URBAN SURFACE RECYCLING

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Over the past decade, pavement construction and maintenance costs have more than doubled while public works budgets have remained relatively constant, sometimes even decreasing. The escalating rise in new street construction and maintenance cost is a direct result of the current OPEC situation, our dependence on foreign oil and the correlation between asphalt and crude oil product prices. Today's Public Works Engineer has fast become maintenance oriented, as he should be. A major concern must be one of increasing the strength and serviceability of existing streets, while adhering to the necessity to economize. The more expensive method of restoring a worn flexible pavement by resurfacing with a strengthening overlay is now often revaluated in favor of surface recycling and applying a seal coat to waterproof the underlying pavement structure.

The idea of recycling pavement sometimes evokes fears that the recycled material may not possess satisfactory quality and will soon fail under traffic loading. Great improvements have been made in quality control, particularily over the past several years, to eliminate uncertainty and upgrade the end result. Work performed using new "Arizona" specifications and Asphalt Recycling and Reclaiming Association (ARRA) standards (1) with rigid inspection bears no resemblence to earlier heater scarifying work. The technology for successfully recycling asphalt pavements has already been developed and is now available to engineers for more extensive usage on urban projects.

Pavement Evaluation

A pavement study to establish a properly budgeted, long range maintenance program is the primary step frequently taken by Public Works Engineers. An ongoing street evaluation program should provide that in each successive year, certain streets previously studied will undergo additional testing. Successive repetitions will permit the establishment of accurate "rates of change" curves. With additional inputs of data, it is possible to accurately program the type, amount and cost of future maintenance, and determine which pavement design, construction method of maintenance technique provides the most economic service to the community.

Corrective procedures may be developed after considering roadway sufficiency, serviceability, structural adequacy and physical conditions of pavement materials. Investigations should include deflection testing, field and laboratory testing of pavement and base materials; correlation of field date with historical design and construction information; reviewing maintenance records and traffic loading and analyzing the information gathered to prepare recommendations.

Recommendations vary from immediate routine maintenance to extensive repairs by means of a program of resurfacing, reconstruction, seal coating, surface recycling or some combination of these to treat existing surfaces and establish priority schedules for each, based on need, with programmed reviews for updating the priorities. This report will focus primarily upon the maintenance procedures involved in surface recycling.

As might be expected, virtually all streets possess some deficiencies that merit maintenance attention. This maintenance may be of major or minor consequence, but failure to correct a deficiency will lead to further deterioration and increased maintenance costs.

Frequently, streets are structurally sound and not in need of improvement insofar as the pavement section is concerned. There may be deficiencies in the pavement materials which will lead to deterioration of the surface and ultimate structural failure, but which can be corrected by proper preventative maintenance.

Many pavements possess highly embrittled asphalt binder and failure to correct this condition will lead to deterioration of the pavement and ultimate structural failure. The asphalt aging phenomenon occurs frequently in the Southwestern United States and is aggravated by the climate, quality of petroleum crude used to produce the asphalt matrix and many other complex ecological and little understood factors.

Deflection Testing and Analysis

An important predesign study is the determination of present structural condition as compared to its original design strength. The deflection testing is often conducted using the "Road Rater" which is a hydraulic test apparatus that determines the pavement's strength by non-destructive means. The machine, with warning devices, is fast moving and allows traffic to pass with very little delay or interruption and no significant congestion. The Benkleman Beam may also be used, but does not equal the former's speed for data collection.

Asphalt concrete overlay requirements are determined by measuring surface deflections resulting from imposing a known combination of static and dynamic loads and relating this to the strength or load carrying ability of the "in-situ" material.

Generally, the greater the deflection, the lower the strength of pavement. Thin pavements are relatively more flexible and permit greater deflections than thick pavements. An exception to this generalization could occur with an older pavement with diminished asphalt viscosity value due to aging. It may give the appearance of strength when, in fact, its rigidity indicates the approach of brittleness, cracking and failure.

Pavement Samples

Sufficient cores are taken from problem pavements to reveal the make-up of the structural section, with data from city records to frequently supplement and verify the findings.

Results afforded by laboratory analysis of the pavement core components are important in understanding the reasons for pavement distress. The laboratory should determine the percent of asphalt in the pavement surface layer, its viscosity and the density of the entire asphalt concrete pavement layer.

Pavement Materials

Although some streets are structurally weak, much of the visible distress can be directly attributed to physical deterioration of the pavement itself. Laboratory analysis (2) of the representative samples extracted from roadways reveal that most pavements have asphalt binder that has become highly embrittled. It is also observed that many areas exhibiting extensive alligator type crack patterns are not structurally weak, thus eliminating load associated reasons for failure.

Non-load associated distress sometimes is the result of thermal cracking of asphalt binder which has lost its viability and reflective cracking of underlying Portland Cement Concrete joints and failures. The inability of a pavement to withstand movement whether due to temperature induced expansion-contraction cycles or the movement of underlying slabs, increases as the asphalt binder hardens and ductility is lowered.

