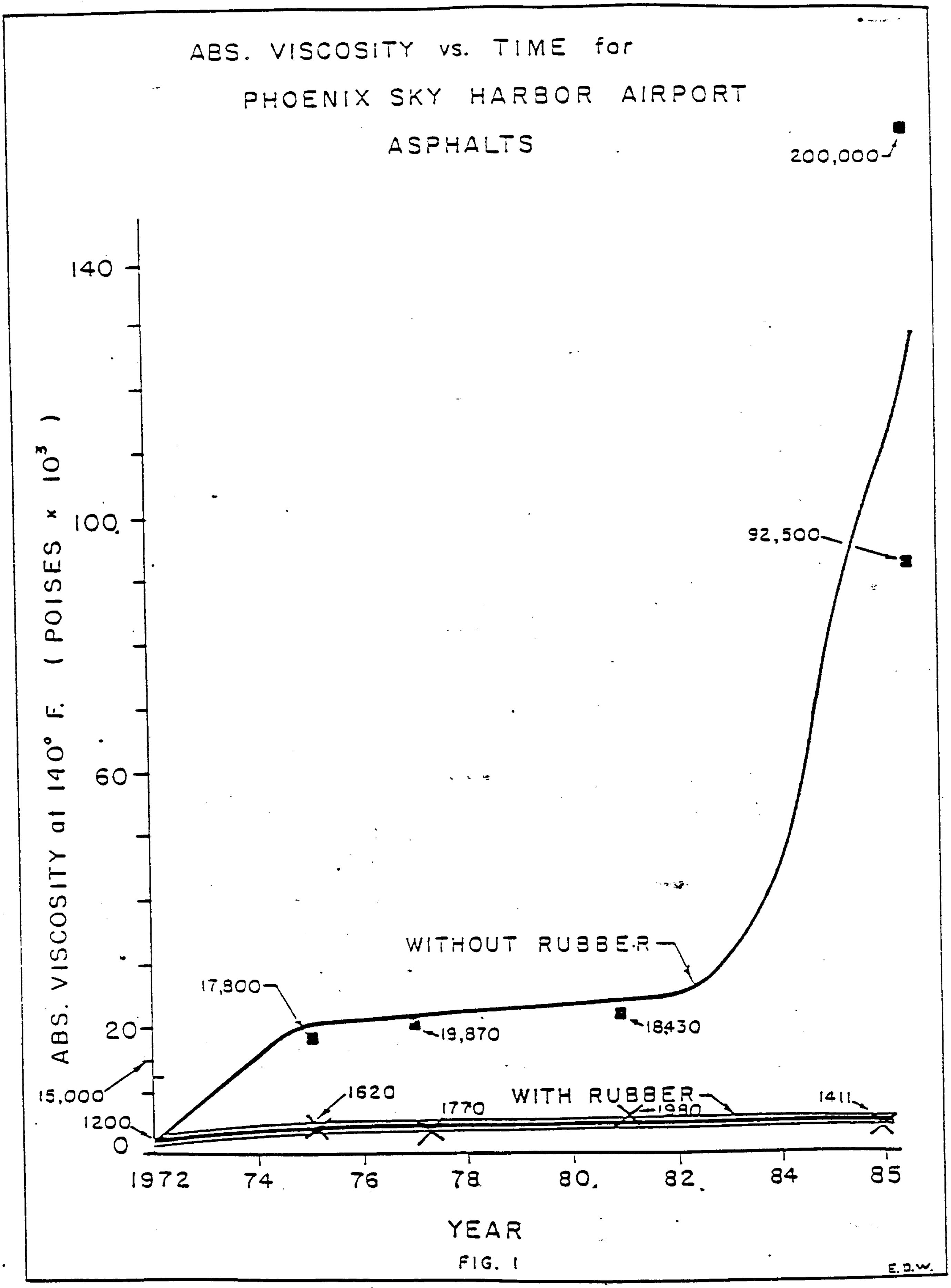

Absolute Viscosity vs Time for Phoenix Sky Harbor Airport Asphalts

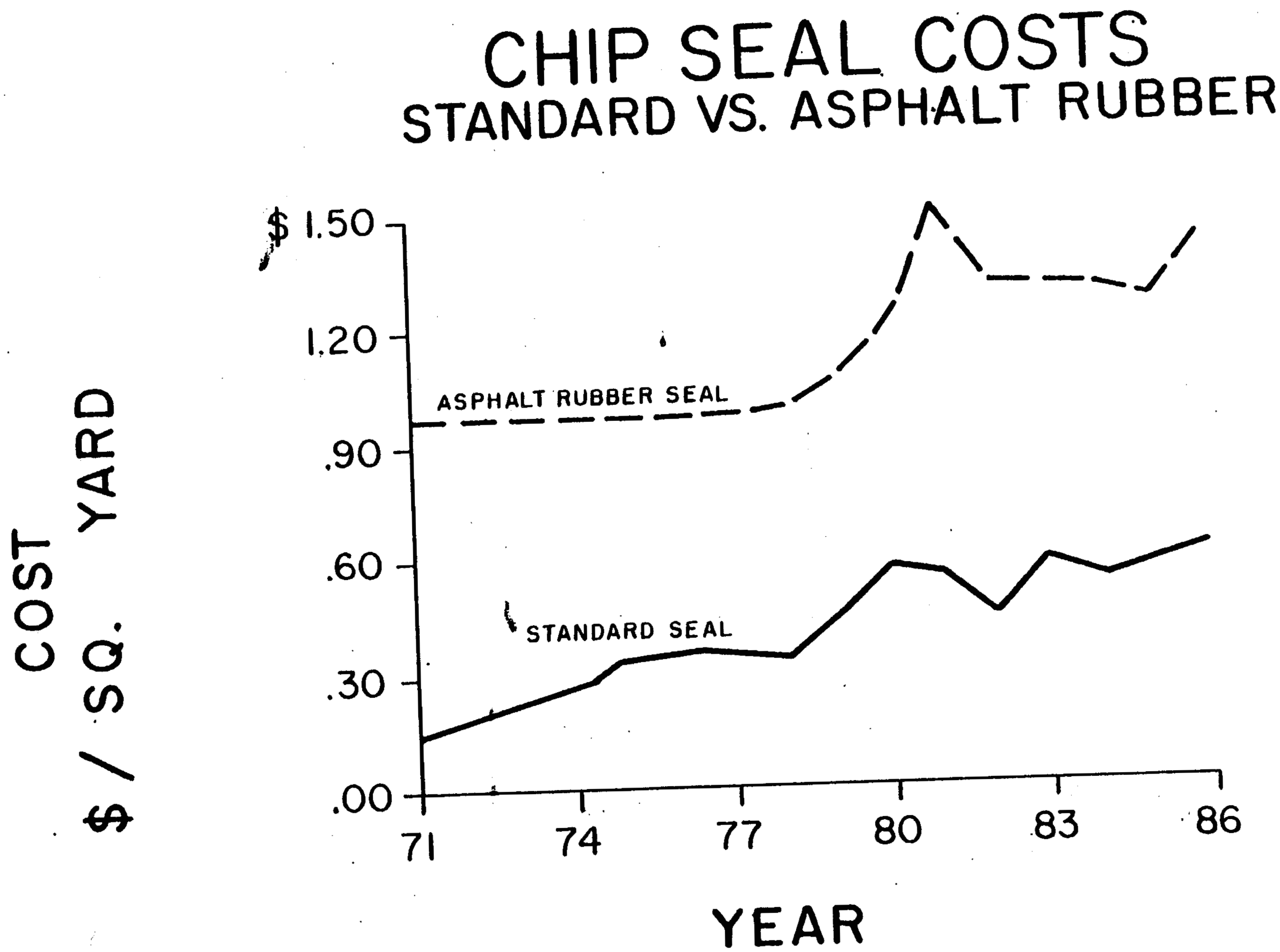
CHIP SEAL COSTS
STANDARD VS. ASPHALT RUBBER
COST
$ / SQ. YARD
$ 1.50
1.20
.90
.60
.30
.00
ASPHALT RUBBER SEAL
STANDARD SEAL
71
74
77
80
83
86
YEAR

