PRACTICAL ASPECTS OF THE USE OF ASPHALT-RUBBER COMPOSITIONS IN THE PREVENTION OF REFLECTIVE CRACKING

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ABSTRACT

Fatigue failure, characterized by "alligator" pattern cracking, has been the most widespread and serious problem of asphalt pavements since asphalt was first used for the purpose. The cause of this problem is the inherent brittleness of asphalt under the influences of oxidation and low temperatures. Since all flexible pavement structures placed over natural ground are subject to deflection under load, fatigue failure occurs in the asphalt binder of pavements when it is at the "glass point", or brittle condition.

This article tells the story of a long period of research and many field trials, followed finally by success and acceptance, of a method to put true flexibility into the structure of so-called "flexible pavements".

The method involved utilizes a waste product, old tire rubber, incorporated at high heat with asphalt to form a composition that is different from either the rubber or the asphalt but has the properties necessary to control "alligator" pattern cracking. The material is tough and elastic and, when used in the seal coat mode, it prevents the reflection of fatigue cracking up thru the surface, thereby substantially preventing "potholing" and eliminating maintenance.

The asphalt-rubber system, as a routine maintenance and construction procedure, has stood the test of time and public agencies are now using it with increasing frequency in the southwestern part of the United States. The pro-

cedure is solving a long standing maintenance problem and at the same time reaping an ecological benefit by eliminating the problem of the disposal of old automobile tires.

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INTRODUCTION

Early in the history of asphalt pavements, cracking and subsequent deterioration of these pavements was experienced. It was readily apparent that brittleness of the asphalt, especially under cold conditions, was a major contributing factor (6). The natural reaction to this observation was to add rubber in some form to introduce elasticity and reduce the temperature susceptibility of the asphalt. The use of rubber in various forms was therefore tried experimentally in bituminous mixes in many places in the United States and in Europe.

The first problem encountered was one of economics. The relatively high cost of the rubber, compared to that of the asphalt, inhibited the use of rubber in percentages much higher than five percent of the asphalt. While some encouraging results were obtained, the degree of modification to the systems used apparently failed to justify the additional expense involved, as general use did not materialize.

The research and development that is reported in this article was undertaken for the purpose of overcoming the above problems and developing a material and system that would be economically effective in preventing, or substantially controlling, reflective cracking with particular reference to "alligator" pattern cracking resulting from fatigue failure (11).

BACKGROUND

The writer worked in the highway materials field for many years for the United States Bureau of Public Roads, as it was then known, and noticed in travels over the United States and other countries an undue amount of deflection cracking, or "fatigue" cracking (See Photo No. 1). It was quite evident that it was the major distress problem in asphalt pavements (8) (9). The cause was excessive repeated deflection under loading.

Obviously the cost of building a substructure so rigid that it would not deflect was out of the question over most of the highways in the United States (4) (7). The alternative was to build a surface structure that would deflect without disruption or transmitting reflective cracking (5) (8). Therefore, in the winter of 1964-65, we proceeded to experiment in the field with elastomers. These elastomers were of various types and it was natural that they should be standard materials that had been used before. These elastomers had been used in small amounts in asphalt systems for many years. These small quantities were not enough, obviously, to do the job and the use of elastomers was relegated to mostly small trial installations with many inconclusive results.

It was decided that if we were going to prevent reflective cracking we must use an elastomer in quantities that would do the job and not be too expensive. In order to meet these objectives it would be necessary to use a thin course containing a high percentage of a low cost elastomer. This principle dictated the course of our research.

SUMMARY OF RESULTS OF INITIAL LABORATORY TESTS

Prior to the placement of field experiments beginning in the winter of 1964-65, we determined in the laboratory that we could make an asphalt-rubber material that had the elastic and lowered temperature susceptibility properties that we felt we needed. Essentially, we found that by combining granular rubber with asphalt at temperatures in the general range of 350°F to 500°F a time-temperature related reaction took place evidenced by a sudden "jelling" and increase in the viscosity of the composition (See Appendix Page 1). We had similar results with several different asphalt grades and rubbers including reclaimed rubber, ground tire rubber, and crumb type unvulcanized styrene butadiene (SBR).

INITIAL SMALL SCALE FIELD TESTS

After studying the results of this work, a field survey was made to determine the location of the most severe test conditions that could be found so that the answers to the experimental work would be quickly forthcoming (11). The criteria were to locate pavements where the traffic was heavy, preferably with a high percentage of heavy truck traffic, and severe elastic type fatigue failure had already occurred. An area where poor drainage was involved was also desirable for our purpose and one of the test areas did have exceedingly poor drainage (12), (See Photo No. 2).

The locations selected, all in the City of Phoenix, for the various test panels were as follows:

Test panel Nos. 1, 2, 3, 4, 5, 6, 7, 10, 12, 13, 14, 15, 16, 17, 36, 37, and 38 were on Seventh Street just south of Jefferson Street where the traffic volume numbered 13,200 vehicles per day, a large proportion of which were trucks as this street serves an industrial area. The pavement surface was generally covered by "alligator" pattern cracking in an advanced state and the drainage was extremely poor. The cracking pattern was similar to that shown in Photo No. 1, and Photo No. 2 shows the poor drainage.

Test section Nos. 8 and 9 were located on north Central Avenue with daily traffic volumes of 30,800 and 38,400 respectively. Most of this traffic is of passenger-type. There was severe "alligator" type cracking in the wheel tracks but it was not spread as generally over the street as in the previous case.

Test Panel No. 11 was placed on Washington Street which had a traffic count of 18,500 vehicles per day. Many of these are of the commercial and industrial type. This section was in an area which had given continuous trouble for some time, and the general condition was also similar to that shown in Photo No. 1. Test Panel Nos. 18 and 19 were located on the commercial jet runway at the City of Phoenix airport. Test Panel Nos. 40, 41 and 42 were placed on Fifth Street south of Elm Street to test resistance to crack reflection from a soil cement base.

Many of the above test panels consisted of cold, prefabricated, "band-aid" type patches (14). These are tacked to an existing surface by applying gasoline or a liquid asphalt tack coat. The gasoline forms its own tack by partial solution of the asphalt in the "band-aid" and the pavement surface. These small patches can be applied in moments without traffic interference between traffic signals. Fatigue type "alligator" cracking will not reflect through this material (See Photo No. 3).

The "band-aid" type, cold applied, patches are made by combining the hot asphalt at temperatures of 420^{O}F plus, together with the rubber and hot aggregate. We have used principally ground tire peel, partially devulcanized, reclaimed rubber, and ground SBR synthetic rubbers of various types.

The ideal proportions for the various rubbers do vary somewhat but generally stay within the range of 25 to 35 percent. The hot jell-like mixture is poured on a backing of paper or other material, and the aggregate can be either combined in the mixture, be placed on the backing, or on top of the hot mixture, for a wearing course. The proportions of aggregate to the hot mixture can be varied within a rather wide range. Minimum percentages of aggregate make for a softer and more flexible patch than where the maximum proportions are used. The aggregate should be clean and free of fines in order to avoid over-stiffening of the final product.

The material can be cut, after cooling, into various sized "band-aid" type patches or it can be made into large rolls from which patches can be cut, according to the dimensions required for an individual.circumstance. Various releasing agents can be used to keep the patches from sticking together when stacked or rolled. In the roll form, the material could also be used to surface concrete bridge decks that have begun to spall, steel bridge decks, military metal landing strip panels, and industrial roofing.

SUMMARY OF FINDINGS OF SMALL SCALE FIELD TESTS

These tests, which take us up to the summer of 1966, demonstrated that the concept of using a thin elastic membrane to prevent crack reflection over "alligator" cracked and broken asphalt surfaces due to fatigue failure was valid. It could also be concluded that there wasn't enough significant difference in the performance of the elastomers used to make a choice based on quality. Therefore, economics became the criterion and the ground tire rubber proved to be the cheapest.

Other findings were that the best temperature range of the asphalt at the time of adding the rubber was $400^{\circ}F$ to $450^{\circ}F$ but the composition should not be held in that range but be permitted to drop to $300^{\circ}F$ to $350^{\circ}F$. This occurs naturally upon addition of the rubber and mixing.

We also obtained some answers to the percentage of rubber, by weight, of the total composition that might be used. Forty percent was the maximum because more would result in ravelling under traffic due to insufficient cohesion in the composition. On the other hand, at approximately 20 percent rubber some crack reflection began to appear. Thirty-three percent rubber gave optimum temperature susceptibility and is probably ideal for very cold climates, but it presents mixing and placing problems due to high viscosity. The cost is also an adverse factor. Twenty-five percent rubber adequately controlled the crack reflection problem and otherwise qualified best by other criteria, so we settled on this percentage for most of our future work.

