Asphalt Rejuvenators
"Fact, or Fable"

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There are numerous methods being employed for asphalt pavement preservation, including rejuvenator emulsions, asphalt emulsion fog seals, a variety of surface treatments (including slurry and micro surfacing technologies), and emerging asphalt thin overlay technologies. These methods range in cost from approximately $0.50 to $2.50 per square yard. To make the most of maintenance budgets, many agencies have resorted to the use of asphalt rejuvenators as an alternative to revive aging and brittle asphalt pavements. With the proven performance of asphalt rejuvenators to revive an aging pavement, the pavement engineer has an economical method to extend pavement life. This type asphalt pavement treatment has the potential to extend the life of an asphalt pavement for several years beyond the point where rehabilitation, or major reconstruction would normally be required; thus significantly decreasing the pavements annual maintenance costs.

The objective of this discussion is to establish criteria necessary to ascertain the performance of a rejuvenator; i.e., the material parameters and a method of measuring its performance. Subsequently, the results of research programs and construction projects are reviewed. Lastly, recommendations are advanced concerning the use of rejuvenators.

CRITERIA FOR A REJUVENATOR

Asphalt binders cannot be represented by a single chemical formula. The American Society of Testing and Materials (ASTM) defines it as "a dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing."

Asphalt binders are, however, fractionated into two subdivisions, i.e., asphaltenes and maltenes as depicted in Figure 1. Asphaltenes (A) are defined as that fraction of the asphalt insoluble in n-pentane. The function of the asphaltenes is to serve as a bodying agent. Maltenes is the collective name for the remainder of the asphalt material left after precipitation of the asphaltenes. Four principle bodies of maltenes have been identified and each has a specific function. These four bodies are:

- Polar compounds or Nitrogen bases (N) - components of highly reactive resins, which act as a peptizer for the asphaltenes.

- First acidiffins (A_1) - components of resinous hydrocarbons which function as a solvent for the peptized asphaltenes.

- Second acidiffins (A_2) - components of slightly unsaturated hydrocarbons that also serve as a solvent for the peptized asphaltenes.

- Saturated hydrocarbons or paraffins (P) – components of hydrocarbons, which function as a jelling agent for the asphalt components.

The cementing agent in an asphalt pavement, the asphalt binder (normally 4-7% by weight) represents the component that experiences premature hardening as a result of oxidation. Asphalt pavements, which are structurally sound, deteriorate as a result of oxidation and occasionally as a result or incorrect design or improper construction practice. The first phenomena, that of oxidation, is prevalent in all asphalt pavements, and is the subject addressed in this discussion.

In tests conducted by Rostler and White (1), it was reported that the "A" and "P" asphalt components were the most stable; and the "N", "A_1", and "A_2" components were more subject to oxidation in descending order, respectively. Consequently, during oxidation the "N" components convert to "A" components rapidly while the conversion process for the "A_1" and "A_2" components proceed at a slower rate. This process results in an increase in the "A" fraction of asphalt with time, and decreases the "N", "A_1", and "A_2" components. It was also reported the "the maltenes parameter $(N+A_1)/(P+A_2)$, the ratio of chemically more active to less reactive components present in the asphalt binder, is a measure of predictable durability."

During the process of weathering or oxidation, the ratio of maltenes to asphaltenes is reduced with the result being a dry and brittle pavement. Therefore, if a rejuvenator is to successfully resurrect an aged facility, it must be able to penetrate the pavement and to a

limited depth improve or restore the maltenes to asphaltenes balance. A reasonable measure of the ability of a rejuvenator to improve a pavement's durability can be had:

- By comparing the penetration at 25^{o}C (77^{o}F) of the asphalt binder extracted from untreated and treated cores.
- By comparing the viscosity at 60^{o}C (140^{o}F) of the asphalt binder extracted from untreated and treated cores.
- By comparing the percentage loss of aggregate when untreated and treated samples are subjected to a pellet abrasion test.

The latter two methods were employed by Rostler and White (1) in laboratory tests performed on prototype asphalt rejuvenators. The use of asphalt viscosity and penetration values has been incorporated into the contract specifications for Federal and Public Works rejuvenation contracts.

