The Development of Asphalt-Rubber & Associated Paving Systems

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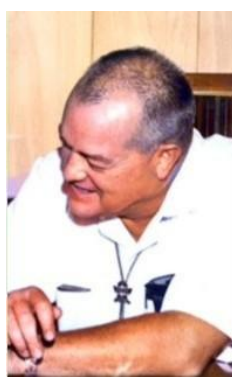
This history of asphalt-rubber is dedicated to two engineers who were not directly involved in the work but without their support the work could never have been carried out. The individuals are Fred Glendenning, Director of Public Works for the City of Phoenix and William N. Price who was the state engineer of the Arizona Highway Department, later the Arizona Department of Transportation. Without their strong and continuing support neither Charles McDonald nor myself would have been able to develop or implement the use of Asphalt-Rubber.



Prologue

This history has been written to report both the engineering and supplier aspects and events that have had significant effect on the development and implementation of Asphalt-Rubber and the associated paving systems. Particularly in the supplier decision area there will be some who disagree, possibly vehemently. So be it. However, discussion of marketing and implementation will be deferred to the latter part of the presentation.

This report is prepared with the engineering developments and supplier decision events running concurrently throughout. There are undoubtedly errors in some of the dates and perhaps some important events omitted. An effort has been made to confirm the accuracy with other sources.

To properly present this history, and more important to understand it, I have found it necessary to define the agencies and the construction industry, their unique circumstances and what forces that they respond to. This knowledge has been developed during fifty years of experience working both for an agency and with the agency from the private enterprise side. If one does not understand the relationships of the Federal government agencies to the states and in turn the state agencies to the construction community, the mistakes made during the development of Asphalt-Rubber will be repeated.

Background Discussion

To understand the history of the development of Asphalt-Rubber (and or modifiers) of asphalt one must look at the development of the highway program itself in America. In the late 1800's, development of the internal combustion engine and subsequently the development of the automobile brought about the need to provide a smoother and safer roadway to handle vehicles capable of higher speeds and heavier loads than horse drawn vehicles previously required. Developments that were critical to the success of the automobile included the discovery of readily assessable oil in Pennsylvania and the manufacture of a temperature stable rubber from latex materials. Each of these developments occurred within a short time period in the last part of the 1800's.

Of interest is the fact that the discovery of petroleum and the associated refining process not only produces a hydrocarbon fuel to provide low cost operation for the mechanical engines, but it also provided one of the two critical materials necessary to develop the low cost transportation network that was also necessary for the implementation of the horseless carriage. At the same time the development of technology to produce rubber and products that were relatively heat stable was also absolutely critical to the use of higher speed vehicles. If rubber (and the pneumatic tire) had not been developed, the automobile and its requirements for pavements other than gravel would not have occurred.

One major problem facing the refining industry was that the production of fuels from crude petroleum was not very efficient and created a substantial waste product with serious disposal problems. A major portion of this product was the material that we call asphalt. The solution to this disposal problem lay in the fact that asphalt could be used to stabilize soils, particularly gravels, and build greatly improved roadways. The industry realized that if the cost of asphalt was subsidized it would encourage the construction of improved roadway systems and help eliminate their waste product disposal problem. These improvements in turn would lead to increased use of the motor vehicles and in increased demands for fuel. The industry heavily subsidized asphalt until the OPEC embargo in the early seventies. At that time the price of asphalt was increased from \$20/ton to \$370/ton. The basic reason for this change was that new technology developed methods by which other products could be profitably produced (polymers, etc.) from what was previously a waste material.

The need for improved transportation systems led to the requirement for individuals skilled in the technical areas of pavement design and construction and the materials engineer was born. This need also lead to the creation by the industry of two organizations that made major contributions to the technology - the Asphalt Institute and the Portland Cement Association. It is important to realize that in the highway industry, the agencies design and specify the products for the pavements and the contractors purchase the specified product and placed it. Although the contractor actually purchases the materials he has nothing to do with the specifying and hence marketing of the materials must be directed to the agency. Further, since the designers are engineers, the marketing must be on a technical basis. It is for these primary reasons that the above organizations were established and funded by the associated material industries to provide the research and technical marketing services. It is equally important that the asphalt-rubber industry also recognize who their real client is.

In the study of asphalt, the waste product of the refineries, it was learned early on that this material varied greatly from one refinery to another and the physical properties varied greatly through the temperature ranges in which it was expected to perform. Asphalt is visco-elastic and its elastic properties are very low or non-existent at the higher temperature ranges and the viscous properties are undesirable the lower temperatures. In fact asphalt becomes a brittle solid at or near 32 degrees F. If one modified the asphalt to provide the desired viscosity at high temperatures, performance was sacrificed at low temperatures and visa versa. Additionally the initial properties were significantly modified by aging and exposure of the material to the elements. To complicate matters, the science of determining stresses and strains created in pavement structures by loads and the environment was in its infancy and even today is not totally understood.

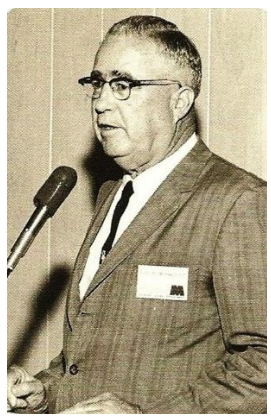
Interesting, rubber, the other material required for the development of the automobile, in some forms was also visco-elastic with excellent viscous properties at high temperatures and improved elastic properties in the lower range of pavement temperatures. Even in the early 1900's it was evident to engineers and scientists that if one could combine these two materials, significant improvement in the performance of pavements could be achieved. There was one major drawback - when you added enough rubber to the asphalt to achieve the desired properties, the cost was excessive. Efforts to provide an economical system continue to this day with such items as latex emulsions and polymer modified asphalts still being evaluated. Generally, all of these modifications improve the material properties to some degree but whenever sufficient elastic material is provided to substantially alter the pavement materials properties the cost is prohibitive or substantial construction and/or performance problems develop.

Two other developments occurred during the evolvement of the highway transportation system that needs to be considered. The first paved roads were designed based on the needs of previous transportation systems. They were narrow, many times just one lane, based on low volume and low speed traffic needs. The development of the automobile was so rapid that the average life of the constructed roadway was less than 13 years, not because of pavement performance primarily but because the geometric design did not provide safe operating conditions for the constantly increasing traffic volumes and vehicle speeds.

After WWII these problems of geometric design were addressed in the interstate highway and freeway systems that were developed around the country. The elimination of the geometric design problems resulted in a need for pavements to last longer and failure modes such as cracking, whether it was actuated by traffic loading, climate and environmental conditions became a major factor. Higher vehicle speeds also required that pavements be built and maintained smoother for the extended life of the roadway and long term skid resistance became a factor. To provide extended life to either flexible pavements (asphalt concrete) or the rigid Portland cement concrete the economical rehabilitation procedure was the overlay.

Compounding the roadway geometric problem was that the pavement design technology/was in its infancy and a majority of the interstate highway system was under-designed. Unexpected rapid increase in traffic volume and magnitude of loads accelerated the problems with pavement cracking. Also truck traffic was now channelized and truck tire pressures were more than doubled. These led to a need for structural improvement in virtually all pavements. The need for overlays was reinforced because materials and equipment to effectively seal the cracks were not available, particularly for flexible pavements. Therefore, overlay of these pavements offered what appeared to be an economical method of rehabilitation. With the construction of pavement overlays a new and unexpected problem developed - that of reflective cracking in the overlay. Field performance revealed that every existing crack (or joint) in the old pavement would reflect through the overlay in a relatively short period of time. The overlay process that had been developed to rehabilitate cracked pavements was not all that the engineers had hoped for. The primary cause of the reflective cracking was believed to be a stress concentration at the tip of the crack in the existing pavement. It soon became apparent that reflective cracking in these overlays presented extremely serious problems. If one provided sufficient overlay thickness to reduce reflective cracking, the cost became excessive because other roadway fixtures such as structures, signs, curbs, and guard rails, had to be substantially modified. On city streets in particular, storm water drainage might be seriously affected. This then was the condition that prevailed in street and highway systems in the 1960's. Geometric design had improved substantially and the system was designed for, or at least forecasted, for a traffic life of 20 to 30 years. Traffic forecasts however were generally too low with the volume of trucks, the vehicle weights, and the tire pressures increased tremendously over past experience. Pavements were simply not lasting their design life. The primary mode of failure was cracking, either caused by fatigue stresses or environmental forces or some combination of the two.

One other development that must be considered in the analysis of this history was the introduction of an additional waste product. That product is the worn out old tire. With the rapid increase in traffic, tire disposal became a major problem for the public. In this case however, industry was one step removed from the development of the waste product and therefore was not directly held liable for its disposal. The magnitude of the problem exploded with the increase in automobile usage and the some 250 million-scrap tires per year were now a major disposal problem in the United States. Thus we now have a second major waste product developed from the two basic products that were required for the development of the motor vehicle, a low cost fuel and wheels with a cushioned effect to provide a high-speed capability. It is of great interest that the two materials necessary for the development of the automobile also provides the two waste materials that can provide the long-term performance of the transportation system. As noted earlier it has long been known that if we could combine the elastic properties of rubber and the viscous properties of asphalt the resulting combination potentially could greatly improve pavement performance. Various uses for the scrap rubber from tires were developed and methods to reduce the rubber to various sizes of granules were employed to respond to these uses. If this rubber from scrap tires could be utilized then it might be economically feasible to combine the two materials. Unfortunately there was little incentive for industry or the agencies to tackle this problem. First of all few pavement engineers employed by agencies had little in-depth technical knowledge of asphalts, let alone rubber. The scientists and engineers of the asphalt industry had limited technical knowledge of rubber and little incentive to improve the asphalt characteristics. The scientists who had technical knowledge of rubber had little if any communications with pavements group and had no incentive to solve the waste tire problem.



This was essentially the situation in the mid 1960's when two engineers in government became involved. The first, Charles McDonald, had been a long time employee of the federal agency responsible for the highway programs, the Federal Highway Administration (FHWA). In the early 1960's McDonald had retired from the FHWA and accepted a position as Chief Engineer of the materials division for the City of Phoenix. At that time this materials division was in its infancy. Charlie McDonald had only a high school education but had an extremely inquisitive and innovative mind and acquired professional registration as a civil engineer through his years of experience, studies and technical contributions to the technology of pavement design, construction, and performance. I was a graduate civil engineer, had spent five years as a field engineer with the Portland Cement Association, and had worked as a consulting engineer specializing in structural design. During college years and for a short time subsequent, I had worked for the Arizona Highway Department in field construction. I rejoined the highway department in late 1962 as a resident engineer. In 1964 I was promoted to senior resident engineer and subsequently to Assistant District Engineer, Phoenix District, in 1965. During my years with the Portland Cement Association I became acquainted with McDonald and a lifetime association ensured. McDonald was driven by two-fold incentive. First, most of the city streets had been under-designed for the greatly expanded traffic volume and the increased axle loads that occurred with the rapid growth of the city. Fatigue cracking was a serious problem. McDonald was also a Scotsman and he knew that if he could develop a material to solve the problem, a patent and associated financial rewards, were also possible. Because drainage and curb height restrictions existed it was, however, obvious that any solution to the problem had to be a very thin section, less than one inch if possible.