Crushed rock chips proved to give excellent service as a wearing surface with high friction properties (10). Sand cover, on the other hand, resulted in over-embedment of the sand, low friction, and poor wearing properties. Some 75, plus or minus, additional small test panels have been placed since 1966 to test various elastomers or combinations. Some of these were placed in cold climates in order to judge cold weather performance. These locations were at high elevations (up to 7,000 feet, plus or minus) in Arizona, New Mexico and Colorado. A panel was also placed in Ohio. The detailing of these tests and the results obtained are far too voluminous for this article. Let it suffice to say that by the end of 1966, we had accumulated enough basic performance information to recommend and proceed with some full scale installations.

FULL SCALE FIELD TRIAL INSTALLATIONS

Our first large scale trial was on the main commercial jet taxiway in January 1967 at Sky Harbor International Airport in Phoenix, Arizona. The pavement in the wheel paths of the large airplanes showed severe "alligator" pattern cracking due to fatigue failure, so this area was selected for a 600 ± square yard test. It was then thought that the best approach would be to use slurry seal type equipment and squeegee the material over the surface instead of trying to spray it. Therefore, an asphalt distributor containing the hot asphalt (85-100 penetration) was connected by a flexible metal hose with the emulsion pump on the slurry seal machine. The granulated rubber was placed in the sand bins and the two materials were combined (67% to 33%) in the mixing compartment. The mixed material then went into the slurry box and was struck off on the pavement by the rubber squeegees. Rock chips were used as a cover on part of the area and sand on another.

This application prevented crack reflection except on the high spots where the squeegees scraped the surface more or less clean of asphalt-rubber. Novertheless, it was still serving after three or four years when reconstruction and realignment of the taxiway took place for other reasons.

Subsequently, four or five larger scale applications were made with the slurry seal equipment and several are still serving to prevent reflection cracking today (See Photo No. 4). However, we were never able to overcome some of the construction problems that resulted in poor workmanship, and a switch was made to spray application.

EXPERIENCE WITH ASPHALT DISTRIBUTOR APPLICATION

We began experimenting with placing the material with standard asphalt distributor equipment in 1967 and by the spring of 1968 had attained considerable experience in the placement of the equivalent of 15 or more lane miles by this method including a major street and portions of the main runways at the principal airport and a satelite airport. In the summer of that year, the Arizona State Highway Department let a contract to apply the material to the frontage roads and ramps of the principal freeway, Interstate 17, in the City of Phoenix.

This experience taught us a great deal about placing problems that we later had to solve. For example, we found that we could not apply a 25 percent rubber, 75 percent asphalt composition without objectionable "roping" (material coming out the spray nipples in ribbons) unless it was applied immediately after mixing. It was necessary to drop to 17 percent to 20 percent rubber to avoid this problem, and our previous tests had shown that we should have 25 percent to be assured of preventing crack reflection.

Another problem involved the mixing of the ground tire rubber into the asphalt in the distributor. We soon found that the circulation system of the distributor was inadequate for the purpose and Mr. Bob Winters, President of Atlos Rubber Company of Los Angeles, had a separate mixer built for charging the distributors. This was a big improvement but it placed an extra operation in the production line. Therefore, Sahuaro Petroleum and Asphalt Company, of Phoenix, Arizona, who are the local applicators of the material, then modified a distributor by increasing feed line diameters, using a larger pump with a more powerful pump engine, and installing an integral power driven mixing device. They now have two of these modified distributors in their fleet and are arranging for two more (See Photos Nos 5 thru 7).

An interesting thing occurred on the first trial of the modified distributor. The test area selected was the principal taxiway for executive aircraft at Sky Harbor International Airport in Phoenix. A wheel path showing advanced fatigue failure was singled out for an application of 0.75 gallons per square yard of asphalt-rubber composition which would be covered with 1/4" nominal sized rock chips. Everyone was so busy watching the mechanical performance of the equipment that we were surprised when the distributor ran out of material far short of when it should have. It turned out that we had accidentally applied 2-1/2 gallons per square yard. We covered the area with chips and as soon as the material cooled the taxiway was opened to traffic. It gave no trouble, and instead of flowing under traffic action, it merely depressed and rebounded elastically. It takes no strain on the imagination to know what would have happened if 2-1/2 gallons per square yard of pure asphalt had been placed instead of asphalt-rubber.

In January 1970 Sahuaro Petroleum and Asphalt Company desired to make a number of tests of their own to discover by full scale trial the practical limits on rates of application for both the asphalt-rubber and chips, grades of asphalt, percentages of rubber, effect of pavement and air temperatures, cold chips, wet chips, hot chips, hot precoated chips, rolling timing, and types of rollers. For this experiment the City selected a half-mile section of a four-lane major street carrying a large percentage of industrial and construction materials traffic, 19th Avenue from Buckeye Road south to Interstate 10. The pavement was in very poor condition and subject to almost constant maintenance.

The section was divided into 152 experimental sections and 105 separate applications, some over bare earth shoulder (See Appendix Page 2 for layout sketch). The details are far too voluminous for this report but are available upon request. Out of it we learned that the minimum rate of application should be approximately 0.50 gallon per square yard of asphalt-rubber, the ideal specifications for the rubber and the asphalt, that its performance over natural ground was phenominally good, and that the optimum rubber content was approximately 25 percent but that we still had a placing problem to solve at that percentage in order to consistently get good workmanship (see the present specifications in the Appendix Pages 3 thru 7 which reflect much of what was learned from this experiment). In spite of the many extreme limits tried on this experiment, almost no maintenance has been required in the three, plus, years since it has been placed and, in many ways, it looks better than when it was first completed (See photos 8 thru 10).

In the spring of 1971 we did a number of experimental projects designed to solve the high viscosity problem and its effect on workmanship which was becoming more important as routine use of the composition and method of application was expanding. We used applications containing from five percent to 20 percent diluent in the asphalt-rubber and finally arrived at 5-1/2 percent to 7-1/2 percent kerosene with a boiling point in excess of 350°F (See specifications in Appendix Pages 3 thru 7).

KEROSENE DILUENT PHENOMENA

In our work in the laboratory with the kerosene diluent, which preceeded the above field applications, we came upon an interesting phenomenon that was useful in the field application. The introduction of the kerosene causes an immediate precipitous drop in viscosity which facilitates spray application. After the passage of as much as 30 minutes the viscosity begins to climb and will eventually reach or exceed the undiluted viscosity without appreciable loss by evaporation (See Page 8 in the Appendix). This delayed stiffening effect is of great assistance in holding the chips against dislodgement by traffic during the early tender period before final "set". It is believed that the phenomenon is due to selective absorption of the kerosene by the rubber particles.

A most important factor in the success of the asphalt-rubber composition in resisting reflective cracking is its much lower temperature susceptibility compared with that of asphalt (See Appendix Page 9). This, of course, greatly increases its cold weather resistance to cracking when subjected to deflection under load.

GROWTH IN GENERAL USE OF THE ASPHALT-RUBBER SYSTEM

There had never been any question about the value of the asphalt-rubber composition after observing results of some of the early field trials and particularly the 19th Avenue experiment. There had been workmanship problems in application, and now that this problem had been solved by the kerosene dilution procedure, management people in public agencies were ready to start using the process as a standard procedure (15). For example, the City of Phoenix added the specification to their "Standard Specifications" book and let contracts for major street application of the asphalt-rubber system as follows:

Phoenix Major Street Placement of Asphalt-Rubber

Date	Major Street Miles	Collector Street Miles	Lane Miles	Total Cost	Cost per Lane Mile
1971	4.0		23	$ 79,292	$ 3,430
1972	5.3	0.3	25	88,442	3,560
1973	22.8	2.2	108	447,049	4,130

(All Phoenix asphalt-rubber placement since 1967 totals a lane mile equivalent of 300± miles)

In addition to the above, the Arizona Highway Department has used the process for resurfacing 40 to 45 miles of primary, urban and interstate mileage, five smaller cities and towns in Arizona and three or four in California, some primary mileage in the States of New Mexico, Nevada and Utah, as an alternate construction procedure allowing reduced pavement structure thickness in residential improvement projects in Phoenix (See Appendix Page 10), on military airfields, and on some 350,000 square yards on Sky Harbor International Airport runways, taxiways and aprons in Phoenix (See Photos 11 and 12). All of this is indicative of the growing appreciation of the useful properties of the asphalt-rubber system, and its transition from an experimental operation to a standard construction and maintenance procedure.

Mr. Robert L. Dunning, a California consulting engineer in the Los Angeles area described the properties of asphalt-rubber treatment quite aptly in a report to the City of Palm Springs, California on their resurfacing program. I quote:

> "It is unfortunate, in my opinion, that the term "seal" is used, as a seal generally implies a maintenance procedure rather than a construction procedure. As an example, in constructing a macadam, repeated chip seals of differing sizes are used to build up the surface. Since it is a construction procedure, we call it a macadam - not a repeated chip seal. In a like manner, the Asphalt-Rubber Seal is not simply a maintenance procedure, but is a system which, when used properly, takes the place of another construction procedure such as reconstruction of a pavement, or overlaying with two to four inches of asphalt concrete.