In summary, the criteria for a rejuvenator must involve two phenomena:

- First, the product must contain maltenes fractions of asphalt in order to improve and balance the maltenes to asphaltenes ratio.
- Secondly, a test method must be employed to measure improved durability of a pavement; e.g., an asphalt penetration, viscosity, or abrasion loss test.

TEST PROGRAMS

Billions of square yards of asphalt pavements make up more than 93 percent of the U.S. pavement infrastructure, and there is a growing interest to employ rejuvenators as an economic pavement preservation technique. Documentation regarding asphalt pavement rejuvenator practice and performance is needed to support Agency Pavement Preservation Programs. Several research efforts have been conducted in an effort to document application of the asphalt rejuvenators. They include:

- A study sponsored by the Air Force Weapons Laboratory, dated May 1970, entitled "Rejuvenation of Asphalt Pavement" (1) which consisted of a laboratory investigation of five products. The method of investigation entailed preparation of sand/asphalt briquettes composed of graded Ottawa sand, Portland cement and asphalt of specified penetration values. Test briquettes were subjected to equal application rates of five rejuvenator products, aged until one-half of the volatile constituents of the rejuvenating agent was lost, and subsequently, subjected to various tests, including permeability, depth of penetration, viscosity, and pellet abrasion. The conclusion of this study revealed that Reclamite and Koppers Bituminous Pavement Rejuvenator (BPR) performed as asphalt rejuvenators in that the viscosity of the asphalt binder was improved and the loss of aggregate from the pellet abrasion test was substantially reduced by application of both products. This conclusion was based on comparisons with untreated control samples and the other products.

- Technical Report R690 (2), dated August 1970, sponsored by the Naval Facilities Engineering Command and conducted by the Naval Civil Engineering Laboratory at Port Hueneme, California, which consisted of a study of the claims of the proprietary product called Reclamite. The report approached the subject in a neutral manner and balanced the claims of the manufacturer against actual field use by several agencies, including several Federal users, the California State Division of Highways and several city and county governments. The conclusion was that the manufacturer's claims for the performance of Reclamite were essentially correct and no further investigations were required to determine the effectiveness of the product.

- Evaluation of Reclamite by the U.S. Navy as reported in their publication "Value Engineering," dated August 1973 (3). This report concerned the application of Reclamite on three roads at the Naval Weapons Center, China Lake, California. The project involved treating the three roads with Reclamite and retaining an untreated test section at each test site. At periodic intervals, judgements, photographs, and core samples for asphalt penetration measurements were taken to assess the effectiveness of the product. The test covered a period of almost two years. The conclusion of this evaluation revealed that field tests and laboratory reports "show conclusively that Reclamite does prolong the life of asphalt concrete pavements."

- A study, sponsored by the Air Force Civil Engineering Center and accomplished by the U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg,

Mississippi, February 1976 (4), involved treating adjacent pavement areas at three Air Force bases with four proprietary rejuvenator products and an asphalt emulsion seal. The tests were conducted at a base in the dry, hot southwestern part of the United States, a base in the humid, hot southeastern part of the country, and a third base located in the cold north-central part of the country. The study covered a period of four years and reached the conclusion that Koppers BPR, Reclamite, and Petroset do rejuvenate the old asphalt binder while Gilsabind and SS-1 Asphalt Emulsion have a hardening effect. Other conclusions were reported, including an indication that the viscosity of treated asphalt is a better indicator of the rejuvenating effect of the materials tested than was the penetration test. There have been no comprehensive independent tests comparing the performance of asphalt rejuvenators since this study was completed (6). Since 1995, at least two rejuvenator products have been introduced into the market; however, the FAA continues to rely on the data presented in the Air Force study.

CASE EXPERIENCE

Asphalt rejuvenators have been used extensively by Federal, State, County an Municipal Agencies over the past 15 years, and predicated on past performance results, it is noted that there are clear-cut opinions regarding success of a rejuvenator product. Once a rejuvenator product has been used, a pavement engineer's opinion appears to be that the project was either totally successful, or completely ineffective. It is hypothesized that these diverse

attitudes stem from proper and improper application of a product, rather than the performance of a product itself.