Because of his long experience with pavements, McDonald knew that flexibility at ambient temperatures was needed in the pavement systems. A previous part of McDonald's life also came into play. In the 1930's McDonald had worked on a survey crew locating highway routes at remote locations. To overcome the housing situation, usually at best a tent camp, McDonald had constructed a small building on a trailer. Unfortunately every time he moved this building the roofing material cracked. McDonald found an elastomeric material and coated the entire roof with it and this solved his problem. In considering the need for a thin flexible coating for pavements he remembered this experience. McDonald reasoned that a similar type of material, an elastomeric material, might solve the problem for the roadways. This led to numerous, probably hundreds, of simple experiments combining other materials with asphalts. McDonald did not have a sophisticated laboratory to conduct these experiments, and in fact the laboratory equipment and procedures to evaluate such materials had not been developed in the 1960's.

During this process McDonald found that low cost elastic material was available in the form of crumb rubber ground from old tires. One source of this was the grindings from shops where tires were retreaded for renewed use. To combine a liquid rubber to asphalt was relatively easy but the cost was too great. To combine ground solid vulcanized rubber to asphalt, one would assume that you had to provide sufficient temperature to melt the rubber. This required temperatures in excess of 500°. This was very costly and was also impractical for field application. Others had tried this approach with unsatisfactorily results since the elastic properties of the combination were not sufficiently improved. During his experiments McDonald discovered that if one cooked the rubber and asphalt together at a lower temperature, a reaction of some type occurred. The viscosity of the mixture increased in time and after a period of time reached a plateau level. Later research revealed that with this reaction the rubber particles expanded to about twice their original size and became soft and sticky. At this level the material also exhibited excellent viscous characteristics at high temperatures and developed an elastic phase. With hundreds and perhaps thousands of simple experiments McDonald evaluated how the percentage of rubber, time and temperature of cooking, and various types of rubber affected the final products properties.

By today's standards McDonald's procedures were crude. However they were practical and effective for evaluating pavement materials. He studied high temperature behavior by placing samples on the roof of his Phoenix laboratory and also on the city streets. He studied the low temperature behavior in his refrigerator and freezer. He also placed small test sections in cold climate areas in northern Arizona. He evaluated elasticity by simple and effective rebound tests. He developed procedures to evaluate viscosity. The results of the tests indicated that a threshold of a minimum rubber content of approximately 15% depending on rubber type and asphalt source was necessary to achieve a desirable viscosity and elasticity. It has since been postulated that at or near this threshold value, the reacted rubber particles form a continuous phase or matrix throughout the mixture.

An optimal percentage of rubber was probably between 20 and 25%. McDonald also settled on a reaction temperature of 350° F and a reaction time of 45 minutes minimum for an optimal and potential production procedure. This process was patented by McDonald and later defined by ASTM as Asphalt-Rubber. Later the US Patent Office in Federal Court sustained these patents. Much of this early work by McDonald was documented and the notes preserved. Many of these reports are presently in the library of the Rubber Pavements Association and can be reviewed upon request. McDonald now had a more suitable material to use as a binder with improved performance at both high and low temperatures. The question now became how to effectively apply this material on the pavement in the field. At this time equipment to spray or apply such a viscous material was not available. McDonald decided that a potentially practical method would be to manufacture or prefab small patches that could be applied manually to the cracked areas. Fatigue cracking in the wheel paths was a major problem in Phoenix and it appeared possible that small patches could correct this.

He applied the asphalt rubber to two-foot squares of wax paper, embedded a single size aggregate to provide body and experimented placing these in the field. He called this product Band-Aids and placed test sections on Phoenix City streets and on Sky Harbor Airport, and to evaluate cold weather performance, at state highway locations in Northern Arizona. We are not talking about a few locations but numerous sites, perhaps hundreds. This work occurred in 1963, 1964, and 1965. Again various combinations of rubber and asphalt mixtures were evaluated. The success of the Band-Aids in providing a thin covering for cracked pavement was evident but it soon became obvious that one must cover larger areas of pavement surfaces to solve the cracking problem. McDonald reasoned that one way the material might be applied was with a system similar to slurry process. To evaluate this he built a small slurry box, pulled it behind a truck, and hand mixed and poured hot asphalt rubber mix into the box. He followed this with single size aggregate mix spread by hand. Although the application and materials were crude, the potential for slurry type of construction seemed good. McDonald then contracted with a slurry seal contractor to place a full-scale test at Sky Harbor Airport.

The use of single size aggregate is important and its development is of interest. The state highway department and the City of Phoenix each made extensive use of asphalt and chip seal coats. The state primarily used emulsified asphalt and the city usually used hot, paving grade asphalt. Over the years mixed results had been achieved. It seemed that one was walking a very fine line between losing all the aggregate and having a bleeding pavement. As Assistant District Engineer, I was concerned with this problem and began looking at aggregate gradation improvement as a corrective option. To this end, in 1966, I placed a seal coat project using a single size aggregate on U.S. 80, west of Phoenix. Shortly thereafter, I was named the Assistant State Engineer for Quality Control. In the 1965 seal coat season the state had placed 36 seal coat projects. One year later, nineteen of these projects were considered failures. As a result the State Engineer assigned to Quality Control the responsibility to develop improved methods for the design and construction of seal coats. When it was noted that the design of seal coats had nothing to do with quality control, the answer was, "It does now." In any case I developed and tested new design, construction procedures, and specifications for seal coats and these were based on the use of single size aggregate. McDonald had followed this work and modified the City of Phoenix seal coat design and specifications to reflect these developments. In the development of asphalt rubber, the use of single size aggregates for chip seals was a basic consideration.

In the airport project the ground rubber was placed in the sand bin in the slurry truck and metered into the asphalt. Because the time for reaction between the materials was limited, the asphalt was heated to 450° F. The slurried asphalt rubber application was covered with a standard chip spreader placing a single size aggregate. The section was then compacted (the aggregate seated) with high pressure, pneumatic rollers. This operation seemed to offer possibilities for successful construction techniques that could be implemented for normal construction usage. This development might be considered the end of the first phase of the development of asphalt rubber. The state of the art at that time could be summarized as follows: 1) Rubber ground from old tires could be combined with asphalt and under certain conditions of time and temperature be reacted to form an elastomeric material that had unique properties that would be resistant to the development of reflective cracking. 2) The percentage of rubber in the mixture was critical. A minimum of 15% rubber by weight of the asphalt appeared to be a threshold with optimal material characteristics obtained at about 23% rubber. 3) The gradation of the rubber did not appear to be critical. The coarser particles - minus ten meshes - seemed to be optimal from both a material properties and cost standpoint. 4) The reaction time and the reaction temperature were important. A reaction temperature 350° F and a minimum reaction time of 45 minutes were established. 5) The material effectively retained aggregate if the binder was sufficiently fluid at a high temperature and the aggregate heated and compacted, to achieve embedment. 6) To control the cracking it seemed that an application rate of at least a half-gallon of binder per square yard was needed.

It was at this point in time that the Arizona Highway Department became more active in the development. I was the assistant district engineer for the Arizona Highway Department in the Phoenix District and was following McDonald's work with great interest.

I had known and respected McDonald since mid 1950's and had collaborated with him on numerous other developments. During the mid 1960's, McDonald and I had developed and implemented new procedures for the design and quality control of asphalt concrete mixtures for the Phoenix district of the Arizona Highway Department and the City of Phoenix. Since the Arizona Highway Department was responsible for construction and supervision of all city projects funded with federal funds, it was only normal that McDonald and I had close association. It had become readily apparent that this new elastomeric material had great promise and that further full scale experimental sections were justified. This conclusion led to an Arizona Highway Department project in 1967 on US 80 (Van Buren) between ninth and eleventh streets, in the City of Phoenix. This pavement was badly cracked and already scheduled for reconstruction so the element of risk of a failure was minimal. The slurry seal process was utilized. The rubber was placed in the sand bin of the slurry truck and the asphalt heated to plus 450° F and pumped into the truck. The slurry box was adjusted to place about 5/10 per gallon per square yard and the entire placement was chipped with single-size aggregate and rolled. This project revealed a serious weakness in this type of operation. First of all heating and then transferring asphalt at 450° F under field conditions was hazardous. It was too hazardous for routine construction operations. Second, asphalt pavements that need rehabilitation may also be rutted, especially if badly cracked. The end result was that while an average of roughly 5/10 gallons per square yard was placed on the roadway, the actual coverage varied greatly between the ruts and the high spots. The slurry type application was abandoned and efforts were directed to develop a different solution. One area of success that did come out of this project was the testing of asphalt-rubber as a potential crack sealant. Sufficient material was obtained and was placed in pavement edge joints on I-17 at Thomas Road. This application performed very well and led to subsequent research and implementation.

Throughout these early years of the development process, which began 1963, McDonald had held discussions with an asphalt supplier in the Phoenix area, Sahuaro Petroleum, a wholly owned subsidiary of Edgington Refinery of Long Beach, California. The asphalt paving construction industry in Arizona was unique in that asphalt suppliers also applied the asphalt for seal coat construction and therefore owned the distributor trucks. Sahuaro management personnel became interested in McDonald's work and agreed to try to spray this new, highly viscous, material (even at 350° F) with their standard trucks. In late 1967 test runs were made on pavements in the parking lot of the Goodyear Airport facilities, which were maintained by the City of Phoenix. The rubber was added manually to the asphalt truck through the top porthole. An air driven propeller device was used to stir the material and the truck was driven back and forth to slosh the material around and help accomplish mixing. In spite of these crude methods, they were able to spray the material by using the largest spray tips available. In 1968 the on and off ramps on Interstate 17 (Black Canyon Freeway) between McDowell and Van Buren streets were in such deteriorated condition that they could no longer be maintained and the state scheduled full reconstruction. These ramps had extensive transverse cracking and virtually total fatigue type cracking in the wheel paths. This gave the Highway Department another opportunity to evaluate the potential of this new material. The project was constructed in August 1968 and from all visual appearances was a disaster. The spray tips on the distributor trucks plugged continually and "roping" existed in virtually 100% of the roadway. As the engineer who was responsible for this I really didn't want to see Asphalt-Rubber again. It was at this time that my career changed directions. I was appointed to the post of Assistant State Engineer for quality control and moved to the headquarters office. My new responsibilities precluded further activity in Asphalt-Rubber area; however I did have to drive over those ramps on I-17 virtually every day and could observe their performance. Essentially none of the fatigue cracking reflected through the chip seal, the wide temperature cracks did reflect through but remained very narrow and did not spall. The surface still looked lousy with all the roping readily apparent. I might note that it still looked lousy twenty years later when these ramps were finally rebuilt in conjunction with freeway realignment and widening construction. McDonald continued on with the program of improving application methods for Asphalt-Rubber. One significant step forward occurred when he discovered that he could temporarily reduce the viscosity of the binder by adding high boiling point after the mixture was reacted. After approximately one hour, the kerosene would have evaporated or have been absorbed into the rubber particles and the viscosity returned to that of the standard material. There were apparently no significant residual affects on the material properties of elasticity, aging, and viscosity. Also during this period many improvements were made in the equipment. Higher capacity pumps were utilized, and larger spray tips with a full circulating bar plus screens served to eliminate plugging of the tips. Later, high-speed, horizontal screws provided greatly improved blending and mixing capabilities. A very significant project was constructed in Tolleson, Arizona, near Phoenix in 1969. This pavement was essentially failed from fatigue and thermal cracking. Subsequently potholes developed and the cracks had significant spalling. McDonald used a regular slurry seal to fill the wide cracks and placed an Asphalt-Rubber chip seal coat. To control the aggregate loss and provide a smoother surface, a slurry seal was also placed on the surface. This type of design is known as a Cape Seal and later on was widely used for rehabilitation of city streets where improved surface texture is needed. Inspecting this project at a later date, a surface condition existed that led to a considerable insight into the behavior of the asphalt-rubber materials. Virtually no cracks reflected through the seal coat, but above every crack could be observed what appeared to be stretch marks in the smooth slurry seal surface. These stretch marks were evident over a width of approximately 4". This clearly indicated that the underlying pavement movement and the stress concentration at the crack tip were being relieved. It is thought that this was achieved by either the elastic properties or the post elastic yield behavior of the Asphalt-Rubber. This later led to the definition of these thin elastic layers as stress absorbing membranes or SAM. To be theoretically correct the definition should have been a "strain attenuating membrane". Professors please note this correction.