FIG. 2

ACTUAL PAVEMENT COST
STANDARD VS. ASPHALT RUBBER SEAL

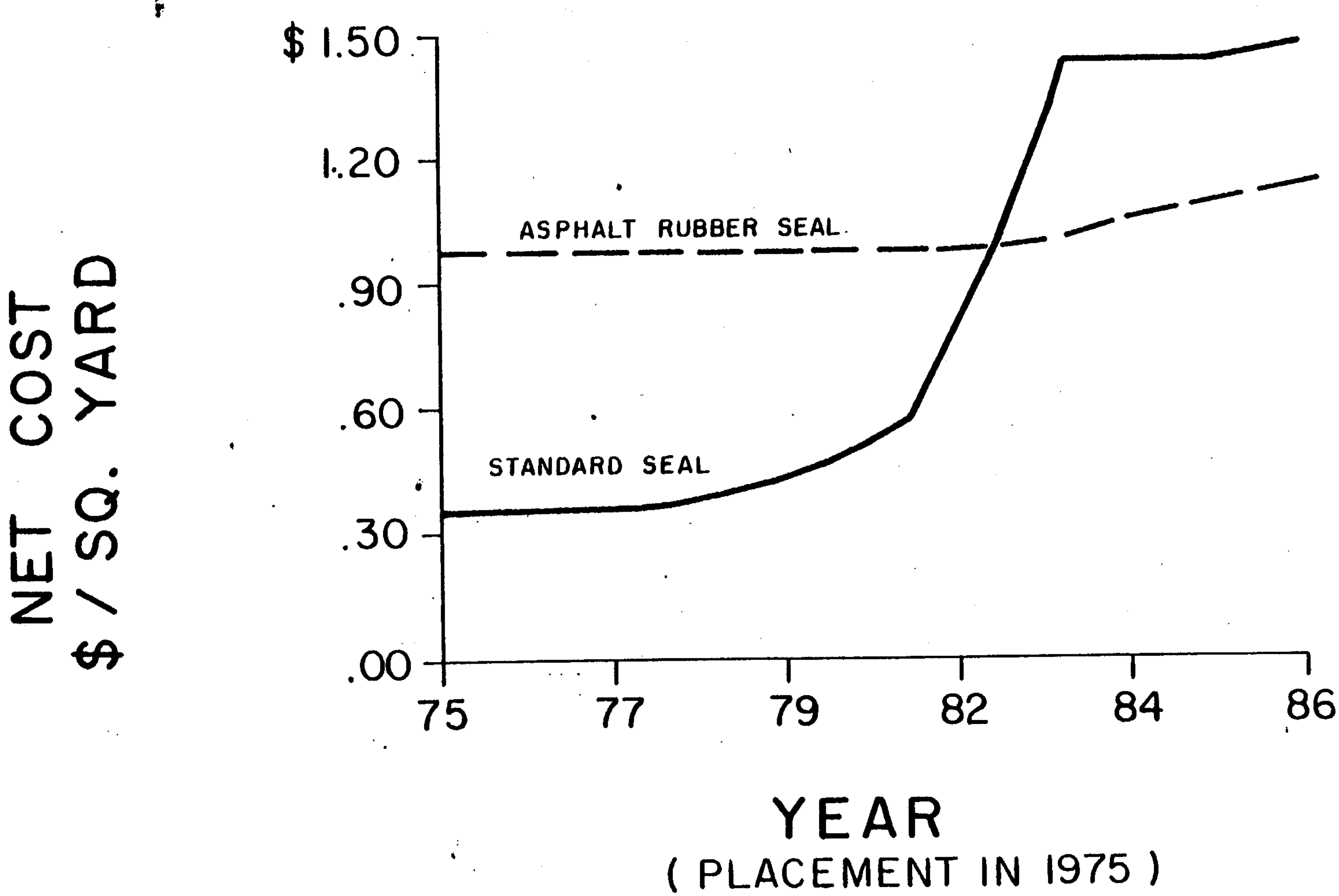

FIG. 3

ASPHALT-RUBBER

RUBBER FILLED ASPHALT CONCRETE

"PlusRide"

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(Transcribed and edited from the presentation)

Presented at Scrap Tire Recycling and Vendor's Workshop

Sponsored by Fayetteville Technical Institute
North Carolina Association of County Commissioners
and Cumberland County Clean Community Committee

Fayetteville, NC
November 13, 1986

We want to continue with use of recycled or reclaimed rubber in the paving industry. Russ Schnormeier spent some time talking asphalt-rubber where the granulated rubber is reacted with the liquid asphalt, and then used as a binder.