Research

A proper evaluation of streets requires extensive knowledge of design, construction and maintenance. Plans and reports should provide design "R" value and Traffic Index, street construction specifications and maintenance history. Additionally, "R" value and construction data may be obtained from County Road Departments and the State Division of Highways.

Condition surveys document distress and street deficiencies, as observed during many trips over city streets. Adverse conditions such as cracks, raveling, bumps and roughness result from failure or deficiencies in the pavement and can be correlated with deficiencies reported by the various testing procedures. Such reviews are often made by city engineering and maintenance personnel and provide information that, when combined with test results and other data gathered, permit development of recommendations.

Historical Recycling Background

Modern surface recycling originated in a process which began in the 1950's. Gibbons and Reed Contractors of Salt Lake City developed early heater planers, utilizing the motor grader chassis equipped with a small combustion chamber. They built and improved these tools which were used throughout the Western United States to remove irregularities and instabilities from asphalt pavements.

Gradually, larger more complex machines evolved which were able to heat, cut and load the upper layers of the asphalt pavement. Increased depth requirements for planing were satisfied by repeatedly cutting the surface one half inch at a time until the desired grade was achieved. The machines often caused visible emissions due to variations of the asphalt content in the pavement being processed. Crack pouring material, transmission oil dripping and paint on the surfaces aggravated ecological problems with the public. The relative hardness of old asphalt pavements and the need to maintain a constant temperature in a combustion chamber (subject to wind and variations of the burner draft) made the heater planer a very difficult machine to operate within stringent pollution standards. The slow production of these machines contributed to high cost of removing deep layers, and heat escaping from the burner to adjoining trees and shrubs caused damage while wasting fuel and energy. The loosened asphalt mix material produced by heater planing could be reclaimed when still hot, which meant that it was only possible to reuse and compact within a short distance of the planing project.

Heater scarifying, or remixing, developed by modifying heater planers with scarifier rakes to probe the surface which had been heated. As burner designs continued to improve, machines were able to penetrate a uniform thickness causing only minor visible emission.

The economic reason for surface recycling (scarifying and rejuvenating) was to relevel the surface and eliminate the cost of transportiang asphalt materials to other locations when it might be utilized on site. The use of cleaner, low sulfur fuels improved the general performance of these machines, although it was a process which had to be closely controlled by the operator when using only one machine.

Surface Recycling Advantages

On certain projects, heater recycling can offer significant improvements to conventional overlays, as well as prepare a surface for receiving thin overlays, chip or slurry seal treatments (3).

Because of the roughened texture caused by the scarifier teeth and elevated temperature of the new asphalt mix placed as an overlay, a bond develops at the interface of new and the existing asphalt layers. This means the resurfacing shows greater resistance to deflection and shear than an overlay installed upon a conventional tack coat.

As a result of heat and the re-arrangement of aggregate particles by scarification, reflection cracks through a thin overlay or seal coat will be minimized.

Pavements exhibiting moderate surface distortion are leveled by the rakes to receive a uniform thickness overlay or seal treatment without a separate and costly planing operation.

When surface treatments or thin overlays are programmed, raw material is conserved and drainage capacities of curb and gutter are retained

longer. More miles of street may be treated due to low cost of surface recycling.

Analysis

Surface recycling can only correct certain defects. Asphalt pavements exhibiting minor corrugations, alligator cracking, raveling, polished aggregate, or bleeding are all candidates for the process. On the other hand, if the distress results from an inadequate base and shows up in pavement failure, pot holes, upheaval, or severe rutting, extensive base reconstruction must be considered.

As the technology improved, it was determined that if a pavement temperature is increased slowly, in steps, using multiple machines, the pavement would never reach a temperature to emit particulate. In some instances, cold planing was required to first remove any imperfections or contaminates which have accumulated on an asphalt pavement and which might produce emissions. E.P.A. standards and maximum permissable limits for emissions may not be exceeded. A current requirement of the South Coast Air Quality District covering the Los Angeles Basin, one of the country's most sensitive ecology areas, is to be found in **Appendix B.**

Today's operation for high quality work (4) is monitored by removing a known volume of scarified material to weigh and determine specification compliance. The design engineer can now specify a weight per square foot of recycled material just as he would when purchasing a new asphalt concrete material. The recycling agent application is also closely controlled after laboratory tests indicate the type and amount of agent needed to renovate or rejuvenate the asphalt binder. When treating deep lifts of surface recycled material, the loosened mix is generally struck off by a screed, then compacted while still at an elevated temperature and the recycling agent is applied uniformly at the end of the work shift. A thin overlay of new asphalt concrete, or a seal coat, is installed sometime later to complete the process. The basic reasons for utilizing surface recycling are:

1. Pavement rehabilitation. Here the depth of scarification is of major importance and the contractor and engineer should endeavor to achieve the maximum depth of penetration from the rakes. This should be done with care to insure the asphalt cement binding material in the treated layer is not damaged or destroyed by over application of heat.
2. Surface preparation for a strengthening overlay. Frequently specified for airport and highway construction. Recycling functions to insure the existing surface does not possess contaminants, such as paint stripes, fuel and oil drippings or rubber tire impact marks. The necessity for load transfer from the new overlay to the old is extremely important and adds to the structural value of an overlay. It is thought that this may be due to the mechanical keying action, but may also be a result of addition of the recycling oil which greatly enhances the performance characteristics of aged asphalt binder in the original pavement.