In 1970 I was asked by the State Engineer and the Director to form a research division for the Highway Department and was named the first research engineer. I had been closely following McDonald's work and in the ensuing years asphalt-rubber became an area of emphasis in the Arizona DOT research programs. In 1971 the materials division of the Arizona Highway Department designed an experimental project to evaluate methods of controlling reflective cracking, under the National Cooperative Highway Research Program. This project contained eighteen test sections with various treatments such as fabrics, heater scarification and reclamite, Petroset, various grades of asphalt, etc. At the request of the Research Division an asphalt-rubber seal coat was included in the project. Also, for the first time, an asphalt-rubber seal coat followed by a thin, one half inch, open-graded, asphalt concrete surface course was also included. This was the first stress absorbing membrane interlayer or SAMI. The reasoning behind this second design procedure was that on high-speed traffic roadways, when a pavement has cracked to the point requiring rehabilitation it also needs improvement in ride. Further by placing the asphalt-rubber system as an interlayer, problems associated with construction traffic control were greatly reduced. This project was closely monitored and several formal reports have been issued including presentations at the Highway Research Board (now the Transportation Research Board, TRB). The results from this project were substantial and important. The two Asphalt-Rubber systems by far outperformed the other 16 sections. The seal coat was very effective in controlling reflection of fatigue type cracking but ineffective in controlling reflection of transverse or thermal cracks. However the cracks that did reflect through were narrow and did not spall. The interlayer or SAMI was effective at controlling the reflection of all types of cracks. Of perhaps even greater importance was that aging rate of Asphalt-Rubber was significantly reduced when compared to the untreated asphalts. Micro viscosity measurements indicated aging rates less than 1/15 that of standard materials.

Other projects to evaluate Asphalt-Rubber in the highway system continued. In June 1972 six (6) miles of US 60-70 east of Aguila had severe fatigue cracking. At this time the route was carrying all of the traffic that later would be diverted to Interstate 10. An experimental asphalt-rubber chip seal was scheduled on this project and also evaluated lightweight aggregate to eliminate potential windshield breakage. Gary Cooper was the Resident Engineer on this project and thus began a long relationship with asphalt-rubber. Sixteen years later, Cooper, as the State Materials Engineer would specify the first use of thin, open-graded, asphalt-rubber overlay of portland cement concrete pavement on I-19 near Tucson. Later he would assume the duties of Executive Director of the Asphalt Rubber Pavements Group.

This project was of interest from other standpoints. It clearly revealed the level of resistance that existed to any new innovations. In this case McDonald and I inspected the project in February, 1973. A light rain had occurred and any cracking was readily visible. This inspection revealed that virtually zero cracks had reflected through although the underlying crack pattern could be observed. On the basis of this inspection I wrote a favorable report to the State Engineer and requested further experimental projects. The next day I was summoned to his office. It seems the District Engineer had verbally reported that the project was a failure and that all of the cracks had come through. The end result of this confrontation was that the State Engineer had the District Engineer and myself out to inspect the project. The request for additional projects was approved. This incident is reported only to demonstrate a typical reaction by governmental employees to change. Both McDonald and myself had to constantly battle to keep Asphalt-Rubber moving forward. On two occasions the Arizona DOT Materials Division called for moratoriums on Asphalt-Rubber based on felonious conclusions. Although this seal coat was very effective in controlling reflective cracking, it did not correct pavement roughness and in 1977 a ½" open graded friction course was placed. Thus the Asphalt-Rubber sealant became a SAMI. This pavement, after 30 years, is still in service to date with minimal maintenance costs.

In 1973 the first project in a severe cold weather area was placed. This project was at 7,200 feet elevation near Flagstaff on U.S. 89 where one could expect temperatures as low as -30° F and an average 100 inches of snow annually. This pavement had received several thin overlays all of which cracked through at an early age. Numerous potholes were developing and created hazardous driving conditions, In this case the District Engineer at Flagstaff advised the State Engineer that he would be unable to hold this pavement through the winter, Funds were unavailable for reconstruction and research was asked to provide a solution, An asphalt-rubber seal coat had never been place in such cold climatic conditions and little was known about its cold weather properties. However, McDonald had placed some of his "band-aids" in areas of extreme climatic conditions and a review of some of these experiments indicated that a reasonably good performance could be expected. On the basis of these tiny test sections an asphalt-rubber seal coat was proposed to solve the problem at Flagstaff. The asphalt-rubber seal coat saved this pavement for twelve years when widening and major geometric improvements were constructed.

In 1974 one other type of application of this product was evaluated in a major project. In Arizona there are large deposits of highly expansive, montmorillonite clays that play havoc with pavement smoothness. The basic problem is that moisture from the pavement section enters the subgrade causing extensive and non-uniform expansion of the clay materials. These clays have expansive pressures as high as 15,000 pounds per square foot and

pavement displacements of six inches to a foot were not unusual. U.S. 89 from Cameron north and Interstate 40 from Holbrook east to the New Mexico state line are two areas of deep deposits of expansive clays. In the case of U.S. 89, within two years after construction, the speed limits had to be reduced to 35 mph because of the roughness developed as a result of swelling of the expansive clay. The Director of ADOT and the State Engineer had ordered that the highest priority of the new Research Division was to find a solution to this problem. In fact the Director promised that if I could solve this problem he would have a statue of me erected in front of the Capitol. The Colorado Materials Engineer, Brakey, had determined that for new construction one could minimize or even eliminate this problem by placing a waterproof membrane directly on the subgrade, i.e., between the subgrade and the granular base. However our problem was not new construction but what could you do with pavements already built and were cracked and distorted. Interesting enough is that the granular base courses would manufacture water from moist air moving through the base materials in a process called hydro-geneses. Previously laboratory research sponsored at the Univ. of Arizona by the Research Division had shown that Asphalt-Rubber was effective as a membrane, and a test section was proposed to encapsulate the roadway section with asphalt-rubber. The problem as previously noted was moisture content in clays varying with the climatic conditions and the development of moisture by hydro-genesis in the open-graded base course materials. It was not known whether an encapsulating membrane could solve this problem particularly in roadways with drainage culverts that were backfilled with large sections of granular material. The research plan was to monitor moisture changes in the subgrade in both control and encapsulated sections. The experimental section was designed to be ½ mile long and was proposed as part of a contract to overlay 12 miles of I-40. The State Engineer knew that if no further treatment were used, the roadway would again be unacceptably rough within a year or two. He therefore ordered that this test section be extended to the entire 12-mile project. As an after thought he extended the treatment to an additional 6 miles long adjacent project. The entire project was monitored for ride and reflective cracking and the moisture changes were monitored in the clay subgrade in treated and the untreated control sections. Essentially the membrane performed as designed and the problems associated with building pavements over expansive clay were alleviated. Reports have been presented at numerous conferences including the Transportation Research Board.
I am still waiting for the statue.

This period from 1968 to 1975 might well be termed the asphalt-rubber seal coat development period although it should be noted that crack sealing materials and equipment were developed by ADOT research in this same period. Greatly improved equipment and application procedures were developed by the industry and the Arizona Highway Department sponsored substantial research beginning in 1972 to quantify the properties of asphalt-rubber and to relate these properties to the pavement design and performance. In 1974 the ADOT Research Section issued a recommendation that all pavements with ten percent or more cracking receive an asphalt-rubber treatment when rehabilitated. This included both seal coats (SAM) and interlayers (SAMI). These recommendations were approved for implementation by the State Engineer and asphalt-rubber was off and running.

Also during this period we looked at different pavement sections designed to improve rideability as well as to control reflective cracking. In 1973, the state had scheduled a rehabilitation project to place a one-half inch, open-graded, surface course over that portion of Country Club Road (State Route 77) extending from Baseline Road south. The Research Division proposed that the performance of these high-friction courses could be improved by under-asphalting the initial hot mix and then spray applying, or flushing in, an application of asphalt-rubber. While ADOT had built seal coat test sections and McDonald had found methods to improve that type of application, this was the first field research directed at improving ride levels as well as providing reflective crack control in thin overlays. Unfortunately the project was a disaster. Sahuaro Petroleum was experiencing labor difficulties and the distributor truck drivers and the 'boot' men had gone on strike. When the new crews tried to spray the asphalt-rubber, the spray tips repeatedly plugged and a uniform application could not be obtained. Later it was determined that the screens in the spray bars to control plugging had been removed. In any case the experimental section of the project could not be completed. The young sales manager, Bill Brake, came over and told me that they would not charge ADOT for that material. I told Brake to go ahead and submit a bill for the materials but that he now owed me one truck load of asphalt-rubber. The difficult part of this scheme was now to find another project that was placing a thin overlay on a cracked pavement. Getting together with McDonald we managed to come up with an ideal project. The City of Phoenix had its own asphalt paver and crew for small repair projects. They also had numerous areas that needed rehabilitation. Some of these were old Portland cement concrete pavements. The state had lots of miles of PCCP freeways but it would be much better to test any new systems in areas where traffic was not so heavy. McDonald and I agreed that if I could furnish the open-graded mix and the asphalt-rubber, the City would provide the construction equipment and labor. Essentially I "borrowed" some open-graded friction course from a nearby project on Grand Avenue (US 60-70) and with the asphalt-rubber from the Country Club project, McDonald and I developed an experimental project on Madison Avenue between fourth and sixth streets in the downtown Phoenix area. This section of Phoenix was in the industrial area and while the daytime traffic was very heavy, the volume of traffic at night was very light. This particular area was known as "the Deuce" and at night was an area highly populated by "winos". This provided us with lots of observers, inspectors, and hecklers. McDonald and I were right at home in this atmosphere. Basically the pavement section consisted of an open-graded, under-asphalted, leveling course followed by a spray application of Asphalt-Rubber. The leveling course was designed with an extremely high void content, (even for an open-graded mixture) and used only sufficient asphalt to achieve placement. The existing pavement was a 50-year-old PCCP, badly cracked, and the slabs had moved over the years so the joint openings were as much as one inch. The width of the pavement covered was 30 feet. The test sections were each ten-foot wide with the A-R application rates of.3 gallons per square yard, .4 gallons per square yard, and .5 gallons per square yard respectively. After the asphalt-rubber had penetrated the open-mixture, the surface was sanded to prevent pick-up. Exact quantities are not now available, but the .5 gallons per square yard application would be equivalent to about a 10% binder content had this been a plant mix. The theory behind this design was that the thin open graded mix would serve to improve ride characteristics and the asphalt-rubber would penetrate the mixture and provide the elastic material to control reflective cracking.