We want to look at rubber-filled asphalt concrete. I would like to speak to you a little bit about asphalt concrete which is the hot mixes that we normally think of and how asphalt or rubber-filled asphalt concrete fits into this scheme. It's part of a hot mix design rather than a binder. I want to talk about the mixture design procedures and about placement of the material and about something on "costing methods," a projected market that at least is estimated as a first cut for North Carolina and some suggested courses of action. We want to address this primarily to the engineers and contractors that will be responsible for the design and construction of these systems and show them what we think in the PlusRide area are some things to be watching for. First a conventional asphalt concrete mixture is a designed mixture of graded aggregants. I want to emphasize that these are designs. They're technology systems and all of the designs for asphalt concrete that you use are custom-built jobs. You've got to use nature's aggregates and Mother Nature is fickle which means that every one of these may be a little bit different and take a look at some of the factors that effect how an asphalt concrete pavement is going to perform. First of course is the aggregate. Now we think that the load carrying capability or the structural capability of an asphalt concrete pavement rests primarily in the aggregate or rock fraction. I point this out because we're going to ask you if you use PlusRide to take another look at the aggregate fraction. Second is the asphalt cement itself. It's the glue that holds the pavement together; keeps the water out; it's responsible for durability and the type and quality of the asphalt are critical. In conventional asphalt rubber, there is a chemical reaction that takes place between the rubber and the asphalt. PlusRide or rubber-filled asphalt concrete is not that dependent on the chemical reaction so its not as sensitive to the asphalt composition as some of the other products are. Third is the production of an asphalt concrete. You can make or break a good pavement in the production. If the production capabilities are not good and the quality is not good, the performance of that pavement will suffer; and the same holds true for PlusRide or rubber-filled asphalt concrete. Last is the placement: How do you build it? Again, in this long chain of events in making a pavement perform, placement can ruin the pavement. Again, this holds true for rubber-filled asphalt concrete. Rubber-filled asphalt concrete or PlusRide is essentially a gap grade asphalt concrete. It's the same kind of hot mix that you use in conventional except we do gap grade the aggregates. Take out some of the rocks sizes and replace that material with crumb rubber, and we do this on a volume basis. PlusRide is the patent tradename for the material. Some of the advantages of using PlusRide as we see it are that it provides some flexing, materials are more elastic, they have more rebound, more give to them. Second, it does improve fatigue resistance. It has a lower modulous. Materials with lower modulous have a higher S-N ratio. It has a greater ultimate strain at failure. You can stretch it farther before it breaks. Finally, it adds a toughness to the mix that you don't see with conventional asphalt concrete. Last and certainly not least by any matter, is the removal of ice. It's been used in northern climates and in Europe for quite a period of time to help remove the thin underlayer of ice that causes skid problems. Now it's not a guarantee but we have noticed that in areas that have been photographed, the areas with PlusRide won't have ice when others do. This is especially true in terms of bridges. What we are trying to say is that PlusRide is the same as conventional asphalt concrete with regards to the keys of production, aggregate control, and placement, except that some of the aggregate has been replaced with rubber. In conventional asphalt concrete large size aggregates have intersteces. These intersteces are filled with smaller aggregates and smaller and smaller on down according to a thing called a Fuller's curve. Some of the aggregates have been replaced with rubber granule particles. These provide the give which gives the elasticity and the toughness. PlusRide presently uses a quarter inch No. 410 and 20 as controlled sieves and normally 3 percent of rubber by weight of mixture is added, sixty pounds to the ton. The part that I think the contractors should be especially interested in are the properties of the PlusRide aggregates. The gap grading, does require some changing in the screens on a hot plant or the screens in the cold screen side. In order to provide this gap in the quarter inch to No. 4 material that PlusRide principally consists of. Setting of these screens and gapping is not that difficult. We've had very good success with it but