Indeed, there is a reason to believe that on badly cracked pavements, the Asphalt-Rubber Seal will perform more satisfactorily than two or more inches of an asphalt concrete overlay. What the Asphalt-Rubber Seal will do is prevent cracking from reflecting into its surface when placed over a badly cracked asphalt surface. The resulting wearing surface has the appearance of a chip seal and performs very well. The Asphalt-Rubber Seal is flexible and will follow deflections or other movements of the pavement without rupture. It may be visualized as an aggregate impregnated rubbery skin which is glued to the pavement as a wearing surface.

As a surface a rock or two thick, we would not expect the Asphalt-Rubber Seal to be used where it is necessary to reform the contour of the pavement. Thus, if there is large scale subsidence or rutting, the same subsidence or rutting should be expected to be present after the placement of the Asphalt-Rubber Seal, although the cracking will be gone. In addition, if rutting is progressive, the Asphalt-Rubber Seal will not stop it from continuing, but will simply follow it."

FURTHER FIELD EXPERIMENTS

Another experiment of interest, the details of which will be found in the Appendix Pages 12 thru 23, was placed in April 1971 for the purpose of seeing how the asphalt-rubber system would perform when placed directly on a moderately plastic subgrade without intervening base course (15). The subgrade had a plasticity index of 13 to 18 and a percentage passing the No. 200 sieve of 59 to 88. The street is classified as a collector and carries 4,000, plus or minus, vehicles a day over this portion. Only a very few breaks have occurred after nearly three years and these appear to be related to application defects. This is in contrast to the asphalt prime coat which showed fatigue cracking after only one week due to the high deflections under traffic of this subgrade (See Photos 13 and 14).

In 1971 and 1972 full scale experiments were conducted using fully reacted asphalt-rubber composition as a binder in open-graded hot plant mixed and machine laid overlays on commercial jet airport taxiways and on a major street in Phoenix (15). Unreacted ground rubber added at the pugmill was also tried.

Data on these experiments will be found in the Appendix Pages 24 thru 33. They have not been finaled but two findings are now apparent--the binder requirement is much higher for asphalt-rubber composition than for asphalt and the mixes containing the fully reacted composition have performed much better than those where the rubber was added at the pugmill.

An experiment placed at Sky Harbor International Airport in Phoenix in November 1971 on a major jet taxiway was for the purpose of levelling a rough, cracked pavement and preventing crack reflection at the same time with a minimum overlay. The existing pavement received a light tack coat consisting of 0.05 of a gallon of SS-1h emulsified asphalt. This was followed by 52 pounds per square yard of hot open-graded plant mix seal levelling course containing only three percent asphalt. The low percentage of asphalt was for the purpose of leaving void space for the next application which consisted of 0.41 of a gallon per square yard of asphalt-rubber followed by 15 pounds per square yard of sand to prevent pickup. Details are in the Appendix Pages 24 thru 33, Step 1, Item 4 and Step 3, Item 4.

This installations has been successful to date both as a levelling course and for the prevention of "alligator" crack reflection from the underlying bituminous pavement. This performance interested the Arizona Highway Department as they have been experimenting with various thin levelling courses for use over a rough concrete pavement on Interstate I-17 that goes thru the City of Phoenix. They are restricted to a thin overlay, as the pavement is confined by curb and gutter and fixed drainage structures.

Therefore, the Arizona Highway Department and the City of Phoenix have cooperated in placing an experiment in October 1973 of essentially the same above design over two city blocks of an old, rough concrete pavement that was originally placed in an industrial section in the 1920's. The street is used by a number of freight line and other heavy trucks and interstate buses so an early "readout" on the results should be forthcoming. The details are in the Appendix Pages 34 thru 36.

If this system performs as anticipated, and it has to date, it should have widespread use for the purpose of providing a thin course that will serve for levelling and prevention of crack reflection, all within the same thin system.

In 1973 the asphalt-rubber seal system was placed on three bridge decks--two overpasses over Interstate 17 in Phoenix and one on I-40 near Flagstaff, Arizona at an elevation over 7,000 feet where it will be subjected to severe climatic and traffic conditions.

The Arizona Highway Department ran standard wet condition resistivity tests on the three installations and found substantially infinite resistivity thru the surface on all three structures. These experiments will continue to be monitored, as time progresses, by the Highway Department and conclusions will then be forthcoming.

Another interesting development is in connection with the problem of slippage between two layers of asphaltic concrete. This problem is particularly critical on major airports where the "jumbo" jets subject the pavements to high tangenital stresses. Overlays less than four inches in thickness are particularly troublesome. Heater scarifying of the underlying lift has been used to obtain bond between lifts, but in some areas the method has been banned for air pollution reasons. The asphalt-rubber system, using large chips to serve as the rough bonding interface, is being considered for use on several major airports. A limited amount of this system has been successfully placed. The tenacity and toughness of the composition is calculated to prevent slippage by preventing dislodgement of the chips.

The Chinle formation in northeastern Arizona consists largely of a series of bentonitic shales with very high volume change properties corresponding to changes in moisture content. In order to maintain the subgrade moisture content in a uniform condition, and thereby minimize subgrade volume change, the Arizona State Highway Department is placing a considerable mileage of this asphalt-rubber material as a buried sealant under roadway, shoulders, ditches, and backslopes of Interstate 40 in 1974. The results of this experiment should be known within a year or two.

SUMMARY

The asphalt-rubber system in the seal coat mode, as described in this article, is no longer in the experimental stage. It is now a proven and routine construction and maintenance tool, supported by standard agency specifications, applied by general contractors, and used by a number of public agencies. It is obvious that a great deal of research and experimentation was employed in bringing it to this stage, but it does not mean that research will cease. It will continue, as this is the key to progress with any system.

This standard procedure has proven to be very effective in the prevention of reflective cracking due to fatigue in flexure, as evidenced by "alligator" pattern cracking of asphalt concrete pavements. It stops the "pothole" maintenance problem before it occurs (See "before" and "after" photo Nos. 15 and 16 as an example). It is not as effective in maintaining closure of large shrinkage cracks where the primary movement of the surface is horizontal but it does minimize this type of cracking.

The various installations have shown that the asphalt-rubber composition forms a tough, rubbery, elastic membrane that is not nearly as subject to oxidation hardening as asphalt (1) (2). This is probably due to the effect of the anti-oxidants in the tire rubber and the carbon black in the rubber which prevents the penetration of ultra violet rays. It also has high cohesion to almost any surface including teflon. It has withstood stripping from siliceous aggregate under adverse field conditions much better than asphalt.

Still in the experimental, or limited use, stage are the uses of the material as the binder in open and dense graded hot mixes, as a bridge deck sealant, prefabricated patch, slippage plane preventative, levelling and crack reflection preventative in combination with a thin overlay over concrete pavements, roofing, concrete pavement joint sealant, and subgrade moisture barrier.

Installations have been made incorporating all of the above uses, and indications are that favorable results will be forthcoming. They are performing well at present but more time is needed before positive statements can be made.

Meanwhile, the asphalt-rubber system in the seal coat mode has been time tested as a solution to the problem of crack reflection from "alligator" pattern fatigue cracking. Its use and application has been standardized for routine construction and maintenance as more and more public agencies are using it in lieu of heavy overlays employing large quantities of expensive and scarce asphalt. The asphalt requirement per square yard is approximately half, the diesel requirement for haulage is approximately one-third, and hot plant energy is one-third of that for a one-inch standard asphalt-concrete overlay. Its requirements are correspondingly less for the two to four inch thicknesses of asphalt-concrete which it is capable of replacing for use in preventing "alligator" crack reflection. In addition, there is the ecological benefit of eliminating a most troublesome problem--disposal of old automobile tires.