Performance of the section was as follows. In the .30 GSY application virtually all the cracks and joints reflected through within the first year. The reflective cracks remained narrow, about 1/16" wide and did not spall. In the.4 GSY application approximately 1/3 of the cracks reflected through with no spalling. In the .5 GSY applications, reflective cracking was virtually eliminated and occurred only at the extremely wide transverse joints. This pavement served for over 15 years when it was reconstructed in connection with new geometric conditions. Also on this project some of the joints and cracks on adjacent areas of pavement were cleaned and asphalt-rubber placed as crack-joint filler.

Between 1973 and 1975 ADOT continued investigation into methods to improve ride while controlling reflective cracking. During this same time frame we also began looking at including the un-reacted rubber in hot mix asphalt concrete. We primarily used open and gap graded mixes in order to provide room for the rubber. These mixes were designed to equivalent rubber-to-asphalt ratios that had proven successful with the spray applied systems. Full-scale projects that were constructed included a section of U.S. 87 in Chandler and also U.S. 60, Grand Avenue, in Phoenix. In both cases adding the rubber without reaction provided little improvement with respect to reflective cracking.

To continue this effort, in 1974 - 1975 we constructed a series of test sections, each ½ mile long and two lanes wide on a divided section SR 79, north of Mesa, Arizona. The northbound lanes of SR 79 were about 20 years old and for most of this life had carried two-way traffic. The pavement was badly oxidized and had extensive cracking, both chicken wire (fatigue) and transverse (thermal) types. One of the primary reasons for building these test sections was to evaluate construction procedures for the 3-layer system proposed for a project on the I-40. In 1972 a four (4) mile section of I-40 directly west of Flagstaff was in extremely poor condition. This pavement was a 9" un-reinforced, un-doweled, two (2) lanes, divided, PCCP constructed in 1969. The shoulders were asphalt concrete with wide thermal cracks spaced from 30ft. to 45ft. apart. Original design procedures did not consider potential frost heave nor thaw weakening of the cement treated base and by 1972 every slab in the heavy traffic lane had structural failures. Essentially the pavement was setting on a series of points with void spaces ranging up to one and one-half inches in depth. The pavement also exhibited faulting and pumping. Because the pavement was so new, reconstruction was nm an option (from a political standpoint). We looked at several different treatments that had the potential to rehabilitate this pavement without total reconstruction. The rehabilitation solution selected consisted of re-establishing subgrade support by injecting a lime - fly ash - sand mixture into the voids, sealing all joints and cracks with asphalt-rubber, placing a ½" open-graded, leveling course followed by an asphalt-rubber interlayer and a ½" open-graded surface course. This was the first three-layer system and was also the first full scale project where the cracks were sealed with asphalt-rubber. This treatment held the pavement in check for 11 years when the entire section was reconstructed. Before we could advertise the project for bids, we had to know whether the system could be built with each layer immediately following the other or whether curing time was necessary. We therefore set up an experimental project on SR 79 to evaluate this method of construction. Now back to State Route 79. Since we had a project available for we also took this opportunity to include several other test sections. The highway department was very interested in incorporating this new material into hot mixes so several test sections were included to evaluate various methods of design and materials. Two sections had mixtures where the rubber was added dry to the pugmill. One section was one mile long and one half of this section was flushed with reclamite, an asphalt-rejuvenating agent with a high content of aromatic type oils. Another dry mix section was constructed with long shard rubber particles. These particles were from 1 to 2 inches long. The purpose of this section was to evaluate whether such materials would perform as elastic fiber reinforcement. Two other sections used open-graded mixtures with the reacted Asphalt-Rubber added at the pugmill to the aggregate mixture. The first section was the standard McDonald blend of #10 mesh rubber blended at a rate of 23% and reacted at 350° for 1 hour. The second section utilized a product developed by Arizona Refining. It was essentially an Asphalt-Rubber but varied from the McDonald (Sahuaro) process by using reclaim rubber, a small percentage of natural rubber and extender oils. Gradation of these rubbers was substantially finer in gradation. Total rubber content was approximately 20%.

From the very onset of Asphalt-Rubber it was very clear that competition to Sahuaro Petroleum would have to be developed. Management at Sahuaro was urged to franchise at least one of the other two asphalt suppliers in Arizona - Chevron and Arizona Refining (a subsidiary of Unocal). Chevron was not interested and Sahuaro decided against granting any franchises. Arizona Refining developed a product that was essentially elastomeric but was not thought to be in violation of the patents. Later this product was accepted as an equal to the McDonald process (Although at the time I felt the product needed more testing (Arizona Refining had used 11 different blends of materials in test sections) the State Engineer ordered that it be accepted. I am quite positive that had this not occurred, Asphalt-Rubber would have been discontinued in Arizona. States simply cannot afford to use noncompetitive materials and Arizona Refining had sufficient political clout to have the use of a patented material stopped.

This project on SR 79 was the first state use of Arizona Refinings product except for small seal coat test sections. Both of the above hot mixes were open-graded and were designed with a binder content of 10% of the total weight of the mixture. The performance results of this project were astounding. The long shard mixture was a failure and had to be replaced in about 6 months. Of the two mixtures where the rubber was added dry to the pugmill, they performed slightly better than the standard open-grade mix with respect to cracking. This improvement in performance was probably associated with increased resistance to aging. The section that was flushed with reclamite performed better than the unflushed section. The two sections where the reacted Asphalt-Rubber was included in the hot mix performed beyond all expectations. Fifteen years later, when this section of roadway was rebuilt for geometric reasons, these two sections were still essentially crack free. The three-layer system also performed excellently and we learned that, yes, we could construct the section on a continuous basis. After this project further efforts to add the rubber dry to the mix were abandoned. We had now built four full-scale test sections of dry mix applications and the slight increase in performance did not justify their use. On the other hand, the open-graded, hot asphalt concrete mixes with the asphalt-rubber binder showed great promise and we now begin the work to determine testing and design procedures to optimize the material characteristics of both the asphalt-rubber blend and the aggregate gradation.

During the 1970's over 30 formal research projects were initiated in an effort to understand and quantify this new material. One basic problem was that virtually all tests for asphalt and asphalt concrete were empirical in nature and could not be used to evaluate other materials. Even such basic tests such as penetration and viscosity could not be routinely used to provide valuable information. One of the first goals we had was to determine the basic nature of the reaction that was obviously occurring and if could be controlled. We knew little about the properties of asphalt-rubber but we knew even less about how these properties affected behavior in seal coats, interlayers, and mixes. For example, we could measure the elastic rebound accurately with the Shell sliding plate rheometer but we had no way of tying this to the control of reflective cracking. Such simple questions as "What grade of asphalt should we use?" could not rationally be answered. The research program of ADOT consisting of over thirty projects performed by the State Materials Division and numerous researchers at the universities and in private laboratories provided a lot of the answers but even today a great many questions are still unanswered. The field research projects, and they were numerous, did provide many of the answers needed for quality construction methods in the field so that implementation could proceed, both Arizona and Sahuaro Petroleum also conducted research, both in house and by contract and this was generally made available to the industry. International Surfacing and Crafco continued this effort in the decade of the eighties, mostly independently but on occasion in association with the industry organization. It should be noted that with the exception of Fernly Smith, Genstar, the rubber grinding industry has contributed virtually nothing to the research needs of the industry.

By 1976 all of the primary uses of Asphalt-Rubber had been developed, except the gap-graded mix and that will be discussed later. One use that has not been addressed sufficiently is that of sealing cracks in flexible pavements. It was obvious early on that the highly elastic and more temperature stable material provided potential for use as a crack sealant. The state of the art for sealing cracks in asphalt concrete pavements at this time was non-existent. There were no suitable materials available that were not exorbitant in cost and equipment for blending, reacting, and placing crack sealant was nonexistent. As noted previously, the first effort at crack sealing was made in 1967 at the time of the slurry seal project on Van Buren (U.S. 80). I asked the District I Maintenance Supervisor to select a suitable location, obtain a 5-gallon sample of the material and try it out. He chose I-17 at the northbound Thomas Rd. ramp as a severe test area. Subsequently in 1973, in conjunction with the Madison Avenue project, we also placed a few test sections. During this period McDonald had also been experimenting with crack sealing. In 1973, ADOT purchased a Bartseal unit and began field-testing Asphalt-Rubber as a crack sealant in both cold climatic areas (Flagstaff) and hot desert conditions (Casa Grande). The Bartseal unit was not designed for blending nor reaction of materials so we had to use a small distributor track in conjunction with the application. These test sections showed that Asphalt-Rubber was ideal for crack sealing and offered a low cost material that made sealing of the cracks potentially an economical procedure providing new equipment and pre-packaging of the reacted asphalt-rubber were developed. In conjunction with an equipment specialist, we prepared specifications for a unit specifically designed for routine crack sealing of asphalt concrete pavements with asphalt-rubber. H. G. (Moose) Lansdon was the engineer in the research division who worked on the development and testing for this process. Ken Hill was the equipment specialist for Sahuaro Petroleum and was also the individual primarily responsible for the development of the improved distributor trucks that could spay-apply asphalt-rubber. Sahuaro was the low bidder and was awarded a contract to build this crack sealer for the state. Subsequently, Edgington Refinery, the parent company of Sahuaro Petroleum, did not care to be in the equipment manufacturing nor crack sealing business and later a new company "Crafco" was formed to manufacture equipment and develop methods for producing asphalt-rubber crack sealants on a routine basis. This company was formed by Sahuaro employees, Fred McWeeny, Bill Brake, and Ken Hill along with Carl Jacobson and E.J. Johnson, owners of J.W.J. Construction. When crack sealing equipment and materials were first developed, I envisioned that this would be a small industry primarily serving as winter fill-in work for the manufacturers. Today virtually every city, county, state, and nation have major crack sealing programs as part of their routine maintenance. So much for my visionary capabilities.