it is a key to the performance of material. Mixture design procedure for the laboratories that are going to be working with PlusRide goes as follows:
Conventional martial or kneading compaction can be used to produce the specimans that are used for testing. The criteria for a PlusRide or a rubber-filled asphalt concrete are voids and filler debitumen ratio, not stability. The rubber-filled asphalt concrete mixtures are extremely low stability because they give and flex under the load. We're saying right now that it probably is not a structural material so we are thinking of using it in relatively thin lips, inch and a half to two-inch lips in lieu of an open graded friction course or in lieu of part of the surfacing mix. We run a conventional density voids analysis on these mixtures and adjust the mixes to provide the voids ratios that we'll talk about in a minute and we use a specific gravity of rubber of 1.19 to make these volume concentrations and to set the voids content of the mixture. Field procedures when using rubber-filled asphalt concrete are somewhat different than conventional asphalt concrete. PlusRide has been produced in both conventional batch plants as well as drum mixtures. The trick is if a drum mixture is going to be used right now we're recommending a split feed mixture with a recycled suit on it so that the rubber doesn't burn in the mixer. Placement of PlusRide is somewhat different than the conventional material but does not require modifications of the system. The biggest difference is, that you cannot use numatic rollers, the rubber will stick to the numatic rollers so we roll these all a skim and then second, because of the compression and sudden rebound

of the rubber particles in the mix, it may need more rolling than a conventional mix, particularly if temparatures are low. Let's look at some cost estimates that we've worked up. I want to separate this concept of cost estimate from pricing. Price is what you pay for it, cost is what it costs you to operate and maintain the material. If one assumes the 145 PCS conventional mix at 5½ percent asphalt content and for a like PlusRide mix, the thing that happens is because of the lower specific gravity of rubber the unit weights of the rubber-filled asphalt concrete are lowered, which means that the same weight gives you about 5 to 7 to 10 percent increased volume. In our cost comparisons, we have included the increased volume of the same weight of material. In general, depending on aggregate and depending on plant flow through cost that I calculate at around a dollar a ton to get the rubber into the plant, if you've got to hand manually open bags and dump it, PlusRide with the royalty will be about 1¼ to 1.9 times the cost of a conventional mix. That's with present costing and pricing. I think that number will go down considerably as the contractors get more used to it, as they get their screen deck set, and as they find better ways to introduce the material that doesn't require such labor and intensive work. Last, we feel that life-cycle cost when one compares not only PlusRide, but any other recycled or recovered resource has to be looked at "life-cycle cost" picture. What we normally do in this area is to take a time span or a cost-analysis period of about 40 years, and we are presently working up a computer program that will say what all the scenarios possible for that stretch of pavement are.

When am I going to overlay it? When am I going to sealcoat it, flushseal it, whatever. Total all of these with your present first cost and with an inflation rate, and then find out what your actual first cost or actual annual cost of the system are. At a 10 percent inflation rate, you're going to find that with two additional years life out of the 8 or 9 year thing, you can afford to pay double down on the front end. These are based on simple discounted cash flow analyses. I think it's something that we have not looked at as deeply and in as much detail as we ought to when one begins to look at first cost or first price. What's the standard way right now of designing a rehabilitation system? I've got this amount of money and hot mix costs me this much a square yard and that's my program. And I think that we have to now start taking a little different look at how the funds are expended. We've made some estimates of a projected market in North Carolina. We've assumed about a half a million tons of asphalt cement utilization. Now I know that varies from time to time. We made a further assumption that 50 percent of the asphalt cement is used in hot mixes. Based on that, we said that there's about five million tons of hot mixes used. That says that you can utilize about 1500 tons of rubber per 1 percent of hot mixes that use 3 percent rubber annually. This is market penetration based on a 1 percent penetration, if you can penetrate 2 percent, use 3,000 tons. That's in rubber-filled asphalt concrete and not in the binders with asphalt rubber. These numbers certainly can be adjusted. As we get better numbers we were speaking with the asphalt institute who couldn't make it here to get a better set of figures on asphalt cement production and hot mix production in the state. I think that the Asphalt Pavement Association of North Carolina can get you these numbers if you want them. Where we get into some other problems is the unintelligent use of these numbers. If you can use it in 1 percent you can't go around assuming that we can penetrate 100 percent of the market because they think the PlusRide people, as well as the asphalt rubber people, will tell you that there are places this can and should be used but there are other places that it shouldn't. Now some suggestions for some courses of action for you, and these are in the form of suggestions, we think that some laboratory studies should be initiated for familiarization with the local materials. What are your local aggregate characteristics and we know they're different in North Carolina than they are in adjacent areas. Hopefully the DOT laboratories can get familiar with these materials and mix designs are a little bit different. You have to get your hands in these materials and get them a little dirty. We would then suggest that you design some modest test sections based on these laboratories studies, and then construct some test sections in highways and city streets heavily traveled, moderate and low travel materials and then monitor the performance of these materials and adjust the design procedures for your own purposes. We know that at North Carolina State University, Dr. Kosler has a good deal of experience with paving materials and performance studies and I think that he would be a good one for some modest efforts at the university level to begin to familiarize with the materials, with the material as a paving material and not particularly looking at it as a method to reuse or recycle wastes. Based on these test sections and performance and I think most of this can be conducted in a year to a year and a half, establish some procedures and specifications as well as performance figures to put into your lifecycle cost studies to find out when and where the materials should be used and how much can't be used. The establishment of No. 4 is going to take some period of time. You cannot accellerate testing of pavement materials. Almost every time we try this, we wind up missing the estimate. So we could take some period to develop these lifecycle costs and then last, there are some specifications available and PlusRide can provide these for you that are ASTM format and are being voted at ASTM now. Let me quickly review what we've talked about. PlusRide or rubberfilled asphalt concrete is the second cousin or the next generation materials along with conventional hot mixed asphalt concrete with the exception that you gap grade the aggregates to provide space for the rubber particles. Mixture design procedure is somewhat different and typical or normal martial or California methods inasmuch as stability is not a criteria. Stability and flow are not. The criteria or voids in filler bitumen ratio. PlusRide field procedures are not too unlike conventional asphalt concrete with the exception that steel wheel rolling should be used rather than conventional numatics so that it won't stick and secondly additional rolling may be required. Our cost estimates on the materials so that it's going to cost you somewhere between one and a quarter to 1.9 times conventional material but they should be based on a lifecycle costing method. Our projected market says 1500 tons percent of the hot mix market that can be penetrated, can be justified to use and lastly there were some courses of action that we think can be started immediately with modest funding that I think are available at the state level or perhaps even the county level to get on with the production and use of this material.