Methods of Recycling

There are two methods of performing surface recycling, i.e., the paving train method and the two stage technique (5). The paving "train" came first and involved pretreating the surface and installing an overlay at the same time in a coordinated operation. This "train" consisted of a heater scarifier machine, oil distributor and conventional paving equipment. All operations are programmed to be performed within a distance of 700 feet. The coordination of such a paving operation and the difficulty in applying a uniform spread of asphalt recycling agent on the treated surface led innovators to develop other methods of installing the surface. The two stage method is more frequently used today and separates the paving operation and surface recycling crew.

Heating

In either case, the process consists of passing one or more machine-mounted high intensity heaters over the surface to be repaired at a speed which will allow the distressed material to be softened. This speed varies widely, depending on several factors. Typical speeds range between 1.5 and 15 m/min (5 to 50 ft/min). The heaters should bring the surface asphalt to a temperature somewhere between 110 to 150°C (230 to 300°F) with the ideal temperature generally in the 125°C (250°F) range during the compaction process. Although much argument and discussion has been directed toward the terms "radiant" and "direct" heating, there is little supporting evidence that any one machine is superior to another in raising pavement temperature. The time of exposure of a constant heat source will cause an elevation of temperature in direct relationship and two machines or more will develop a uniform rise of temperature in the recycled layer without harm to the binder.

Care should be exercised to avoid charring the pavement which may damaged the asphalt, resulting in undesirable visible emissions. This can be avoided by either reducing the burner combustion heat or increasing the equipment rate of travel. The temperature may be verified or measured by mounding the scarified mix and inserting a thermometer as with conventional new paving material.

Scarifying

A scarification depth of 19 mm or 3/4" minimum is recommended; and as mentioned, for certain types of pavement, multiple heaters may be necessary to allow the heat to penetrate a seal coat. When multiples are used, the first preheats only to raise the temperature, while the last machine heats and scarifies the pavement.

Equipment Improvements

1. Extended length, high reflective combustion chambers (16-30 feet) insure deeper heat penetration.
2. Improved down pressure on scarifier rakes with stronger rake assemblies improves operation.
3. A heavier power train facilitates scarifying.
4. Better combustion is achieved with LPG fuel for cleanliness in a lightweight refractory oven.
5. Dual operator controls help.

Applying Recycling Agent

The process of pavement aging or oxidation consists of a chemical reaction which slowly changes the characteristics of the asphalt cement. The effect of this change is a gradual embrittlement of the pavement (6). An oxidized pavement usually appears gray, dried out and dull.

The theory for surface recycling is based on the fact that oxidation occurs most rapidly at the surface, which is in contact with the elements. The surface may have lost some of its resiliency and perhaps has begun to show cracking; while underneath the asphalt binder is relatively unaffected

by its environment and in nearly new condition. Studies reported by Coon and Wright (7) indicate no change in relative viscosity of binder below 3/4" level on pavements 4 to 151 months of age.

Chemical additives, called recycling agents, have been developed which reverse this oxidation process by restoring some of the lost constituents, and in so doing, replasticize the asphalt cement. The selection and application of one of these liquids is an important step in surface recycling.

Some agents are proprietary recycling agents, while others are emulsified asphalts which are usually applied using a distributor truck. The agent should be applied at the highest temperature recommended by the refiner to permit even distribution throughout the loosened material.

Testing

The amount of recycling agent to be applied to the scarified material layer is determined prior to beginning work. This is done by removing three or more six inch diameter core samples from the structure for testing in a laboratory (8). One core is tested as is to determine the viscosity and ductility of the existing asphalt in the top 3/4". The other two are heated, scarified to a depth of 3/4", then 0.1 gsy of recycling agent concentrate is pread on one core and 0.2 gsy on the other. These cores are then placed in a 140°F oven for a minimum of three days, after which the asphalt is extracted from the top 3/4" of each core and tested. The quantity selected is mathmatically added to the existing asphalt percentage to determine feasibility of improving the binder qualities without overasphalting the layer. Regardless of the type of recycling agent used, the same type of test can be performed to first ascertain the lowering of viscosity obtained from using a specific additive and then compare various agents available to treat a hardened asphalt cement. Field adjustment should be made by the inspector when it is apparent that there is a discontinuity in material or that the indicated laboratory amount is causing either a deficiency or excess of oil.