Thus far this narrative sounds as if everything during this development was peaches and cream. Nothing could be further from the truth. First of all we knew very little about the properties of this material, how the individual components affected the final product, and more important we did not have the established laboratory procedures or the equipment to properly evaluate the process. Virtually all test procedures for asphalt and asphalt concrete were empirical and were not applicable to different materials. For this reason one of the first formal research project initiated by ADOT was a study of the reaction process by Green & Tolenon. Bob Dunning, Asphalt Chemist, was retained to advise this project and he made significant contributions. The report from this research is still in demand. All of the early testing and evaluation used asphalt from the Edgington refinery in Long Beach, California.

Asphalts from this source were highly aromatic. When the implementation program expanded, other asphalts were used and sometimes the results were disastrous. Early on a major failure occurred on a project in Douglas, Az. when Sahuaro used asphalt from a refinery in Texas. The end result was a very irate District Engineer and we learned the hard way that the asphalt-rubber blends had to be individually designed for different asphalts or any change in rubber characteristics. Also the construction procedures necessary to obtain quality projects turned out to be substantially different than for standard materials. For example, the normal application of asphalt for a chip seal was usually .30 GSY of emulsion. For an asphalt-rubber seal coat to control cracking, an application rate of at least .50 G/SY, and sometimes more, was required. Initially engineers (and contractors) were reluctant to apply this increased quantity of material and the specified rates were reduced and the asphalt-rubber did not perform as expected. Asphalt-Rubber is also a very viscous material and must be applied at a high temperature to achieve uniform application. Unless the aggregate is placed and compacted while the binder is sufficiently fluid, bonding of the aggregate may be insufficient and aggregate loss occurs. Many times this loss of aggregate does not occur until the first cold weather. One such occurrence was on Highway 95 north of Lake Havasu City. We finally realized that it was wise to use hot, pre-coated aggregates for asphalt-rubber seal coats. You might get by without it sometimes, but sooner or later you were going to have problems.

A re-cap of the various development phases of asphalt-rubber would be:

1963-1967 McDonald developed the basic asphalt-rubber and established the material's primary parameters.

1967-1972 McDonald and Sahuaro Petroleum developed the equipment and the procedures to successfully apply asphalt-rubber with spray equipment.

1972 - ADOT initiated use of asphalt-rubber as a low modulus, strain attenuating, interlayer for overlays.

1973 - ADOT utilized asphalt-rubber seal coats in extreme cold climate conditions.

1973-1975 ADOT built field test sections to evaluate potential of providing improved ride as well as resistance to cracking by flushing open-graded mixtures with asphalt-rubber.

1973-1975 -ADOT constructed field test sections to evaluate effects of adding dry rubber particles to asphalt concrete mixes. Results clearly indicated that little improvement in performance resulted.

1975 - ADOT constructed field tests with asphalt-rubber utilized as the binder in asphalt concrete. Results were astounding.

1975 - ADOT specified first use of asphalt-rubber as a crack sealant in a full scale project.

1975 - ADOT designed crack sealing application equipment and advertised for bids. Prepackaging of reacted asphalt-rubber materials was developed. Sahuaro Petroleum submitted the low bid for manufacturing the equipment.

Thus by 1975, the basic uses of asphalt-rubber had been developed, with the exception of suitable dense graded asphalt concrete mixtures. Between 1975 and 1980 both Sahuaro and Arizona Refining were extremely busy. Arizona Refining had established franchises in California, Texas Rhode Island, and the State of Washington. During this period Arizona Refining and its associates alone built 170 seal coat projects in 26 states. In addition projects had been built in Canada, South Africa, Australia, France, and Belgium.

In the middle of the 1980's two groups working independently developed the gap-graded dense mixtures. The materials division at ADOT under the leadership of Gary Cooper had to develop a plan to reconstruct the four miles of pavement on I-40 west of Flagstaff. To accomplish this with least interference to traffic it was necessary to construct a four-mile long detour which would be subject to extremely heavy traffic for at least two years. Because they were concerned with the potential performance of the open graded mixtures in these climatic conditions they experimented with dense gradations of aggregate in which the gradations were widely gapped to provide room for the rubber particles. At the same time, Joe Cano, now the City of Phoenix Materials Engineer, was faced with strong public reaction to the use of any type of seal coats on the city streets. Much of this opposition was fueled by the slurry seal industry which was trying to replace seal coats of all types with their product. In any case, Cano conducted extensive field tests on various asphalt-rubber and aggregate combinations to develop a dense graded hot mix for city streets. These efforts of ADOT and the City of Phoenix resulted in virtually the same design parameters and have proved to be highly effective. When the City Council, under political pressure, banned all seal coats, Cano immediately implemented the use of gap-graded hot mixes. The aggregate gradation in these mixes is essentially the same as in the stone mastic mixes developed in Europe. The basic difference is that the stone mastic pavements use asphalt with an inert material as a filler while the asphalt-rubber mixes use the highly elastic asphalt-rubber material. Side by side field tests of stone mastic and asphalt-rubber on interstate highways in both hot and cold climatic conditions have clearly demonstrated that the asphalt-rubber mixture is significantly superior to stone mastic materials.

At this point I think it is necessary to discuss other issues and developments that greatly affected the implementation process of asphalt-rubber. To understand these items one must first examine the basic relationships of the highway departments, the federal government, the contractors, and the materials suppliers. As the highway system grew and the use of the automobile (and trucks) skyrocketed, it became obvious that some type of federal control and funding was needed. A tax on gasoline was the obvious method of providing funding but meant that the densely populated states could be properly funded while the sparsely settled western states would not have sufficient funds to build the routes that were needed to develop a national highway system. Thus the federal government imposed a basic gasoline tax and the Bureau of Public Roads (later the Federal Highway Administration) was created (in 1916) to manage these monies. The states resented the federal government taking their tax money and then telling them how to spend it. From the very beginning, and particularly after the laws establishing the Interstate Highway System went into effect in 1952, the states bitterly resisted any edicts from the federal government regarding design, materials, construction, etc. The basic attitude was that "What does some jerk from Washington, DC, who's probably a political appointee, know about building roadways in my backyard?" Many times the federal government would issue mandates bur would not provide the funds necessary for the states to comply. Further, although the bulk of funding for highway construction came from the federal level, the funding for the state and local government highway departments and roadway maintenance came from local taxes. This meant the state and local highway officials were subject to local political pressures. Essentially every highway department had better keep the interests of the local contractors and material suppliers in mind or their jobs would be in jeopardy. In many cases even a change in political administration resulted in extensive revamping of personnel. Thus we have the situation where the highway personnel were highly resistant to federal edicts – good or bad - and were very susceptible to political pressure from the local construction community.

Now let’s examine the interest of the contractor. First he doesn't care what materials a project is built of as long as he has the equipment and where-with-all to do the job. To obtain a construction project he must be the low bidder and he has to make a certain minimum profit to stay in business. His main concerns are that he must maintain current in construction equipment and techniques and he doesn't look kindly on any stranger from out of state (county or city) coming in and taking over part of his work or any portion of the highway funding dollar. The material suppliers (for pavements primarily producers of aggregate) have similar but different interests. Their primary concern is the volume of material they sell and how much does it cost to produce it. Basically they have zero interest in any system that might cut into their volume of material and they could care less about extending the life of a pavement. In many cases the material supplier and the contractor are the same organization and simply put, they do not welcome outside competitions (who do not have extensive local property taxes) and they would like to see the roadways use the largest amount of material possible and yet have relatively short service lives. Of course both groups will deny such thinking but it is a fact.

Because of the political clout of these local contractors and material suppliers, one of the primary incentives to the highway engineer is to keep these groups happy. Therefore the highway engineer himself has no real incentive to develop new techniques that might result in substantial improvements in performance - unless it is something that the local construction community is interested in. If some new procedure fails, the engineer may be blamed for the failure. Because of this the highway engineer is highly resistant to the change.

To counter this resistance the change, the FHWA established a program to encourage the highway engineer (and contractors) to try out new concepts. This program is called the Demonstration Projects Program and the group is constantly on the lookout for new methods and products that could prove advantageous. For example they spearheaded the implementation of recycling pavements and helped introduce the dryer-drum asphalt-concrete plant. Basically they provide special funding and technical assistance to the highway departments and the contractors to try out new concepts. Charlie McDonald had worked for over thirty years with the BPR & FHWA and of course had lots of friends and acquaintances in the agency. One of these friends was R.E. Olsen who just happened to be in the Demonstration Projects Division. McDonald convinced Olsen that asphalt-rubber was a suitable subject for a demonstration project and in 1973 such a project was implemented. Basically this project provided funds and technical support to any state that wished to build an experimental seal coat project with asphalt-rubber binder. The Arizona DOT assisted this project with the technical support by loaning H.G. Lansdon to FHWA for several months and Sahuaro Petroleum and Arizona Refining jumped at the opportunity to expand to other states. Although this development appeared to be a great thing at the time, it led to decisions that did not consider the basic relationships of the DOT's, the contractors, and the material suppliers. Thus the entire industry was led down a route that in the long run was a primrose path.

Another occurrence during this "seal coat" period was the astounding, world interest III these concepts to utilize old tires and yet provide cost effective improvements in pavements. As the knowledge of asphalt-rubber design and construction developed, McDonald, myself, and others, prepared reports for presentation at various meetings such as the Highway Research Board, American Association of State Highway and Transportation Officials, and elsewhere. The response to these reports was enormous and in a short time we were inundated with visitors - not only from the state highway departments, but also from countries worldwide. The potential visitors would usually contact me and I in return would involve McDonald, Sahuaro, Arizona Refining and Atlos Rubber (who in the early days supplied the ground rubber and who subsequently was involved in the ownership of the patents). As a result of these meetings asphalt-rubber was implemented in Europe, South Africa, and Australia. In the middle and late 1970's the impact of these visitors occupied probably 1/4 to 1/3 of my time, particularly in the winter months when construction was slow in the northern and eastern states.

To meet the demands of the Demonstration Program requests, Sahuaro had to greatly expend its equipment fleet. This and the obvious State and worldwide interest led Sahuaro to make an ill-advised decision. They basically had two choices. (1) To franchise contractors in the other states and provide technical support and marketing or (2) To develop the equipment, construction personnel, and marketing staff to service the entire United States (and the world). They chose the latter and this decision has haunted the industry ever since. This decision at least to some degree had to be guided by their experiences in Arizona where the asphalt producers also provided the distributor trucks to construct the seal coats. But this situation was unique to Arizona and in virtually all the other states the contractors owned the asphalt distribution trucks. This decision meant that you were taking business away from the local contractor and as noted earlier this is something that they cannot tolerate. Even the material suppliers were not happy with asphalt-rubber. An asphalt-rubber seal coat should be designed with a large (1/2") single size chip, which should preferably be pre-coated and applied hot. It is also important that the optimum quantity of aggregate (chips) not be exceeded. The material supplier did not like several aspects of this system. First to provide a single size chip he had to screen out the sand and finer particles for which he might not have a market. Second, many aggregate producers did not have the facilities to heat or precoat aggregate.