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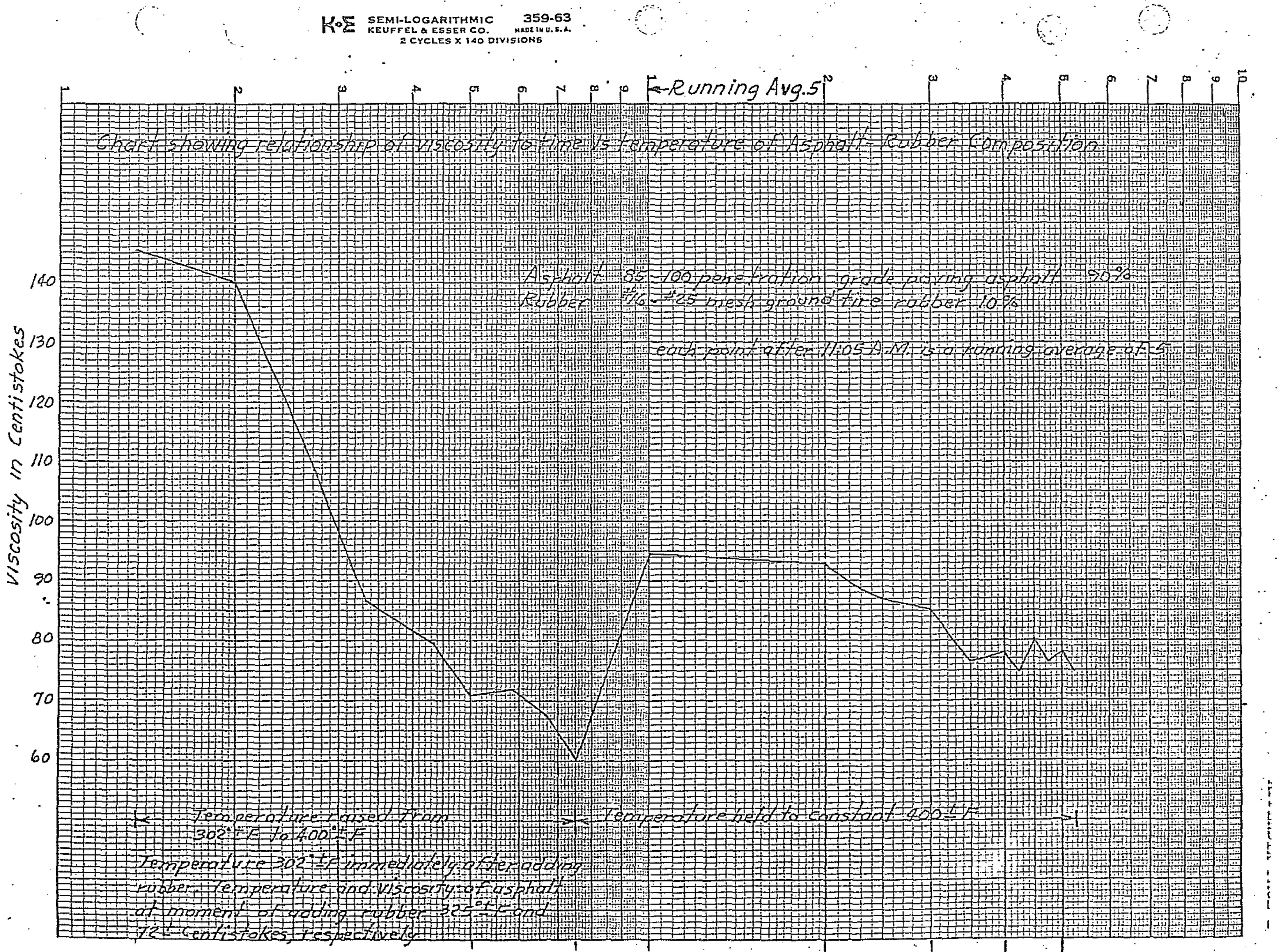
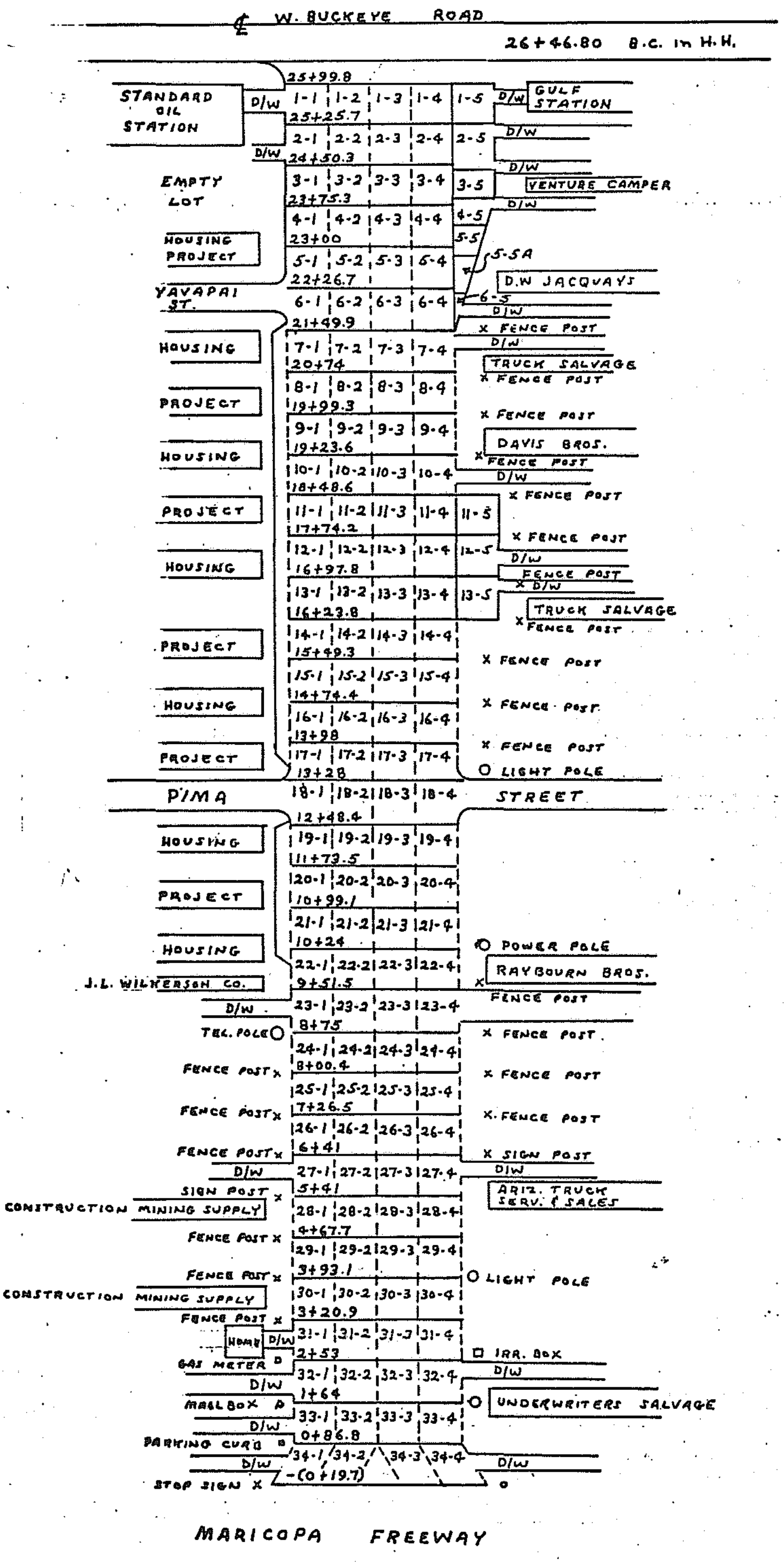

K+E SEMI-LOGARITHMIC 359-63
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 140 DIVISIONS
Chart showing relationship of viscosity to time vs temperature of Asphalt-Rubber Composition
← Running Avg. 5
Asphalt 85-100 penetration grade paving asphalt 90%
Rubber #16-#25 mesh ground tire rubber 10%
each point after 11:05 A.M. is a running average of 5
Viscosity in Centistokes
140
130
120
110
100
90
80
70
60
Temperature raised from 302±F to 400±F
Temperature held to constant 400±F
Temperature 302±F immediately after adding rubber. Temperature and viscosity of asphalt at moment of adding rubber 325±F and 72± Centistokes, respectively



EXPERIMENTAL PROJECT FOR ASPHALT RUBBER APPLICATION ON 19th AVE.

GENERAL SPECIFICATION FOR HOT ASPHALT-RUBBER SEAL TREATMENT FOR STREET AND AIRPORT APPLICATION

(Based on City of Phoenix, Arizona Standard Specification No. 566)

.01 General

(a) This work involves the placing of a hot asphalt-rubber seal treatment on an existing pavement surface in accordance with the following specifications.

.02 Materials

(a) The asphalt cement shall conform, prior to the addition of rubber and kerosene, to the Pacific Coast User's Conference specifications for viscosity grading AR-1000 or AR-2000. (Note 1)

(b) The ground tire rubber shall meet the following requirements:

(1) 95 percent shall pass the No. 16 sieve and not more than 10 percent shall pass the No. 25 sieve. The sieves shall comply with AASHO Designation M-92.

a. The specific gravity of the material shall be 1.15 ± .02 and shall be free from fabric, wire, or other contaminating materials except that up to 4 percent of calcium carbonate shall be included to prevent the particles from sticking together.

(c) Cover Aggregate

(1) The cover aggregate shall have a percentage of wear not to exceed 40 at 500 revolutions when tested in accordance with AASHO Designation T-96, and shall not have a loss greater than 12 percent when tested in accordance with the sodium sulphate soundness test AASHO Designation T-104.

(2) Aggregates of questionable polishing characteristics shall not be used.

(3) It shall be clean and free of any clay coating. A minimum of 75 percent of the material, by weight, retained on the No. 8 sieve, shall have at least one fractured face produced by crushing.