Asphalt Pavement Overlay

Generally, in the "train" mode, a standard overlay follows surface recycling as soon as practical. It takes but a few minutes for the remixed material to cool to ambient temperature, but the new mix arriving on the job at 270°F reheats the loosened material, welding the surface together. A closely spaced operation can cause difficulties in that large construction equipment (heater scarifier, distributor truck, haul trucks, asphalt paver and rollers) is concentrated in a relatively small area. Coordination of the equipment to function smoothly can be a problem. If it is not possible to achieve an even oil spread application or coordinate recycling equipment production with paving material, it may be advisable to adopt two stage operation.

The thickness of the pavement overlay chosen depends upon the purpose of the recycling. If the primary goal is to rejuvenate the upper layer of existing material and improve the riding qualities of the street that is structurally adequate, a minimum thickness will suffice. This minimum thickness depends mainly upon the gradation of aggregate in the new mix. As a general guide, the overlay thickness should be no less than 1.5 times the maximum particle size in the new mix.

Crack Prevention

The pavement overlay mix design selected to cover the recycled surface requires consideration of its function. In areas of sparse rainfall where existing pavements show signs of actinic aging, an open graded plant mix is extremely effective. The wide shrinkage cracks common in desert regions due to the drying out of the pavement, render the surfaces rough. During cold weather, wind blown materials often fill the open cracks preventing them from closing during the warm season which causes an extruded bump on either side of the crack. The open graded plant mix fills the crack and the heavier asphalt film on the aggregate keeps the crack from reappearing in the finished surface. This improves the appearance and riding qualities of an otherwise difficult pavement for a much longer duration of time.

Waterproofing Structure

In other sections of the country, a dense graded asphalt plant mix is chosen for its waterproofing qualities to prevent snow and moisture from penetrating the subgrade and softening the entire structure. Should alligator cracks indicate a diffused or even distribution of stresses in the existing pavement, the addition of a conventional dense graded plant mix overlay will improve the structure and provide years of continuous service.

Heavier Load Service

If the primary purpose of resurface/recycling is to increase the structural capacity, the overlay should be designed according to conventional procedures to yield the required strength. While each project must be analyzed for its specific needs and thickness of new asphalt to be placed, it generally is placed at 1" minimum thickness; however, the upper limit can range from 2 to 4" depending upon the improvement to the structural section that may be required.

Variations of the Procedure

Frequently, the sequence of operations in the paving "train" method recycling is reordered. The steps in the two stage construction are heat, scarify, compact, apply oil additive and overlay. Usually there is a delay between application of the recycling agent and the overlay. A roller should follow immediately behind the scarifying machine so that the mix is compacted at an elevated temperature. The recycling oil is than applied, usually at the end of the working day, insuring a continuous uniform application.

After the pretreatment is completed, the asphalt laydown operation proceeds at a uniform rate of speed, coordinated with the arrival of trucks to the spreader. This is most evenly matched with the plant capacity which leads to a higher quality finished surface at a reduced paving cost.

If the street is open to traffic for a prolonged period before a cover is installed, some caution should be exerted to prevent high speed traffic degradation of the surface. This can be done by signs or a light application of emulsified asphalt on the surface to tighten up the aggregate and provide an armour until the resurfacing or seal treatment is scheduled.

Process Improvements

1. Contaminants or multiple chip seals should be cold planed in advance to allow proper heat transfer to underlying material.

2. Multimple machines raise temperature in even gradients without damaging asphalt binders.
3. Mechanical screeding levels and redistributes material from deep scarifying.
4. Rolling densified recycled mix while temperature remains elevated.
5. Recycling agents available in varieties to suite different pavement conditions are applied after compaction.
6. Two stage construction permits lower cost of installing thin overlays.

A project will usually be more efficiently accomplished using stage construction for the following reasons.

The two stage operation is more economical for each operation and will actually provide a more uniform and better product in the final analysis. In post job samples of two stage and train operations, there is no visible lack of bond when using the two step operation.

The inspector viewing surface recycling can measure scarification depth and control the rate of application of recycling agent. He can later observe the paving operation without dividing his time between the two functions. Density requirements specified by most agencies can be more easily obtained in the two stage operation. A rubber tired compactor is preferred, but a steel roller may be utilized to densify the remixed surface and provide compaction immediately following heater scarifying.

Should the condition of the existing pavement warrant a heavy application rate of recycling agent, a delay of several days may be necessary for the agent to be absorbed into the pavement so that bleeding through the overlay is avoided. A uniform application eliminates the distributor marks caused by overspray and laps.