So now, the two elements that can and do exert heavy political pressure on the agencies are not very happy with what's going on. Another basic problem that also slowed implementation was that asphalt-rubber was patented. The states have problems utilizing patented materials in general and when there is no competition, it becomes virtually impossible. The entrance of Arizona Refining solved this problem in Arizona, Texas, and California where local, franchised, companies were established. The other states however also needed local interests and this did not occur.

This history would not be complete without discussing the role of the tire reclaiming plants that supplied the ground rubber. Atlas Rubber, located in Los Angeles, was involved with McDonald at a very early date and helped finance some of the early development. Subsequently, Bob Winters, President of Atlos, had ownership in the patents and also played a major role in the various associations that were formed to represent the industry.

When Arizona Refining began exploring the possibility of developing a competitive product, they worked very closely with U S. Rubber reclaiming whose plant was located in Vicksburg, Mississippi. Bobby Lagrone with that company had previously done considerable work attempting to combine reclaimed rubber with asphalt and although they had never arrived at the method to optimize the process, they did have depth knowledge of rubber and rubber products.

During the latter half of the 1970's a major Canadian corporation explored the potential future for asphalt-rubber and decided to establish itself strongly in ground rubber supply end of the industry. Genstar, a group with strong interests in the financial world, owned some nineteen cement mills, ready mix concrete producers, and concrete block manufacturing facilities. They developed a plan to become a major supplier of ground rubber. This plan included purchasing of U.S. Rubber Reclaiming, obtaining a facility in Chicago, and building ten additional plants strategically located through out the United States. The first of the plants was built in Chandler, Arizona in 1978. There plan indicated that this plant was to provide a needed research facility for the industry. Fernly Smith, who had previously operated a rubber reclaiming facility in Ohio, was named to direct this effort. Smith in turn employed Ken Wardlaw, a civil engineer and former field engineer for the Asphalt Institute, to assist with the marketing promotion for the industry. Wardlaw's experience with the Asphalt Institute had provided him with a solid knowledge of the state highway departments and how to market products to them. Smith and Wardlaw organized the first industry association and established a technical advisory board with nationally recognized experts in pavement design and construction among its members. This group also sponsored the first national conference on asphalt-rubber and it was held in Scottsdale, Arizona in 1980. In 1983, the controlling management of Genstar changed and the decision was made to divest the company of all interests except those directly connected to the financial world. To this end all of the facilities associated with reclaiming rubber were sold. I believe that the asphalt-rubber industry lost a strong force for the marketing of their products.

One other company that made significant contributions to the industry was Baker Rubber. Tim Baker took up where Fernly Smith left off, revitalized the Asphalt Rubber Producers Group and reestablished the technical advisory committee. In the early 1990's, Baker built a new and updated rubber grinding facility east of Phoenix. This facility today is utilizing approximately 90 percent of the waste tires in Arizona.

The 1980's bought numerous changes to the asphalt-rubber industry. The embargo by OPEC and the inflationary trend of the latter years of the previous decade had put the highway departments through-out the country in financial chaos. Many states virtually eliminated their new construction programs and were just barely able to maintain their highway systems. To compound these financial problems the industry seriously erred when they ignored the basic relation of the states to the federal government and embarked on a marketing program based on political action. This program was directed towards the goal of convincing the Environmental Protection Agency to promote a regulation to require the states to use a minimum quantity of waste rubber in their highway construction. The Federal Highways Administration deeply resented this intrusion into their affairs by an outside agency and immediately took action. They sent a letter to each state informing them of what was happening and asked that they report on their experience with asphalt-rubber in the Demonstration Projects Program. All fifty states responded to this request and all fifty states, including Arizona, replied that asphalt rubber did not offer any benefits and was just a costly and worthless additive to asphalt. The implementation and use of asphalt-rubber was set back several years.

During these lean years several other significant changes occurred in the industry. The Edgington Refinery had previously been sold to the Penn Companies because of the health of the owner, Ralph Edgington. In a few short years the Penn Companies found that the rehabilitation of their aging refinery was too costly and in 1983 declared bankruptcy. Their subsidiary, Sahuaro, was a profitable enterprise but they were also forced to close their doors. Arizona Refining was a wholly owned subsidiary of Uno cal, and was the only portion of the corporation that dealt with asphalt supply. Don Nielsen had served as President of Arizona Refining for many years bur decided to retire in 1982. Within a short time Unocal decided to divest themselves of Arizona Refilling. Jacobson and Johnson, who were now sole owners of Crafco, purchased all of the asphalt-rubber equipment from these two companies and in May, 1983 established International Surfacing, Inc. The use of the patents outstanding on asphalt -rubber were also acquired at this time and many of the experienced employees were hired by I.S.I.

Among those employees were Bob Smith and Paul Oliver who served I.S.I. as C.E.O. and General Superintendent, respectively. Both Bob and Paul were dedicated to quality and improving asphalt-rubber so that a consistent and high quality of material was placed. To this end major improvements in equipment were accomplished and quality control in the field was emphasized. They also used the laboratories at Crafco to prepare the asphalt-rubber blends for all projects. The Crafco laboratory also conducted extensive research and evaluation of the material characteristics of asphalt-rubber and helped prepare suggested specifications.

Beginning in the early 1980's the use of asphalt-rubber as the binder in hot mixes was implemented. Early projects included the steep highway grade from Mule Pass tunnel near Bisbee and State Route 95 north of Kingman. As the excellent performance of the open-graded hot mixes became readily apparent, its use was extended to numerous airports, both in California and Arizona. In 1988 the first open-graded overlay of portland cement concrete pavement was placed on 1-19 just south of Tucson. This overlay was only one inch thick and numerous critics said it could not possibly last. Previously, in1979, a three-layer system had been placed on the I-17 freeway in Phoenix to evaluate heavy traffic, hot weather, performance. This project and the cold weather performance of the similar system on I-40 clearly illustrated that these materials could control reflective cracking over rigid pavements. The open-graded hot mix, however was easier to construct, more economical, and caused less interference with traffic and from all indications would perform as well or even better that the three layer system. In 2001 this pavement was inspected and after thirteen years of service it was found that there were no reflection of cracks or joints, no rutting and the skid resistance was still very high. A review of the maintenance records revealed that the pavement surface had required zero maintenance in this entire period. A further aspect that became evident from this project was that a significant reduction in traffic noise was achieved with these open-graded asphalt-rubber pavements. Word got out to the public and later when ADOT decided to rehabilitate Bell Road through Sun City, the citizens demanded that the surface be an open-graded asphalt- rubber hot mix. As the concrete freeway pavements in Phoenix and Tucson required rehabilitation this asphalt-rubber paving system was used by the state to correct the problems. Today the citizens of the Phoenix area are clamoring to have all the freeways receive an asphalt-rubber overlay specifically for noise reduction.

The 1980's might well be termed the hot mix years or the I.S.I. period. After acquiring the equipment from Sahuaro and Arizona Refining and access to the patents, I.S.I. placed 10,900 tons of asphalt-rubber in 1983, primarily in seal coats. The production climbed to 15,400 tons in 1984 and in the next five years grew to 18,000 tons. This increase in volume was the result of an aggressive sales program and emphasis on quality control. In 1990 their production jumped to 38,400 tons as ADOT and the City of Phoenix implemented the wide spread use of gap and open graded hot mixes in overlay projects. Maricopa County also began substantial use of open-graded hot mix overlays. The primary use of asphalt-rubber was in California, Arizona, and Texas. The other states and their constituents still remembered the fiasco of 1981 and the efforts of the industry to shove this material down their throats.

I had resigned from ADOT in January, 1983 and joined the firm of Western Technologies, Inc., essentially a material engineering and testing firm with thirteen laboratories located in Arizona, New Mexico, and Nevada. In our engineering section we designed many pavement projects, particularly airfields, and several of these projects utilized asphalt-rubber in one form or another. W.T.I. had also performed extensive research on asphalt-rubber under contracts from ADOT and many of its engineers were well qualified in pavement design. In January of 1988 I joined International Surfacing, Inc. as their Technical Director with responsibilities of providing technical support to construction, establishing a laboratory and research program, and providing technical direction to their marketing effort.

In 1990 the future looked very bright for asphalt-rubber. I.S.I. had a banner year and we were making progress in obtaining projects in other states. It didn't look bright for very long - disaster struck again. Several different actions occurred that had significant effects on the industry. First, I.S.I. had been working with the Texas Dept. of Highways to implement the use of open-graded mixes for surface courses. To this end an agreement had been reached that called for 1.S.I. to present technical seminars in each of the 25 Highway Districts. It was agreed that these seminars would be strictly technical, covering the properties of asphalt-rubber and the methods that had been developed for the design of blends, mixes, and construction quality control. In turn the highway department agreed to build an overlay project in each District. A team composed of Gary Cooper, formerly Materials Engineer for Arizona DOT and then Director of the Asphalt Rubber Pavements Group, Joe Cano, Materials Engineer for the City of Phoenix, Jeff Smith, Director of Sales for I.S.I. and myself presented these 25 seminars. We were assisted by key personnel from the Texas Materials Division. Also in Texas we had been working with the Public Works Director for the City of Houston to develop a program that involved recycling of their old tires. In this case I.S.I. retained Dr. John Zanewski, Arizona State University, to analyze the pavement maintenance programs and the old tire disposal problems that existed in Houston at that time, to determine the actual cost of the two, and to evaluate the economics of using asphalt-rubber as a rehabilitation tool. The end result of this analysis was a proposal to the City from I.S.I. to assume responsibility for all of their old tires and in return provide the city with asphalt-rubber for their pavement rehabilitation projects at a prescribed price. The asphalt-rubber could be used in either spray applied applications as SAMs or SAMls, which-ever the city desired or in hot mix. It had been shown that the financial savings to the city would be substantial. Both of these potential programs came to an abrupt end when the holders of the asphalt-rubber patents sued Cox Construction, who had been the franchisee for Arizona Refining in Texas. So much for good sense. Neither the state of Texas nor the City of Houston were about to utilize a material where lawsuits were involved. Howard Cox was also a respected, long time, Texas contractor and he and his friends responded to this threat.