(4) Grading of the stone cover aggregate, when tested in accordance with AASHO Designations T-11 and T-27, shall comply with the following gradations:

NOTE 1: The grade shall be designated in the bid schedule. The lightest grade consistent with climatic and service conditions should be used. AR-1000 grade is suitable for most conditions in the United States. AR-2000 should be used on runways for heavy commercial or military aircraft or where high volumes of starting and stopping traffic are involved.

TABLE NO. 1

1/4-Inch Nominal Cover Aggregate
(for airport and for light street traffic volume)

Sieve Size	Percent Passing
3/8 Inch	100
1/4 Inch	80-100
No. 8	0-5
No. 200	0-2

TABLE NO. 2

3/8-Inch Nominal Cover Aggregate
(for heavy street traffic volume)

Sieve Size	Percent Passing
1/2 Inch	100
3/8 Inch	70-100
1/4 Inch	0-10
No. 8	0-5
No. 200	0-2

(5) The cover aggregate shall be preheated to a temperature between 290°F and 350°F and precoated with not more than 0.75 percent of penetration grade asphalt, as directed by the engineer. (Note 2)

(6) Canvas or similar covers that completely cover each load shall be used to minimize temperature drop of the exposed material.

.03 Equipment

(a) The equipment used by the contractor shall include a power broom for cleaning the existing pavement surface, and three pneumatic tired rollers, each carrying a minimum of 5,000 pounds on each wheel and a minimum of 100 pounds per square inch on each tire; aggregate spreading equipment that can be so adjusted as to spread accurately

---

NOTE 2: Precoating and preheating of cover aggregate may be waived when proper facilities are not available and application conditions are favorable. Precoating is often used for dust control.

the given amounts per square yard, a self-powered pressure distributor equipped with a separate power unit, distributing pump capable of pumping the specified material at the specified rate through the distributor tips, and equipment for heating the bituminous material. The distribution bar on the distributor shall be fully circulating with nipples and valves so constructed that they are in such intimate contact with the circulating asphalt that the nipples will not become partially plugged with congealing asphalt upon standing, thereby causing preliminary streaked or irregular distribution of the asphalt. Any distributor that produces a streaked or irregular distribution of the material shall be promptly removed from the project. Distributor equipment shall include a tachometer, pressure gages, volume measuring devices, and a thermometer for reading temperature of tank contents. The spray bars on the distributor shall be controlled by a bootman riding at the rear of the distributor in such a position that operation of all sprays is in full view and accessible to him for controlling spread widths.

(1) The method and equipment for combining the rubber and asphalt shall be so designed and accessible that the engineer can readily determine the percentages, by weight, of each of the two materials being incorporated into the mixture.

.04 Construction Details

(a) Mixing

(1) The materials shall be combined as rapidly as possible for such a time and at such a temperature that the consistency of the mix approaches that of a semifluid material. The temperature of the asphalt shall be between 350°F and 450°F. At the lower temperature, it will require approximately 30 minutes for the reaction to take place after the start of the addition of rubber. At the higher temperature, the reaction will take place within five minutes; therefore, the temperature used will depend on the type of application and the methods used by the contractor. The engineer shall be the sole judge of when the material has reached application consistency. After reaching the proper consistency, application shall proceed immediately; and in no case shall the mixture be held at temperatures over 325°F for more than one hour after reaching that point.

(2) The proportions of the two materials, by weight, shall be 75 percent, plus or minus 2 percent asphalt, and 25 percent, plus or minus 2 percent rubber. After the full reaction described in (a) Mixing (1) above has

occurred, the mix shall be diluted with kerosene. The amount of kerosene used shall be 5-1/2 percent to 7-1/2 percent, by volume, of the hot asphalt-rubber composition as required for adjusting viscosity for spraying or better "wetting" of the cover aggregate. The kerosene shall have a boiling point of not less than 350°F, and the temperature of the hot composition shall not exceed this temperature at the time of adding the kerosene.

(b) Spreading

(1) Prior to the hot asphalt-rubber treatment, the surface to be sealed shall be cleaned, patched as required, and treated with a "bituminous tack coat" consisting of 0.05± gallon per square yard of diluted emulsified asphalt of the type commonly used in the area for tack coating purposes.

(2) The application rate of the hot asphalt-rubber mixture shall be 0.47 to 0.53 gallon per square yard unless otherwise specified for special conditions (based on 7-1/2 pounds per hot gallon).

(3) Hot asphalt-rubber seal shall be placed only when the pavement temperature is (Note 3) °F or above, and rising. The ambient temperature in the shade shall also be not less than (Note 3) °F.

(4) The application rate of the cover aggregate shall be 25 to 40 pounds per square yard (generally 25 to 27 pounds for 1/4-inch nominal and 35 to 39 pounds for 3/8-inch nominal) as directed by the engineer to prevent pickup by the equipment involved in the spreading and compacting of the cover aggregate. A minimum of four complete coverages shall be made with the pneumatic roller. The rolling of the cover aggregate shall proceed immediately after application in order to ensure maximum embedment of the aggregate. Traffic shall not be permitted on the completed surface until permitted by the engineer but shall be not less than two hours after the completion of rolling.

(5) An application of five to ten pounds per square yard of sand shall be applied after rolling and before opening a lane to traffic.

NOTE 3: Use temperature limitations according to local conditions. Because of the high viscosity of the binder, it is recommended that high, but practical, temperature limitations be used.

General Specification for Hot Asphalt-Rubber
Seal Treatment for Street and Airport Application

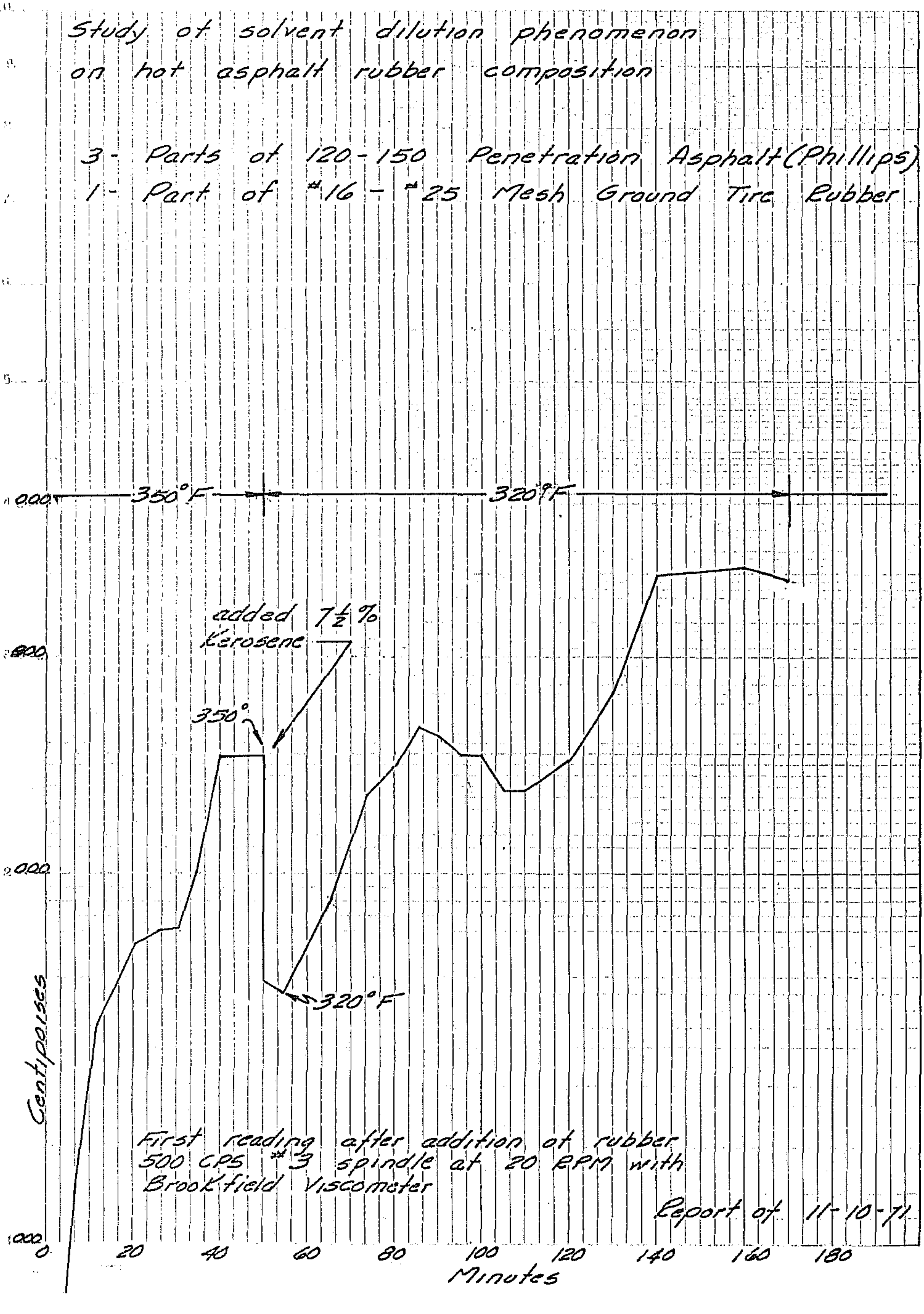
(6) All joint edges shall be swept clean of overlapping cover material prior to the adjacent application of asphalt-rubber material. All reasonable precautions shall be taken to avoid "skips" and "overlaps" at joints and to protect the surfaces of adjacent structures from being spattered or marred. Correction of any such defects will be required at the contractor's expense. All transverse joints shall be made by placing building paper over the ends of the previous applications, and the joining application shall start on the building paper. The paper shall be removed and disposed of to the satisfaction of the engineer.