It is my belief by the use of seal coats and thin asphalt overlays to cover the streets that need improved riding qualities the waterproof flexible structures can be extended. Surface recycling offers engineers an ideal way of preparing and rehabiliting the pavement section to bring it to the conditions where these thin overlays can be installed to add life. Many Western cities have pioneered the development of higher quality surface recycling to virtually eliminate reflective cracking through thin asphalt overlays and save as much as 25 to 30 percent of the cost of new material at today's prices. As the cost of asphalt cement escalates and its availability diminishes, the use of surface recycling must be considered in more and more instances to rehabilitate existing streets.

References

1. R.A. Jimenez, State-of-Art of Surface Recycling, (page 40 this volume) National Seminar on Asphalt Pavement Recycling, Dallas Fort Worth, Texas, October 14-16, 1980.
2. Interim Guidelines for Recycling Pavement Materials, NCHRP Report No. 224, Transportation Research Board, 1980.
3. G.F. Whitney, Thin Overlays and Special Applications, Symposium on Urban Paving Problem - MCAI, Washington, D.C., January 13-17, 1969.
4. R.J. Peters, Surface Recycling - Quality Control, Asphalt Recycling and Reclaiming Association, Palm Springs, California, March 1980.
5. Asphalt Institute MISC 77-3, 1977, Surface Recycling of Asphalt Pavements by the Heater Overlay Process.
6. D.D. Davidson, William Canessa and S.J. Escobar, Practical Aspects of Reconstituting Deteriorated Bituminous Pavements, 1979, American Society of Testing Materials.
7. R.F. Coons and Paul H. Wright, An Investigation of the Hardening of Asphalt Recovered from Pavement of Various Ages, Proceedings of the Association of Asphalt Paving Technologists, Volume 37, 1978, Page 510.
8. William Canessa, Reclamite's Function with the Heater Scarifyer, Fifth Annual Texas Public Works Short Course, Texas A&M, College Station, Texas, February 23-25, 1976.

Appendix A - Guide Specification

The work shall be accomplished by heating, scarifying, releveling, compacting and applying a recycling agent to the existing asphalt surface.

Equipment

1. The equipment used to heat and scarify asphalt surface shall be fueled by liquified petroleum gas. It shall fully meet the standards of the State and Local Bureau of Air Pollution Control. The combustion chamber shall be insulated, rear wheel positioned and equipped with burners rated at a minimum of 15,000,000 BTU's per hour. The machine shall be equipped with two rows of spring-equalized scarifier leveling rakes, removable heard-faced teeth incorporating an automatic release for manhole and valve protection. A competent operating crew, including a service vehicle shall be provided.
2. The equipment used to distribute and level the scarified material shall be an approved paving machine equipped with an operating vibratory or oscillating heated screed. A two man operating crew shall be provided.
3. One pneumatic-tired roller with operator shall be furnished to compact the scarified material. The contractor alternately may furnish another type compactor if approved by the engineer.
4. One asphalt, cab-controlled, liquid spreader with operator shall be furnished to distribute the asphalt rejuvenating agent.

Construction Details

Prior to commencing surface recycling, the pavement shall be cleaned of all extraneous material. Power brooming may be supplemented by hand brooming until all deleterious material has been removed.

A minimum of two heater units will be utilized in tandem so that the heat emitted and the rate of travel will achieve specified requirements. The number of additional heater units shall be determined by the contractor; however, only the scarifier rakes on the final heater unit of the series shall scarify. A minimum production of 15,000 square yards per day shall be required.

The existing asphalt surface shall be heated from 6 to 12 inches wider than the width to be processed. The temperature of the scarified material shall be between 200 and 300°F when measured behind the scarifier.

The weight of existing asphalt surface has been estimated to be approximately 144 pounds per cubic foot. On this basis, a minimum of nine pounds per square foot of existing surface shall be scarified to obtain a depth of between 3/4 and 1 inch. If tests indicate that the material weighs either less than 137 or more than 151 pounds per cubic foot, the weight per square foot requirement will be adjusted accordingly by the engineer.

Scarification will be deemed acceptable when the moving average of three consecutive random weight tests per hour indicates that the required depth has been scarified. The weight of the existing asphalt surface will be determined in accordance with the requirements of AASHTO T-166 from scarified material compacted in accordance with requirements of AASHTO T-245, with the exception that the compaction temperature shall be 270°±F.

The scarified material shall be distributed and leveled only the width processed and be rolled immediately while it possesses sufficient heat to be properly compacted. Following compaction, the asphalt recycling agent shall be applied undiluted to the retreated surface. The rate of application shall be determined by the enigneer based on laboratory tests of the material and analysis of the effect on the embrittled asphalt binder.

In addition to the applicable specification covered by R.A. Jimenez (1), the following items are of special interest for urban work.