ASPHALT - RUBBER

Rubber Filled Asphalt Concrete

"PlusRide"

Dsk RDP 68 (86-1326)

TOPICS

1. Asphalt Concrete.
2. Rubber Filled Asphalt Concrete.
3. PlusRide Mixture Properties.
4. PlusRide Mixture Design.
5. PlusRide Field Procedures.
6. Cost Estimates.
7. Projected Market.
8. Suggested Course(s) of Action.

ASPHALT CONCRETE

1. __Designed__ Mixture of Graded Aggregates, Asphalt, and Modifiers.

2. Factors :

   A. Aggregate --- Carries Loads.
   Type and Quantity Critical.

   B. Asphalt --- Cement, Durability.
   Type and Quantity Critical.

   C. Production.

   D. Placement.

RUBBER FILLED ASPHALT CONCRETE

1. Gap Graded Asphalt Concrete Filled With Elastomeris Aggregates (Crumb Rubber).

2. "PlusRide" (Patented).

3. Rubber Imparts Elasticity or "Give".

   A. Claims :

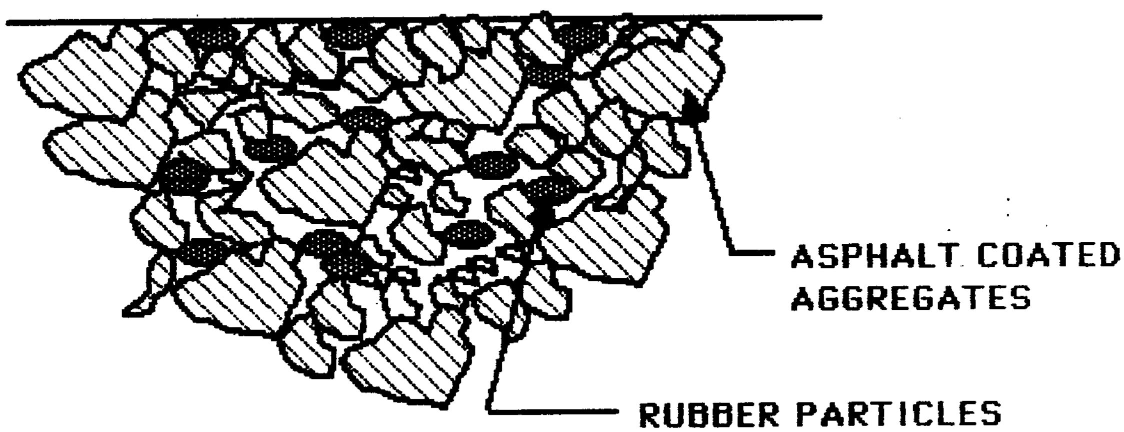
      "Flexing" Provides :

      Improved Fatigue Resistance.