As rejuvenators increase in popularity, proprietary specifications are being given widespread use. Initially, this situation did not create any major problems, as the manufacture of rejuvenators was regional with competitive products separated by the distance across the United States. Typical examples of projects accomplished under method type specifications were US395, North of Carson City, Nevada, which was treated with Reclamite at a rate of .12 gallons per square yard in 1965, and an airfield pavement at Wright-Patterson AFB, Ohio, treated with Koppers BP at a rate of .15 gallons per square yard in 1972. As use of the products increased and competition intensified, proprietary specifications were challenged. Specifications were then written to permit competitive products. A specified rate was included in the contractual documents. This practice is common in current specifications. However, the rejuvenator products perform differently among themselves in a given environment, and differently within themselves in changing environments. Therefore, a given application rate, in most projects, does not insure a desired end product. In a project at Kincheloe AFB, Michigan, in the summer of 1974, a performance specification was used. The specification called for a 30 percent increase in the penetration of the asphalt in the top 1/4 inch of the pavement 60 days subsequent to application. Cores were required prior to treatment and 60 days subsequent to application. The contractor used Reclamite and achieved an average increase in the asphalt penetration of approximately 120 percent.

Further restrictions are suggested to govern application rates to avoid unacceptable anti-skid, softness and/or performance characteristics. These were:

"The contractor shall be responsible for conducting preliminary testing to determine the proper application rate for the rejuvenator so as to achieve the required end results specified above. This shall be accomplished without causing the pavement to become unstable to 90 degree turns of an automobile at 5 MPH, or exhibit more than a 25 percent loss in measured friction resistance values at 12 hour periods subsequent to application of the rejuvenator," and

"Should the required increase in penetration value not be achieved, additional applications of the rejuvenator and mineral aggregate shall be made at application rates not to exceed 50 percent of the initial application rate. Retreatment and retesting shall be at the expense of the contractor. The Contracting Officer shall hold the contractor's performance bond in full force and effect until final test data indicates the work was completed in accordance with the specifications."

A contract was awarded in June 1976. The rejuvenator product Reclamite was used and the contract was accomplished and successfully completed with the above specification requirements in November 1976. This was the first documented case of using a rejuvenator emulsion performance specification on an asphalt pavement. Satisfactory performance guidelines or targets should be based on the capability of the material to decrease the viscosity and increase the penetration value of the asphalt binder. In the case of asphalt pavements less than 2 years old, the viscosity shall be reduced by a minimum of 20 percent and the penetration shall be increased by a minimum of 10 percent. For asphalt

pavements more that 2 years old, the viscosity shall be reduced by a minimum of 40 percent and the penetration value shall be increased by a minimum of 20 percent. Testing shall be performed on recovered asphalt binder from the pavement to a depth of three-eighths (3/8") inch. Standard ASTM Test methods to measure the viscosity @ 60°C (140^{o}F) and penetration @ 25°C (77^{o}F) on the recovered asphalt binder should be specified. Treated test cores will be extracted no sooner than 60 days following rejuvenation of pavement, or as approved by the Contracting Agency.

USING REJUVENATORS - GUIDE

All rejuvenators are applied in the same way--by spraying the chemical onto the pavement surface with an asphalt distributor. However, from this point the procedures vary because of the different products and because of the different end results desired. Discussion of the use of rejuvenators can be considered in three separate categories; new construction, maintenance, and re-construction.

Using a rejuvenator on new construction does not seem to be logical at first glance. However, it has been established that the greatest change in composition of an asphalt binder takes place during the manufacture of the hot mix asphalt (HMA). Applying a rejuvenator to a new surface a few weeks after it has been laid does several things to the pavement. Besides restoring the original asphalt properties that were lost in the HMA manufacture, the chemical assists in sealing the pavement as well as in improving the durability of the surface course.

Maintenance can be subdivided into preventive and corrective maintenance. Preventive maintenance should be applied to pavements at the first signs of aging of the surface course, pitting, raveling, shrinkage, and cracking. Some pavement experts maintain that preventive maintenance should begin before any of these described signs occur. However, to do this, there must be a certain amount of clairvoyance involved in determining the right time before these conditions show up. Starting a maintenance program too early can become a costly item. Nonetheless, applying the rejuvenator at periodic intervals can restore the asphaltene-maltene balance so essential to maintain a ductile, pliable pavement. This type of preventive maintenance is particularly applicable to pavements in the hot, dry southwestern section of the country.