Protection of Existing Improvements

Since high temperatures are required in the surface recycling operation, the Contractor shall exercise care against possible injury or damage to existing improvements. The Contractor shall protect all existing curbs, gutters, trees, shrubbery and other improvements from damage. The smaller parkway trees shall be protected by shields and overhanging trees may be sprayed with water to inhibit damage. No machine with an open flame exhaust will be permitted. Existing improvements damaged by the Contractor shall be repaired or replaced to the satisfaction of the City Engineer at no cost to the City.

Smog Control

The Contractor shall minimize the escaping of solids into the air by either the machine or burning of pavement during the heater-remix operation. The machine shall be operated under a permit of the local Air Pollution Control District and shall not be in violation of Rule 1120, South Coast Air Quality Management District requirement. In the event that a smoke problem develops and becomes excessive, it may be necessary to remove the contaminant by cold planing to reduce the problem. No additional compensation will be allowed for any necessary steps required to reduce emissions.

Testing and Control

The Contractor shall furnish the services of a registered professional engineer and laboratory specializing in asphalt technology. Abson recovery tests shall be made on representative cores prior to construction to obtain asphalt penetration (ASTM D-5) and to determine results of treating binder with variable types of additive. No work shall be undertaken until the laboratory report has been approved by the Engineer. At an appropriate period following construction, cores shall be taken from the streets and a report made to the Engineer indicating changes in asphalt penetration and ductility obtained by recycling. The cost of testing and preparation of reports shall be included in the cost per square yard for heating and remixing surface. The number of cores required shall not exceed 1 per 10,000 square yards of treated pavement.

Measurement and Pavement

Cost of pretreatment, including cleaning and heater-remixing, but excluding recycling agent, shall be paid for in square yeards of surface area covered regardless of the number of operations involved to obtain a satisfactory job in the opinion of the Engineer.

The asphalt recycling agent, paid for by weight, shall be weighed on sealed scales regularly inspected by State Bureau of Weights and Measures, or may be measured in some other approved manner. A load slip shall be furnished for each vehicle weighed and slip shall be delivered to the Engineer at point of delivery of material. Asphalt concrete overlay required shall not be paid for under this section.

Appendix B

Rule 1120 - Asphalt Pavement Heaters

A person shall not operate an asphalt pavement surface heater or an asphalt heater-remixer for the purpose of maintaining, reconditioning, reconstructing or removing asphalt pavement unless all of the following requirements are met:

1. Black or gray smoke emission of more than 60 consecutive seconds duration shall not be discharged to the atmosphere and in aggregate, black or gray smoke emissions shall not exceed a total of three minutes in any one hour of heater operation. For the purpose of this rule, black or gray smoke is to be viewed by an observer at the point of greatest opacity.

2. Visible emissions of more than 40% opacity, other than black or gray smoke, shall not be discharged to the atmosphere for a period of periods totalling more than three minutes in any one hour. For the purpose of this rule, visible emissions are to be viewed by an observer at a point no lower than 36 inches above the pavement.

3. All units of equipment are fired with gaseous fuels that do not contain in excess of 80 ppm by volume of sulfur compounds calculated as H_2S, or with diesel fuels that do not contain more sulfur than specified by the California Air Resources Board.

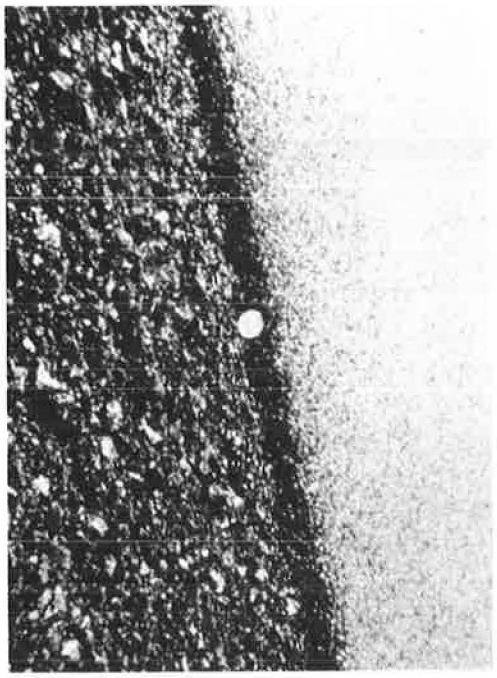
4. Grease, crack pouring materials or oily substances that burn or produce smoke are removed by mechanical grinding, by cold planing or by other mechanical means prior to the use of the heating equipment on the contaiminate area.

5. Asphalt pavement at the work site is cleared of paper, wood, vegetation and other combustible refuse prior to operation of the heating equipment.

6. The Executive Officer is notified of an operation using pavement heaters within 10 days after a contract is signed authorizing such work and again, at least 24 hours before an operation starts. Each notification shall describe the location, estimated starting time and an estimate of the time to complete the work.

7. The equipment is operated only during days on which open burning is allowed. However, an operation that begins on a day when open buring is allowed, may be continued on successive days whether open burning is allowed or not allowed. Information concerning whether a proposed operating day meets the criteria specified in this subparagraph (g) may be obtained from the Executive Officer or his authorized representative.