(7) It has been found that maldistribution of the asphalt-rubber material occurs when distributor bars in excess of ten feet are used for spreading. Therefore, the maximum distributor bar width permitted shall be ten feet, but this may be reduced by the engineer if specification requirements on the uniformity of distribution are not met.

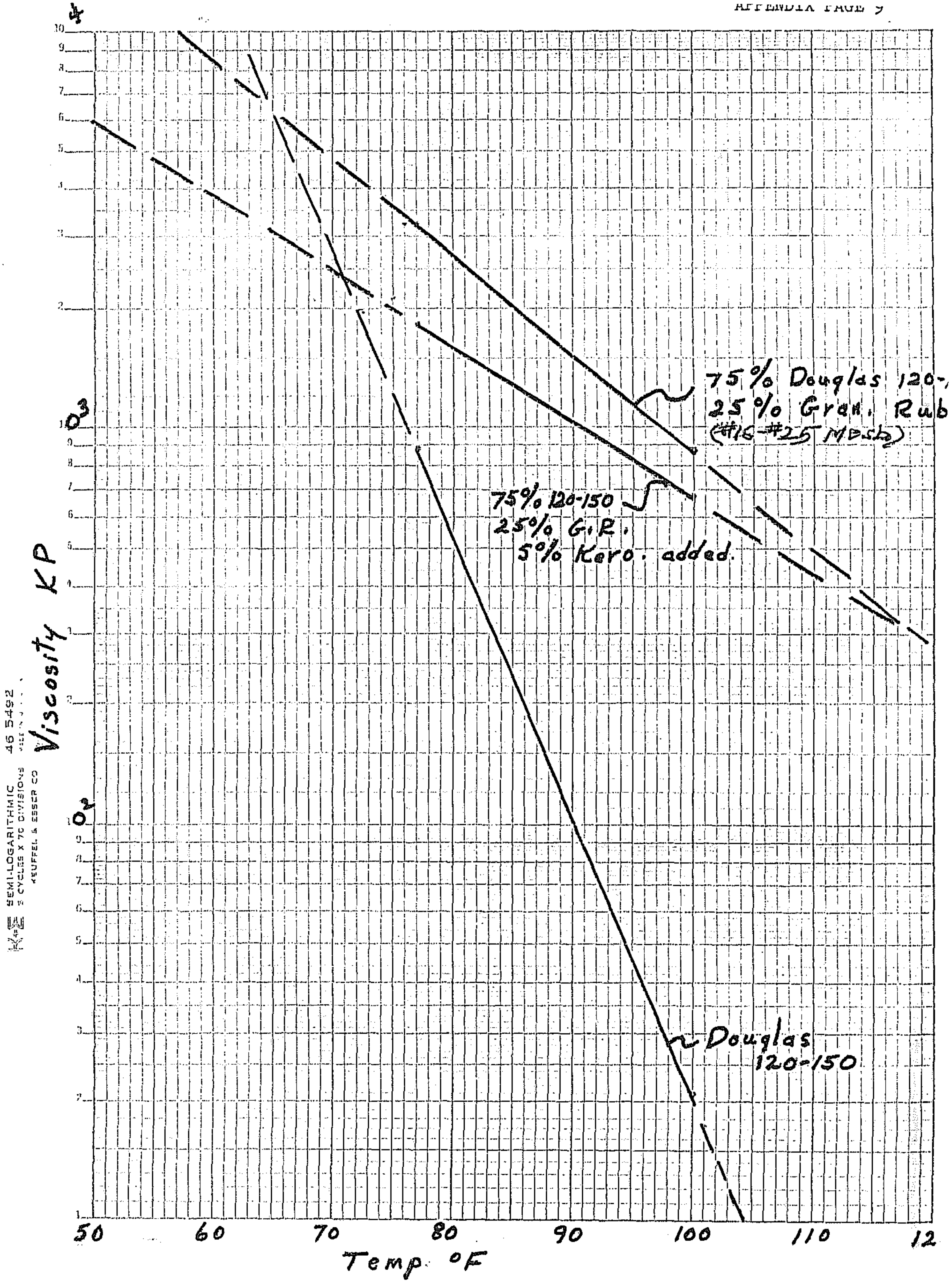
(8) After a final sweeping, and prior to striping, a flush coat shall be applied, if directed by the engineer, except for 200 feet either side of signalized intersections, to the asphalt-rubber treatment consisting of 0.05 to 0.10 gallons per square yard of emulsified asphalt diluted 50-50 with water. The application of the flush coat may be delayed to facilitate curing or to avoid placement under unfavorable high temperature conditions. It may be deleted if chip embedment is 50 percent or greater. The purpose of the flush coat is to prevent chip loss, and its use should be limited to that objective.

.05 Measurement and Payment

This and other incidental specification items to be included in accordance with local specifications.



Study of solvent dilution phenomenon on hot asphalt rubber composition
3- Parts of 120-150 Penetration Asphalt (Phillips)
1- Part of #16 - #25 Mesh Ground Tire Rubber
350°F
320°F
added 7½%
Kerosene
350°
320°F
4,000
3,000
2,000
1,000
Centipoises
First reading after addition of rubber
500 CPS #3 spindle at 20 RPM with
Brookfield Viscometer
Report of 11-10-71
0
20
40
60
80
100
120
140
160
180
Minutes
SEMI-LOGARITHMIC 1 CYCLE X 60 DIVISIONS
KEUFFEL & ESSER CO.
46 4533


75% Douglas 120-, 25% Gran. Rub (#16-#25 Mesh)
75% 120-150 25% G.R. 5% Kero. added.
Douglas 120-150
Viscosity KP
Temp °F
50
60
70
80
90
100
110
12
SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO
46 5492

CITY OF PHOENIX
ARIZONA

DATE September 7, 1971

TO Mr. A. L. Samson

FROM Mr. Charles H. McDonald

SUBJECT Subgrade design alternates for residential streets based on a minimum of five years of trouble-free service as outlined in the September 2, 1971 conference on this subject.

A-2 SECTIONS FOR TYPICAL GOOD SUBGRADE

	Select	ABC	Soil Cement	AC	Asphalt-Rubber
Standard	0	6"	0	2"	0
*1st Alternate	0	0	4½"	1½"	0.5 GSY
2nd Alternate	0	0	0	3½"	0
3rd Alternate	0	0	0	2½"	0.5 GSY

A-2 SECTIONS FOR TYPICAL AVERAGE SUBGRADE

	Select	ABC	Soil Cement	AC	Asphalt-Rubber
Standard	3"	4"	0	2"	0
*1st Alternate	0	0	4½"	1½"	0.5 GSY
2nd Alternate	0	0	0	4"	0
3rd Alternate	0	0	0	3"	0.5 GSY

A-2 SECTIONS FOR TYPICAL POOR SUBGRADE

	Select	ABC	Soil Cement	AC	Asphalt-Rubber
Standard	5"	4"	0	2"	0
*1st Alternate	0	0	**6" 4½"	**2" 1½"	0.5 GSY
2nd Alternate	0	0	0	**7" 5"	0
3rd Alternate	0	0	0	**5" 3½"	0.5 GSY

A preservative seal at six cents per square yard will be required for the standard and second alternates.

*This design (1st alternate) is adequate for the poor subgrade condition, but cannot be significantly reduced for the better subgrade conditions for practical reasons. For the same reasons it is also good for much more than five years without maintenance

**For use on commercial or industrial streets.

The standard section is also good for better than five years, provided that extra precautions are taken to keep surface water out of the base course.

The second and third alternates would probably require an additional treatment of some sort at approximately the five-year interval.

Lignin treatment could be substituted on an equal basis for cement where an A-1 section is used and surface water into the base is eliminated.

Charles H. McDonald

Charles H. McDonald
Engineering Supervisor

CHM:lem

cc: Mr. Glendening
Mr. Attebery
Mr. Harmon
Mr. Nelson
Mr. Schnormeier
Main Reading File

EXPERIMENTAL PROJECT

Kerosene Diluted Asphalt-Rubber Surface on Clay Subgrade

INITIAL REPORT

1) EXPERIMENT NO. 109 PROJECT NO. 55th Avenue

2) DATE OF EXPERIMENT April 13, 1971

3) LOCATION The east 27' of 55th Avenue and the adjacent shoulder slope from south of Indian School Road at Clarendon to 674' north. Also the west 8' of 55th Avenue from the centerline of Clarendon, 40' north.