There was continued resistance by several states who wanted to use asphalt-rubber but would or could not do so because of the patents and the industry decision to not franchise local suppliers or contractors. Florida was a good example. Florida finally arrived at a solution to lower the rubber content and avoid the patents. These lower rubber content mixes were still an improvement over normal asphalt concrete construction, but certainly did not approach the level of benefits of asphalt-rubber. We did place projects in Nebraska, Missouri, Wisconsin, New Mexico, Nevada, and other states but inevitably the local entities would not tolerate the inroad into their market place. One other group tried to take advantage of this situation. The investors who had purchased the Vicksburg tire recycling plant from Genstar developed a process based on the success of asphalt-rubber but using a reduced quantity of rubber that was an extremely fine grind - minus eighty mesh. They thought that the use of fine particles would reduce the required reaction temperature and time and would also produce a product equivalent to the McDonald process. They convinced several state highway departments that this assessment was correct and they built a scaled down system of the blending and reaction equipment to supply hot plants and perhaps distributor trucks. Our laboratory evaluation of these materials reacted at the maximum temperature and time of reaction possible with such equipment indicated that a continuous phase of the elastic material was evidently not achieved and the materials properties fell far short of the McDonald process results. Never the less some mid-western states built full-scale projects which evidently failed and left a bitter taste in every ones mouth. This process has not been heard from in recent years.

The above fiascos were minor, however compared to the scheme that one of the officers of I.S.I. concocted with Manhole Adjusting, Inc., the company in Southern California that had previously been one of the Arizona Refining franchisees. In 1990, Manhole Adjusting was granted an exclusive franchise by the patent holders to market and sell any and all asphalt-rubber in Southern California. The franchise basically covered a zone that included all areas in Southern California that fell within a section created by extending a line due west from Blythe to the Pacific. I.S.I. had been very active in this area in marketing and in the 1990 season had placed 8000 tons of asphalt-rubber. It was very puzzling that such an action should be taken. After all Manhole Adjusting could already take advantage of our marketing efforts and bid on any projects, anywhere, anytime. Soon the reasons for this action dribbled out. The patents were due to expire soon and there was a possibility that a patent extension could be obtained. The FHWA had placed asphalt-rubber on the experimental list as a product not yet totally proven. In the pharmaceutical industry, when a product was classified experimental by the Food and Drug Administration, its patents were eligible to be extended when it was finally released for use. The owners of the parents had become convinced that asphalt-rubber should be eligible for the same consideration. The owner of Manhole Adjusting was at this time was also President of the Asphalt Rubber Producers Group and he believed that with the proper lobbying in Washington D.C. this could be accomplished. He also believed that these same political connections could include a requirement in the next highway financing bill that all states must use asphalt-rubber in some minimum percentage of their federal aid projects. The rumors at that time were that the lobbyist could accomplish this for $150,000. The owners of the parents were evidently in dire financial straits at this time, supposedly from real estate investments that went sour, and they agreed to grant the exclusive franchise in Southern California as a means to finance this scheme. What a scheme! With an exclusive franchise one could charge an extra $100 per ton and with 8000 tons this would amount to a bundle. What a salesman the owner of Manhole Adjusting proved to be.

The scheme to achieve the usage mandate was announced at the ARPG meeting held in Washington D.C. where representatives of industry were attending the Transportation Research Board annual meeting. The plan to get the patents extended was never brought to light at this meeting. Several individuals warned that such an action would result in a backlash that could destroy the industry. Gary Cooper, Director of ARPG and formerly the Materials Engineer for the Arizona DOT resigned in protest. He could not ethically allow himself to be connected to such political action. Shortly after this meeting, ARPG was disbanded and a political lobbyist, Gordon McDougal of Beacon Consulting Group located in Washington D.C. was retained as the industry representative. They managed to get the mandates into the highways bill but were not able to get the patents extended. The response by the states and the entire construction industry connected to paving was rapid, loud, and forceful. Opposition to the bill was expressed by all fifty states. The asphalt concrete industry, nation wide, expressed its concern. Congress responded the following year by requiring extensive additional research before the mandate could be implemented. The mandate was never implemented and in 1996 the requirement was rescinded.

The end result of this ill-guided political attempt was that all of the states were angry and blamed ARPG for the attempt to force asphalt-rubber down their throats. ARPG had a very difficult time denying this charge when the facts were that they had run off a very capable and well known materials engineer as their director had moved the headquarters to Washington and had hired a political lobbyist to represent the industry. One point of interest is that neither the lobbyist nor the president of ARPG showed any interest in preserving the technical library that had been developed at APRG. This library even included the myriad of reports of test results of Charlie McDonalds in addition to hundreds of reports prepared by others.

The result of this ill-advised scheme was that all of the states agencies were upset with the industry and provided the paving industry with the ammunition they needed to stop any further implementation of asphalt-rubber by additional states. Only four states continued their programs with asphalt-rubber and that was because of their excellent firsthand experience. This situation continues to date with only California, Arizona, Texas, and Florida having active programs. There is a small glimmer of light in that Tennessee and Nebraska have each build one project with the help of FNF Construction in recent years. Previously there was great potential with interest by at least twenty five other states. After 1991 this interest was and remains zero.

The decade of the nineties might well be called the holding period or the reorganizing era. A new association, Rubber Pavements Association, was formed and has done an excellent job with limited resources. One of their basic committees, the Technical Advisory Board, has been able to attract nationally known experts in pavement design and construction to serve. A sizeable research program has been developed and carried out with the help of this group. Marketing of asphalt-rubber has been greatly restricted. When the patents expired none of the asphalt-rubber contractors have any incentive to market outside their established area of operation. Where I.S.I. had previously maintained a marketing staff to cover the entire country, and had also established a laboratory to provide quality control and develop new products, their successor, International Surfacing Systems, has not found this to be necessary to their operation. All of the other contractors have limited marketing, if any, to their local area. For example, in Arizona, I would guess that not one representative from the contractors or material suppliers has called on any of the major cities, counties, or federal agencies in Arizona in the last ten years.

One should not prepare a history without at least commenting on how the experience from the past might guide the industry future. In virtually any industry the basic material suppliers are responsible for the marketing efforts except perhaps in limited cases. For example masonry contractors do not promote brick or concrete block on a regional or national basis. They may promote locally if their business is threatened. The local brick or block manufacturers will market within their area of operation, bur regional or national marketing is the responsibility of the basic material supplier. The same is true of virtually all industries. Look at the automobile industry, the asphalt industry, the cement industry, the electronics industry and virtually any other industry you would care to compare. Local interest will market locally but they are strongly supported by national interests. In the case of the asphalt-rubber industry, you have basically two groups that have regional or national interests - the asphalt suppliers and the rubber recycling plants. Unfortunately the asphalt suppliers have zero interest in or any incentive to market asphalt-rubber and the rubber recyclers have been totally silent in the last few years and never really put forth much effort. Possibly this is because of their lack of knowledge of the technology or more likely the lack of understanding of how the agencies involved in the highway programs function. These suppliers would need assistance in any marketing program because they are not familiar with the governmental agencies that prepare the designs and write the specifications. I would note however that they are in the unique position of being able to prepare innovative programs that might be very attractive to cities, counties, and even states that are experiencing major problems with tire disposal. They are also in a position to counter the local political opposition that many of the anti-asphalt-rubber entities are using. A good example of such a program would be the project in Oregon where I.S.I. accepted old tires from the local community, shipped the tires to Indiana for reduction, and was still able to offer the agency savings in cost compared to the alternate design. Among other thing, this gave the local agency a great boost in their public relations program.

Another group that has never been heard from is the equipment manufacturers who certainly should have a national interest. You would think that they would have great interest in seeing the market expand, but certainly they would need direction and assistance. Maybe all they need is a little push and some education. One other group of industry that should be interested is the tire manufacturers. Sooner or later they may well be held responsible for the disposal of these old tires and there have been indications in recent years that they are very concerned about this possibility. The actions of Ford Motor Co and Michelin tires certainly indicate that it would be very timely to approach this industry with a program for support. Once again, perhaps all they need is a little push and education on what the potential of the asphalt-rubber industry is with regard to solving the waste tire problem.

The marketing of asphalt-rubber requires that local construction interests be involved on a permanent basis and the first thing that must happen is to convince a local entity that this is an excellent opportunity for him. Certainly in other states there must be established contractors who wish to expand their area of activity and with proper assistance from the rubber recyclers and the equipment manufactures would enter the market. It seems to me that RPA might concentrate an effort to develop a national marketing program with the entities noted above. This would require RPA to provide training and education in the methods of successful marketing to public agencies and technical back-up where required.

Asphalt-rubber represents a major technological breakthrough in pavement design and construction and it would be a great shame if it were allowed to wither on the vine because of narrow and short-sighted thinking. Use the experiences of the past to guide your industry to the bright future it should have.

Robert “Bob” Winters reply letter Gene Morris AR history

March 20, 2003

Mr. Gene Morris
26610 S. Sageberry Dr.
Sun Lakes, AZ 85248

Dear Gene,

With reference to your draft of "The Development of Asphalt Rubber & Associated Paving Systems", we commend your efforts and know this was a project near and dear to you, as was your relationship with Charlie McDonald; however, we do have some comments and facts to offer, most of which may seem self-serving, but are nonetheless factual.

When Charlie McDonald first contacted me, asking for crumb rubber samples for his experiments, we were advised of his concepts and responded immediately, sending him samples of various grades of crumb rubber from scrap tires. His reported experimental results were very exciting, and we were on the next plane to Phoenix to observe his test panels on the streets of Phoenix and to get to know Charlie.

Our observations of his test panels were very impressive. We had felt for many years that somehow the addition of the elastomeric properties of ground tire rubber to asphalt pavements should result in benefits, which justified the cost of adding such materials.

McDonald was brilliant in his concept of adding a pre-reacted mixture of crumb rubber with paving grade asphalt which, when applied as a thin membrane (and when protected by the addition of aggregate chips), showed a remarkable ability to hold badly cracked pavements together with virtually no reflection of the underlying cracks.

Over the next months, we established a working relationship with Charlie, which resulted in his having the degree of confidence and trust in me and our company (Atlos Rubber, Inc.) to enter into an exclusive licensing arrangement with us on his then pending patent application. This license provided that Atlos Rubber, Inc. (ARI) would thereafter assume the responsibility for the prosecution of his then patent pending application, together with paying all legal expenses that went along with such prosecution. ARI was given the exclusive right to manufacture Charlie's "Band Aid" patches as well as sub-licensing others. Charlie's patent application was filed on what the Patent Office calls an "instant application". That is, he filled out the application without the benefit of a patent attorney. Being a novice at such things, he incorporated a paper he had written on the subject by reference. Well, as we all found out over the ensuing years, one couldn't incorporate any claims in a patent application by reference; they must be embodied in the application itself. It took seven years and over $250,000.00 of ARI funds to rectify this problem. ARI employed the services of a patent attorney to prosecute the application. The Patent Examiner eventually notified us of eight points of final rejection of this troubled application. When we were notified of the eight point final rejection, we sent our patent attorney's litigator to Washington D.C. to argue the final rejection on appeal. We had to reverse the examiner on all eight points of final rejection. The rest is history. We were successful on appeal, were allowed to re-file the application and include all of Charlie's claims in the body of the new application. It finally resulted in a Patent Issued!

As you know Gene, Charlie and I obtained several additional Patents which covered the addition of the Kerosene diluent, other percentages of rubber to asphalt, the "Band Aid" Patch and two emulsion versions of the reacted mixture (one cationic and one anionic).