LARGE SHRINKAGE CRACKS FROM EMBRITTLED ASPHALT, ACCUMULATED TRANSMISSION OIL DRIPPINGS, AND WATER DETERIORATION AT GUTTER

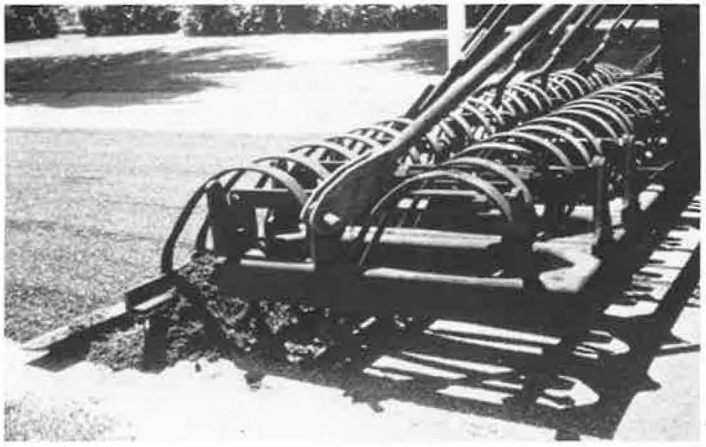


LOOSE REMIXED PAVEMENT ON LEFT
THIN 10 LB/SQ. FT. OVERLAY
AT RIGHT

1963 PHOTO OF FATIGUED SECTION
(2" AC OVER 8" CRB) WITH RECYCLED
SURFACE AND 1" AC BLANKET AT RIGHT,
OVERLAY IS STILL IN SERVICE TODAY
WITHOUT MAINTENANCE