      Greater Ultimate Strain at Failure for Improved Reflection Crack Control.

      "Toughness".

      Ice Removal Aid.



RUBBER FILLED
ASPHALT CONCRETE

Dsk RDP 68 (86-1326)

PLUSRIDE MIXTURE PROPERTIES

3 Percent Rubber by Weight of Mixture (60 Lb. Bag of Rubber Per Ton of Mix).

Rubber Gradation :

Sieve	% Pass
1/4"	100
No. 4	76-100
No. 10	28-42
No. 20	16-24

Aggregate Gradations (Without Rubber):

Sieve	PR-8	PR-12	PR-16
3/4"	100	100	100
5/8"	100	100	-
3/8"	100	60-80	50-62
1/4"	60-80	30-44	30-44
No. 10	23-38	20-32	20-32
No. 30	15-27	13-25	12-23
No. 200	8-12	8-12	7-11

PR 12 And 16 : Pass 1/4, Ret. No. 10 - - 12% Max.
or Pass No. 4, Ret. No. 10 - 10% Max.

Voids Filled With Rubber and Filler. Adjust to 2-4% Voids With F/B +/- 1.0-1.2.

Normally, 7-8% A.C., 1-1% Filler.

PLUSRIDE MIXTURE DESIGN

1. Marshall and Kneading Compaction Procedures Modified to Accomodate Rubber.

2. Voids and Filler/Bitumen Ratio (Not Stability) are Criteria.

3. Conventional Density-Voids Analysis With Rubber Specific Gravity = 1.19.

PLUSRIDE FIELD PROCEDURES

1. **Production.**

   PlusRide Has Been Produced in Conventional Batch and Drum Mixers.

2. **Placement.**

   Cannot Use Rubber Tired Rollers Because Rubber Sticks.

   Additional Rolling May be Necessary to Compensate for Rubber Compression and Rebound.

COST ESTIMATES

1. Assume Conventional Mix at 145 pcf, 5.5% A.C.

   PlusRide at 135 pcf (Approx. 5% Volume Increase), 7% A.C.

2. PlusRide With Royalty Will Be 1.25 to 1.9 Times The Cost of Conventional Mixtures.

3. Life Cycle Costs Should be Considered for the Local Situation.

PROJECTED MARKET(S)

1. Assume Annual Asphalt Cement Utilization at 550,000 Tons (North Carolina).

2. Assume 50% of Asphalt Used in Hot Mixes With Approximately 5,000,000 Tons of Hot Mix Produced.

3. Approximately 1500 Tons of Rubber can be Used If 1% of Hot Mixes Use 3% Rubber.

   (1500 Tons Rubber Per 1% of Hot Mix Market Penetration).

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SOME SUGGESTIONS

1. Initiate Laboratory Studies for Familiarization With Local Materials (Aggregates and Rubber).

2. Design Test Sections Based on Laboratory Studies.

3. Construct <u>Modest</u> Test Sections (Highways and City Streets).

4. Establish Procedures (Specifications) and Life Cycle Costs.

FINAL REPORT

THE EVALUATION OF RUBBER ASPHALT SURFACE TREATMENT IN PREVENTING FATIGUE CRACK REFLECTION IN BITUMINOUS OVERLAY CONSTRUCTION

M. P. Strong
Highway Research Engineer
North Carolina Department of Transportation

Prepared in Cooperation With
U. S. Department of Transportation
Federal Highway Administration

SCRAP TIRE RECYCLING
AND
VENDOR'S WORKSHOP

SPONSORED BY

Fayetteville Technical Institute Continuing Education

North Carolina Association of County Commissioners

Cumberland County Clean Community Committee

Supported by the North Carolina Pollution Prevention Pays Program
with funding through the North Carolina Board of Science and Technology

NOVEMBER 13, 1986
Fayetteville, North Carolina