ARI also successfully sub-licensed Sahuaro Petroleum and Asphalt Company. Together with our marketing and R&D efforts, including the production of two documentary films and brochures, Sahuaro began to experiment with both slurry seal and distributor truck applications of Charlie's mixture to pavements, with mixed results on application success, but demonstrable in-place properties of even the poorly applied (roped) mixture. This instilled confidence in others and resulted in continued development of this remarkable product and its application equipment. ARI was responsible for calling on agencies in an effort to demonstrate to them the properties of Charlie's material. ARI built a facility to produce the "Band Aid" patches. None of these were ever sold. However, they were provided at no charge to agencies and ARI assisted these agencies with their application over badly cracked pavements. This resulted in many of the larger scale projects over the years based on observations of the "Band Aid's" properties.

Gene, I am sure you were not aware of the role I played and the efforts and money spent by ARI to keep Charlie's dream alive and see it through to commercial results and a degree of initial success.

I feel our contributions should be included in your piece. Without our efforts and sizable investment, Charlie's efforts and troubled patent application could well have died on the vine.

Additionally, ARI sponsored and paid for Charlie's laboratory, which he founded after his retirement from the City of Phoenix. As you know, this lab helped develop improvements and test methods for Charlie's concepts.

To praise Femley Smith and Genstar as the only crumb rubber supplier who contributed to the success of Charlie McDonald's concepts is to ignore the contributions of Atlos Rubber, Inc. and myself. I was also a cofounder (with Carl Jacobson) of the Asphalt Rubber Producers Group (ARPG) and served two terms as its President and CEO (with Donna Carlson as our Executive Director). Atlos and many other crumb rubber companies were active and supportive of the RPA for many years. Some still are.

I am not comfortable blowing my own horn, but facts are facts, and I felt you should know who did what.

Good luck and best wishes. I hope you are enjoying your retirement and are in good health.

I am enclosing a copy of your draft with typo's, etc. noted.

Sincerely,

ATLOS RUBBER, INC.
Robert E. Winters
President

REW/lg
Encl.
Cc: Bob Smith, Tim Baker, Doug Bemard, Gary Cooper, Joe Cano, George Way and
Donna Carlson.

Don Neilsen reply letter to Gene Morris AR history

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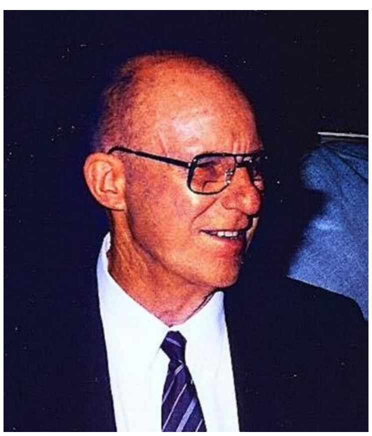

Gene Morris
26610 S. Sageberry Dr.
Sun Lakes, AZ 85248

Dear Gene:

I read your "The Development of Asphalt Rubber & Associated Paving Systems" with interest. You did a great job and I know that you put in many hours on the effort.

My following comments are not meant top be critical - just food for thought.

1. Page 1 - asphalt history. As a matter of interest Union Oil company was the first refiner in the U.S. to make asphalt from crude oil in 1890. In the east, the already established competition was Trinidad Lake Asphalt. Union Oil supplied 20 to 80 Pen asphalts in wooden barrels to many cities in the east - Wash. D.C., New York, Bluffton, Ind., Toronto, Canada, Toledo, Ohio just to name a few. They supplied one hot-mix job in Victoria, British Columbia in 1905 that lasted for 50 years. An interesting thing about that job was that the roller man was Henry Kaiser. Most of the asphalts supplied by Union were on the hard side, 30 or 40 pen. I went to work at Union in 1945 right after I got out of the service, and within 2 years, I was handling orders for asphalt shipments. So, I've been in this racket for a long time.

2. Page 2 - I don't recall the cost of asphalt ever being subsidized. At Union, the product had to stand on its own and show a profit. The alternate use for such heavy oils was for heavy fuel oil and we always had to make a profit over that alternate value.

There were many reasons that asphalt production got tight and the prices rose. The Arab embargo was just one factor. Refiners came up with new processes that made more gasoline and diesel fuel from crude oil, thus greatly reducing the amount of asphalt made, and in some instances, asphalt was eliminated completely. Another factor was the environmental requirements placed on the refiners. They all had to spend large sums of money to comply and the small refiners couldn't afford it so they went out of business. In 1952, for example, there were 12 refiners making asphalt in the L.A. area and of those 12 only 3 are still doing so. Another 2 new small ones have come on the scene since then so now there are 5 refiners there making asphalt.

3. Page 4. - You mentioned latex emulsion and polymers. Neither of these additives will give much boost to durability. Further the amount of such modifiers added to asphalt does not markedly increase the viscosity of the blend, with a couple of exceptions. So, when using these products, the asphalt content in hot mixes remained in the area of 5 to 6%. As you know, the asphalt contents with asphalt rubber are much higher. We all know that the more binder you can cram into a mix without ruining stability will make a much longer lasting product.

4. Page 6 - I got the impression from your write up that waste rubber wasn't recycled until asphalt rubber came along. U.S. Rubber Reclaiming started grinding and recycling tire rubber in Buffalo, N.Y. in 1890. Most of that rubber went back into rubber products, although, U.S. Rubber Reclaiming did have their own asphalt rubber product in the 1960s.

5. Page 7 - Reference to FHW A as McDonald's employer. We in Arizona Refining used to deal with (Don did not finished this sentence)

6. Pages 9 & 13 - On the early development of asphalt rubber, I recall that McDonald's first blends used for his "band aids" contained 35% rubber. Sahuaro had the maintenance contract with the City of Phoenix; so naturally, Charlie looked to them for blending and application assistance. The 35% blend was too viscous for Sahuaro to spray apply so it was reduced to 25%. 25% minimum was the basis for McDonald's first patent. Even then, Sahuaro had to add kerosene at times to reduce the viscosity. By the way, that kerosene did not evaporate. It reacted with the rubber, and stayed in the blend.

6. Page 25 - On the Beeline Highway job, the Arizona Refining product followed the formulation used by U.S. Rubber Reclaiming. So, the blend had only reclaim rubber in it. That was in May, 1975. It wasn't until the following August when they did a test seal coat job on Van Buren near 51" Ave. in Phoenix that was a product with 4 components. That test was unusual in that the spreader driver screwed up on a short stretch and shot 2 gals/sq. yd. We threw additional chips on it and it performed well for many years. Barney Vallerga did an audit on this job, taking core samples. That 2 gallon/sq. yd. section looks like a hot mix ½ inch thick. Barney concluded that you could ignore normal chip seal thinking and apply any thickness you wanted as long as you put on sufficient chips. In effect he said that you should set your asphalt rubber application to whatever level you wanted and vary the chip application to accommodate. He developed a monograph to make that chip calculation. He published a paper on this and I believe that it was presented at TRB. But it showed the big difference between thinking on regular asphalts and asphalt rubber.

Also on page 25, you bring up the matter of patents. McDonald's first patent was for 2 components-asphalt and rubber with the rubber a minimum of 25%. He next collaborated with Bob Winters and patented the addition of kerosene to the brew. Arizona Refining's patent was for 4 components - asphalt, granulated regular rubber, reclaim rubber and extender oil. The devulcanized rubber was later dropped because it was found that it reduced the viscosity of the blend and hurt the resiliency and viscosity of the asphalt rubber. So, Arizona Refining ended up making a product that did not meet their own patent. Nor did this blend conflict with any of McDonald's patents. Arizona Refining never did patent their 3 component blend. By the way, Beth Wilkes of Arizona Refining obtained a patent for an asphalt rubber emulsion. The rubber content was at a much lower level. The product worked well on the few jobs done for ADOT and Maricopa County but Arizona Refining was going out of business at the time and it was never promoted.

7. Page 27 - Fernley Smith of Genstar. I felt that Ken Wardlaw did more to promote the product than Fernley.

8. Page 28 - I think you should identify Ken Hill as President and owner of Bearcat Manufacturing.

9. Page 29 - Requirement that hot-precoated chips be used. I believe the pre-coating was first required by the city of Phoenix on all their chip seals as a means of reducing the dust on the chips. You mentioned the job on Hwy 95 north of Lake Havasu City where they experienced a large loss of chips on Sahuaro's high vis. product. I visited that job later, and the loss was so heavy that it looked like windrows of chips off to the side of the pavement. Arizona Refining had a short stretch of that job and their product was wasn't viscous enough, so the seal bled. But, there was no loss of chips. So, after that, Sahuaro gradually reduced the viscosity of their product and Arizona Refining increased the viscosity of theirs.

10. Page 43 - Arizona Refining did not have a franchise with Manhole Adjusting, but they did sell 2 used distributor trucks to Manhole at the time Manhole got into the business, I was their consultant and it was just at the time that ISI took over all of Arizona's business. In fact, ISI's lab did some formulation work for me. I should point out that Manhole soon had the asphalt rubber business of 41 cities and Counties in Southern California, in part because of the good work done by Cliff Ashcroft who was with Manhole at the time.

11. Page 44 - The lobbying in Washington D.C. to create a mandate for the use of asphalt rubber was also financially backed by both Arizona Refining and Sahuaro. That was after I retired from Arizona Refining.

12. Page 45 on the mandate, you correctly indicated it created a lot of opposition to asphalt rubber by the states. ARPG backed away from that mandate. I attended a meeting with Donna Carlson, Doug Bernard of FHW A and someone from EPA where we made it clear that we were not supporting the mandate. Even then, the man from EPA wanted to have some law that would require a larger usage of asphalt rubber.

Other

1. Arizona Refining built a lab to do mix designs with asphalt rubber in the mid 1970s. They also did a lot of asphalt rubber formulation work. John Partenan put out a long report about the effects on the finished asphalt rubber depending on temperature and time, different asphalt sources, etc. Most of the agencies who agreed to try asphalt rubber at that time had this lab do their mix design work.

2. Arizona Refining hired Bamey Vallerga as a consultant in 1975. He issued many meaningful reports on the subject.

3. You didn't mention the Caltrans research job at Ravendale in 1983. This job established the equivalency ratio of 2 to 1 for regular asphalt concrete vs. asphalt rubber concrete. This put asphalt rubber, a higher priced product into a lower cost category. Subsequent tests done by the Heavy Vehicle Simulator in South Africa and California showed that it was more like 4 to one or even higher.

4. As asphalt rubber was promoted across the U.S., both Arizona Refining and Sahuaro were sending their trucks all over the place. They had to negotiate special working rules with the Teamsters union to allow this to happen.

5. Arizona Refining began using the Haake Viscometer at the job site as a quality control in 1981. The use of this instrument has spread all over the world.

Well, I've certainly blabbed on a long time here. Take what you want and ignore the rest.

Fondly

Cc: Bob Smith, Bob Winters, Tim Baker, Doug Bernard, Gary Cooper, Joe Cano and George Way.