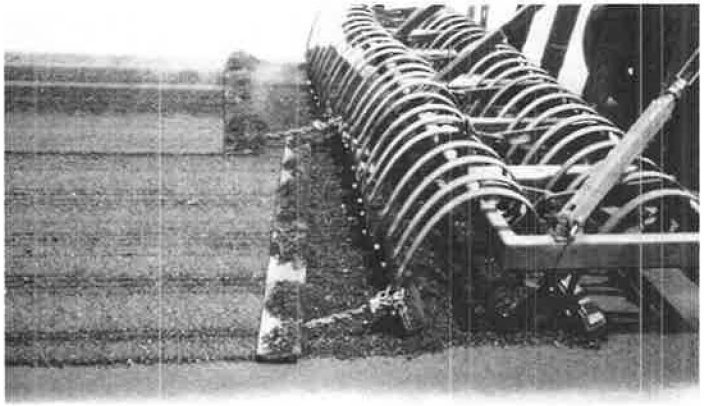
HEATER SCARIFYER, RAKERS AND ROLLER FORM CITY MAINTENANCE PROGRAM

RECYCLING OIL ADDED TO COMPACTED PAVEMENT



CLOSEUP OF RAKES SHOWING LOOSENED MATERIAL AND STRIKE-OFF

SECOND SLURRY COAT APPLIED OVER PRETREATMENT TO FINISH THIS PROJECT



DEEP SCARIFYING LEVELING WITH SIMPLE BLADE DRAG

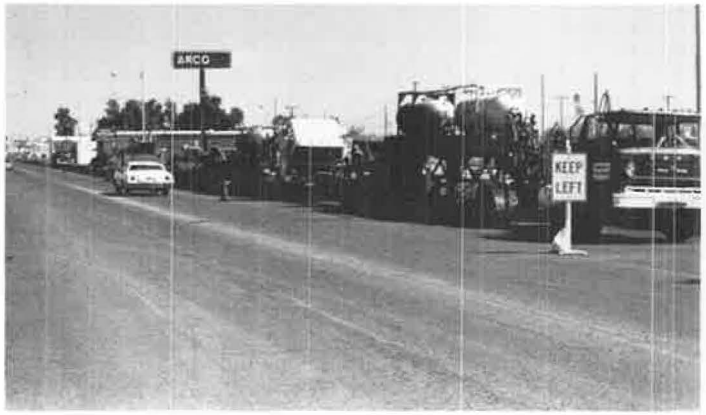
CHIP SEAL WITH UNSEALED CONTROL SECTION IN FOREGROUND

COMPACTED SURFACE AFTER RECLAMITE APPLICATION

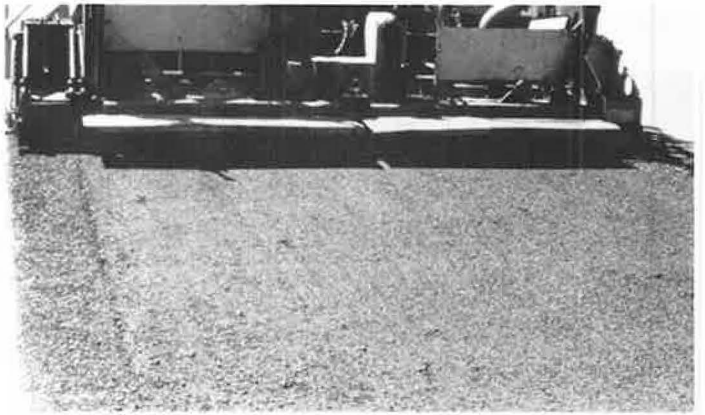
CLOSEUP OF 3/8" MAXIMUM CHIP TREATMENT ON RECYCLED PAVEMENT

EXTRA LONG 30' COMBUSTION CHAMBER FOR SURFACE RECYCLING MATERIAL, COURTESY ASPHALT EQUIPMENT, INC.

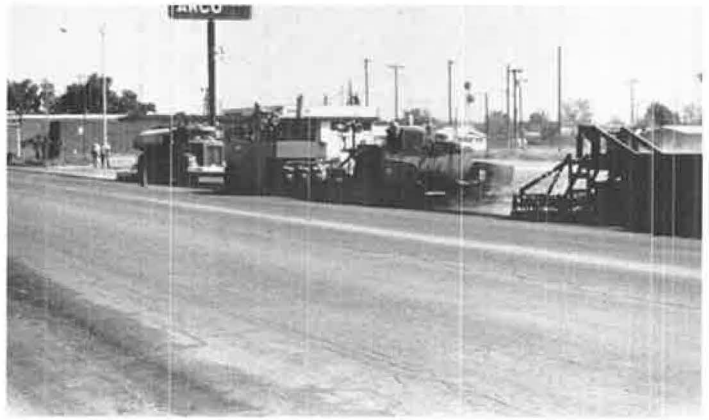
CLOSEUP OF RAKE PENETRATION FROM H.D. SCARIFYER ASSEMBLY PRODUCING 1" SURFACE RECYCLING - NOTE SHRINKAGE CRACK AT RIGHT



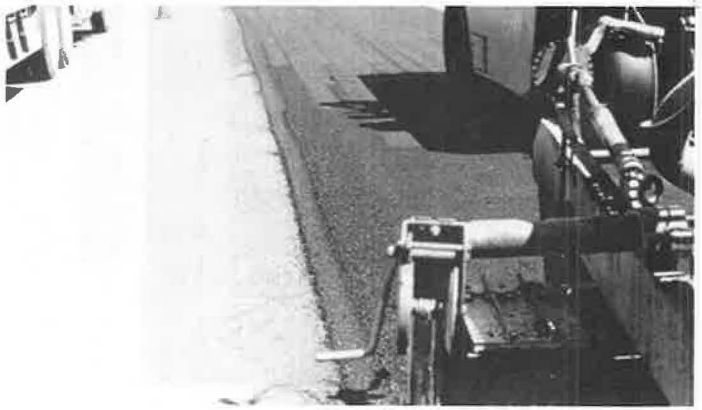
TWO STAGE RECYCLING IN COOLIDGE, ARIZONA WITH 2 HEATERS - NOTE CLEANLINESS OF OPERATION



SCREEDED MATERIAL 9 LB/SQ. FT. AT 270°F PRIOR TO COMPACTION



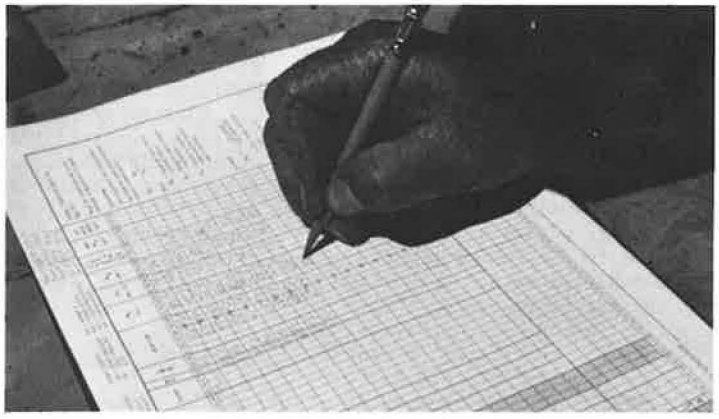
SCREED, RUBBER TIRED COMPACTOR AND OIL SPREADING TRUCK



RUBBER TIRED COMPACTOR FOLLOWS CLOSE TO SCREED

INSPECTOR MEASURES TEMPERATURE AND TAKES SAMPLE
OF RECYCLED MATERIAL FRONT OF SCREED

CLOSEUP OF MATERIAL AND GRADUATED TEST RING



SAMPLE WEIGHT IS NOTED AND MOVING AVERAGE OF
3 PER HOUR DETERMINES COMPLIANCE