4) LOCATION and/or CHARACTER OF UNTREATED CONTROL: Untreated subdivision pavement adjacent to the test section.

5) PURPOSE OF THE EXPERIMENT: To provide a durable, flexible, and economical roadway surface over untreated clay subgrade without benefit of an intervening base course.

6) MATERIALS USED: Disintegrated granite; "Peneprime"; 120/150 penetration grade asphalt (75.6%); Atlos ground tire rubber, #16-#25 mesh (24.4%); kerosene in the proportion of 7.8% of the asphalt-rubber mixture as a diluent; 3/8" nominal sized cover aggregate varying in moisture content from dry to wet (2% ± H_2O)

7) TESTING CONSTRUCTION METHODS: The previously compacted (95%+) subgrade was finished and leveled with 1"- of disintegrated granite after which the entire area was treated with "Peneprime" at the rate of .50 gal. per s.y. and allowed to cure. The asphalt and rubber were combined in an especially constructed distributor truck at the plant. Kerosene was added to the mix at the job site, and the designated areas treated in 8' passes. Cover aggregate was spread immediately behind the distributor and rolled. See attached for details.

8) WERE PHOTOGRAPHS TAKEN? Yes

PROGRESS REPORT #1

9) DATE May 3, 1971

10) INSPECTION, OR TESTS, MADE BY: Charles H. McDonald

11) CONDITION OF EXPERIMENT: The roadway surface is in excellent condition particularly in view of the fact that the "Peneprime" prime was showing considerable fatigue failure (alligator cracking) after one week and prior to application of the asphalt-rubber (see photo). A heavy pneumatic roller (5000# plus wheel load and 100 PSI tire pressure) was used to demonstrate superior chip setting properties. Under this load, visual observations indicated deflection of the surface over the weak subgrade. A few spots of "pickup" occured which should be repaired. Shot location #2 showed more chip imbedment and was somewhat darker than shot location #3 but not objectionably so (see photos). A hot gross application of .50 gals. per sq. yd. appears to be ideal for the conditions of this experiment.

5-7-71

EXPERIMENT NO. 109

FINAL REPORT

12) DATE: January 15, 1974

13) INSPECTION MADE BY: Charles H. McDonald

14) CONDITION OF THE EXPERIMENT:

Surface shows minor ravelling in places but no "alligator" cracking. The asphalt-rubber composition shows very little signs of oxidation hardening and remains elastic.

It is concluded that this is a practical and economical method for surface treating low traffic roads without incurring future high maintenance costs.

MIX DATA

MATERIAL	TIME	TEMP. F	LBS.	GALS.	% OF MATERIAL	REMARKS
120/150 Penetration Grade Asphalt	10:15	350°	16,050	(Stick) 2,100	by wt. 75.6%	Scale Weight
Ninety 60# Bags of Ground Tire Rubber	Began 11:15 Ended 11:45	340° 290°	(5,400)	(Stick) 2,830		Theoretical Wei by Bag Count
	11:55	295°	5,190		by wt. 24.4%	Actual
Total Asphalt-Rubber			21,240		100%	Scale Weight
Total Asphalt-Rubber	2:35	285°		(Stick) 2,750	100%	Receded Volume
Kerosene Added	Began 12:40 Ended 12:45	285° 275°		215	7.82%	% of Asphalt-Rubber by Volun (7.5% by volume intended)
Total Mixture				(Stick) 2,965		

APPLICATION DATA

Shot Location (See Sketch)	Time of Application	Time Elapsed from Start of Adding Rubber	Pavement Temperature	Ambient Temperature	Chip Temperature	Mixture Temperature	Rate of Application of Mixture Hot gal. per s.y.			REMARKS
							Goal	Gross	Net	Net gal. per s.y. Excludes Keros
(Backslope only) 1	1:10 p.m.	1 hr. 55 min.	140°F	98°F		270°F	.50	1.57	1.46	bar pressure 60# speed 400' per
2							.50	1.00	.93	bar pressure 60# speed 400' per
3							.50	.50	.46	bar pressure 30# speed 400' per
4							.50	.58	.54	bar pressure 30# speed 400' per
5	2:05 p.m.	2 hr. 50 min.	118°F	98°F		270°F	.50	.67	.62	bar pressure 30# speed 400' per
										Total gallons used 1,640
							.50	.74	.68	Total s.y. shot - 2,225 Job Average
										Total chips used 73,360#
										Total s.y. covered 2,225 33# chips averaged per s.y. Distributor (No. 9) equipped wit #5 (8/32") tips and 5/32" screen

RUBBER EXTRACTION TEST ON ASPHALT-RUBBER
PLACED ON 55TH AVENUE, SOUTH OF INDIAN SCHOOL ROAD
APRIL 13, 1971

Kerosene Content as a % of Asphalt-Rubber	Solvent Used: Benzene (B) Methyl Ethyl Ketone (MEK)	Total Weight in Grams of Sample Tested	Weight in Grams of Extracted Residue	Rubber as a % of Total Sample	Rubber as a % of Asphalt-Rubber	Disolved Rubber as a % of Asphalt-Rubber	Undisolved Rubber Aggregate as a % of Asphalt-Rubber
7.82%	B	15.31	3.25	21.22	22.88		
	MEK	16.73	4.52	27.02	29.12	6.24	22.88

ENGINEERING DEPARTMENT
MATERIALS SAMPLE CARD

MATERIAL Soil	DATE 2-1-71
SOURCE Sub	LAB NO. 50721
CONTRACTOR St. Maint	PROJECT NO. 57021
INSPECTOR McDonald	DEPTH OR THICKNESS 0-6"
PROJECT LOCATION	
SAMPLE LOCATION 6th Ave N/o Clarendon 25' 2/6 N.E.	
TESTS REQUIRED Plasticity	SAMPLED BY

122-130 REV 3-69

REMARKS: APPENDIX PAGE 17

SIEVE SIZE	WT. RET. Accum.	WT. RET. Individ.	% RET. Individ.	% Passing	SPEC.# % Passing
3"					
1-1/2"					
1-1/8"		Street			
1"					
3/4"					
1/2"					
3/8"					
No. 3					
+ No. 4					
- No. 4					
No. 8					
No. 10					
No. 16					
No. 30					
No. 40					
No. 50					
No. 80					
No. 100					
No. 200		175.2		59	
Pass. 200		248.0			
TOTAL		423.2			

COARSE

Total Weight of Sample______

FINE

Wt. of Sample used 423.2

Wt. Oven dried______

Wt. washed & Dried______

Wash______

MATERIAL PASSING #40 SIEVE

L.L. 30 P.L. 17 P.I. 13

Maximum Density______

Optimum Mositure______

FRACTURED FACES

Results	Req'd
0 ____ %	
1 ____ %	
2 ____ %	

TESTED BY Jr. Sills

DATE TEST COMPLETED 2-4-71

4/13/71

122-
Rev.

MATERIALS SAMPLE CARD

REMARKS: APPENDIX PAGE 10

MATERIAL Soil	DATE 4-7-71	TIME
SOURCE Sub B	LAB NO. 50722	
CONTRACTOR St Maint	PROJECT NO. 57721	
INSPECTOR McDonald	DEPTH OR THICKNESS 0-12"	
PROJECT LOCATION		
SAMPLE LOCATION 65th Ave 700' N/o Clarendon		
TESTS REQUIRED PI & wash	SAMPLED BY RMc	

SIEVE SIZE	WT. RET. Accum.	WT. RET. Individ.	% RET. Individ.	% Passing	SPEC.#___ % Passing
3"					
1-1/2"					
1-1/8"		[illegible]			
1"					
3/4"					
1/2"					
3/8"					
No. 3					
+No. 4					
-No. 4					
No. 8					
No. 10					
No. 16					
No. 30					
No. 40					
No. 50					
No. 80					
No. 100					
No. 200		77.5		70	
Pass. 200		177.8			
TOTAL		255.3			

COARSE

Total Weight of Sample___

FINE

Wt. of Sample used 255.3

Wt. Oven dried___

Wt. washed & Dried___

Wash___

MATERIAL PASSING #40 SIEVE

L.L. 35 P.L. 17 P.I. 18

Maximum Density___

Optimum Mositure___

FRACTURED FACES

Results		Req'd
0___	%	___
1___	%	___
2___	%	___

TESTED BY [illegible]

Kawate W.S.

DATE TEST COMPLETED 4-13-

[illegible]
4/13/71

122-8 Rev.