Corrective maintenance involves reworking and salvaging existing road mixes. Using a rejuvenator in this type of maintenance can facilitate scarifying and mixing. It will aid in replasticizing old asphalt and improve its durability. This form of maintenance should be considered when the road mix surface appears weathered and crusted and cannot be restored by applying only a rejuvenator.

The third category of rejuvenator use is that of re-construction. This involves more than applying a rejuvenator emulsion onto the surface and rolling the treated pavement. Work in the category is undertaken when the pavement has outlived its life; when preventive maintenance has failed to stop the pavement deterioration; or when a HMA overlay is to be placed over the existing pavement. The overlayment may be due to a need for increased

structural strength, or it may be necessitated by failure of the old surface to respond to normal maintenance.

If the existing pavement possesses good structural qualities and the overlay is being placed to increase its strength, a rejuvenator can be applied to the old surface several days before the overlay is constructed. This application will cause the existing surface to soften, regain some of its original ductility, and will promote a good bond between the old and new surfaces.

Where the existing surface has progressed to a condition where cracking, pitting, and raveling has occurred, and it is feared that these structural deformations will reflect through the new pavement, different procedures are being advanced. Cracks as much as two inches deep in the airfield pavements at the civilian airport at Augusta, Georgia were repaired by a treatment with Koppers BPR and a lengthy follow-on program of constant rolling (5). Reclamite, on the other hand, has had excellent success with heater planing and heater mixing of old pavements. One of the most successful projects of this nature was completed at the El Paso International Airport. The heater-planer process involves heating the surface of the existing pavement with a traveling infrared heat source. Once the old asphalt is heated, it becomes very pliable for a short period of time. During this time of pliability, a sharp blade following the application of heat peels off the oxidized or deteriorated asphalt to the desired depth. The applicator truck follows immediately behind the heater-planer. Once the old asphalt is removed, the process is similar to that described previously, i.e., the rejuvenator helps to rejuvenate the old surface and promotes a good bond between the old

and new pavements. The heater-scarified method is very much like the heater-planer method. The difference is that instead of planing off the old surface, the pavement is scarified to the desired depth, usually less than an inch, then treated with the rejuvenator. The new asphalt, if an overlay is to follow, is laid directly over the treated and scarified material. The thickness of the overlay lift may be as small as three-fourths to one inch.

An advantage of the heater-planer or heater-scarified method is readily evident when one considers grades and drainage when several overlays are applied to city streets. By continuing to use the existing material, restoring and balancing the asphaltene-maltene ratio through rejuvenators, expensive hot mix is no longer needed and design drainage elevations between curbs can be maintained for longer periods.

RECOMMENDATIONS

- Rejuvenators should be applied before raveling and other serious deterioration begins. A final conclusion reached is that problems may be experience with of improper rates
- The Using Agency should adopt a performance type specification.
- Develop a periodic maintenance program using rejuvenators in three to five year cycles will extend the life of existing pavements.
- The secret to proper rejuvenation application procedures is CAUTION. It is better to apply two or more low-rate applications of the emulsion to achieve the proper rate of application than to make only on pass and have it be too heavy. The

project engineer must be wary of areas that might contain free oil, grease, petroleum, or asphalt when applying the chemical. The engineer must also take care not to apply the rejuvenator to a densely graded pavement or to a surface that has been treated in a manner that will prevent penetration by the rejuvenator.

CONCLUSIONS

An asphalt rejuvenator emulsion offers three beneficial reactions:

- Increases penetration values and lowers the viscosity of the asphalt binder in the top portion of the pavement, which extends the pavement's life cycle.
- Seals the pavement against intrusion of air and water, thereby slowing oxidation, preventing stripping and raveling and protects the pavement in-depth.
- Increases the durability of the asphalt binder in the top portion of the pavement by improving the balance of chemical fractions of the asphalt binder.

As in most engineering projects, the project specifications are as important as the project design. The specifications should require a given measure of results rather than payment for quantity of emulsion. The reason for using a rejuvenator is to improve or restore the viscous properties of the asphalt; therefore, requiring the rejuvenator to achieve a given measure of standard penetration or measure of viscosity will insure a more satisfactory result than simply specifying a given rate of application.

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Figure 1. Asphalt Binder Fractions, Asphaltenes and Maltenes.