MATERIALS SAMPLE CARD

MATERIAL Soil	DATE 4-7-71 / TIME
SOURCE Sub ⊕	LAB NO. 57?
CONTRACTOR City St. Mark	PROJECT NO. 57921
INSPECTOR McDonald	DEPTH OR THICKNESS 0-6
PROJECT LOCATION	
SAMPLE LOCATION 55 Ave 100' N/o Clarendon	
TESTS REQUIRED PI & wash	SAMPLED BY RC

122-130 REW 3-69

SIEVE SIZE	WT. RET. Accum.	WT. RET. Individ.	% RET. Individ.	% Passing	SPEC.# % Passing
3"					
1-1/2"					
1-1/8"		Soil	Test		
1"					
3/4"					
1/2"					
3/8"					
No. 3					
+No. 4					
-No. 4					
No. 8					
No. 10					
No. 16					
No. 30					
No. 40					
No. 50					
No. 80					
No. 100					
No. 200		121.6		70	
Pass. 200	[illegible]	281.6			
TOTAL		403.2			

REMARKS:

COARSE

Total Weight of Sample

FINE

Wt. of Sample used 403.2

Wt. Oven dried

Wt. washed & Dried

Wash

MATERIAL PASSING #40 SIEV

L.L. 35 P.L. 17 P.I. 18

Maximum Density

Optimum Mositure

FRACTURED FACES

Results		Req'd
0	%	
1	%	
2	%	

TESTED BY Kowalski W.

DATE TEST COMPLETED 4-14

122-
Rev.

ENGINEERING DEPARTMENT
MATERIALS SAMPLE CARD

MATERIAL Soil	DATE 3-26-71 / TIME
SOURCE	LAB NO. 50392
CONTRACTOR Street Maint.	PROJECT NO. WO 57821
INSPECTOR	DEPTH OR THICKNESS 1.0' - 2.0'
PROJECT LOCATION	
SAMPLE LOCATION 55th Ave. 250' N/O Clarendon	
TESTS REQUIRED Proctor P.I. & Wash	SAMPLED BY R G

122-130 NEW 3-69

SIEVE SIZE	WT. RET. Accum.	WT. RET. Individ.	% RET. Individ.	% Passing	SPEC.# % Passing
3"					
1-1/2"					
1-1/8"					
1"					
3/4"					
1/2"					
3/8"					
No. 3					
+No. 4					
-No. 4					
No. 8					
No. 10					
No. 16					
No. 30					
No. 40					
No. 50					
No. 80					
No. 100					
No. 200		25.0		88	
Pass. 200		188.7			
TOTAL		213.7			

REMARKS:

COARSE

Total Weight of Sample

FINE

Wt. of Sample used 213.7

Wt. Oven dried

Wt. washed & Dried

Wash

MATERIAL PASSING #40 SIEVE

L.L. 35 P.L. 20 P.I. 15

Maximum Density

Optimum Mositure

FRACTURED FACES

Results		Req'd
0	%	
1	%	
2	%	

TESTED BY Jasik

DATE TEST COMPLETED 4-8-71

122-8 Rev.

CITY OF PHOENIX
Public Works Department
Engineering Division
MATERIALS TESTING SECTION

COMPACTION REPORT

TYPE OF MATERIAL Soil

DATE OF REPORT 4/8/71

GRANULAR NON-GRANULAR ✓

PROJECT NO. 57821

DATE SAMPLED 4/7/71

CONTRACTOR Street Maintenance

SAMPLED BY R.G.

INSPECTOR Street Maintenance

LAB NO.	LOCATION	Depth of Hole From - To	Optimum Moisture	% of Moisture	Maximum Density	% Density	% Required
50720	55th Avenue North of Clarendon 75' South of North End	0-0.5'	14	10	115	98	95.
50723	55th Avenue 300' ± North of Clarendon	0-1.0'	14	14	115	96	95
50724	55th Avenue 100' North of Clarendon	0-0.5'	14	8	115	98	95

REMARKS:

Copies to:

4-12-71

ENGINEERING DEPARTMENT
MATERIALS SAMPLE CARD

MATERIAL 3/8 Chips (Nominal)	DATE 4-1-71	TIME
SOURCE Union Co Creek	LAB NO. 50553	
CONTRACTOR St Maint	PROJECT NO. 110 57821	
INSPECTOR	DEPTH OR THICKNESS	
PROJECT LOCATION		
SAMPLE LOCATION		
TESTS REQUIRED Gradation	SAMPLED BY Cano	

122-130 REW 3-69

SIEVE SIZE	WT. RET. Accum.	WT. RET. Individ.	% RET. Individ.	% Passing	SPEC.# % Passing
3"					
1-1/2"					
1-1/8"					
1"					
3/4"					
1/2"		0		100	100
3/8"		4.04		78	80-100
1/4"	17.47	13.42		5	0-10
-1/4"		.92			
No. 4					
No. 8					
No. 10					
No. 16					
No. 30					
No. 40					
No. 50					
No. 80					
No. 100					
No. 200					
Pass. 200					
TOTAL					

REMARKS: APPENDIX PAGE 22

COARSE

Total Weight of Sample 18.39

FINE

Wt. of Sample used

Wt. Oven dried

Wt. washed & Dried

Wash

MATERIAL PASSING #40 SIEV

L.L. P.L. P.I.

Maximum Density

Optimum Mositure

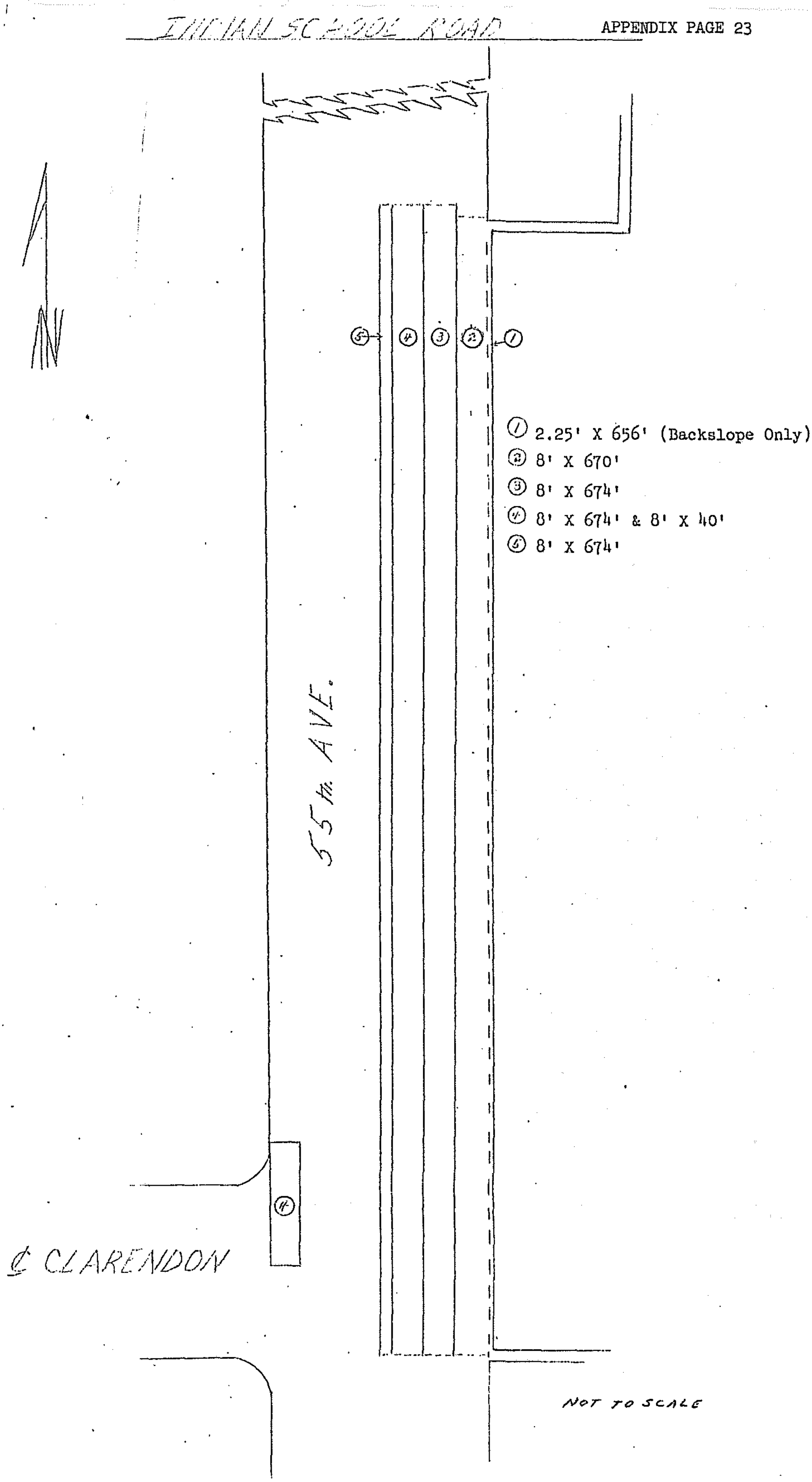
FRACTURED FACES

Results		Req'd
0	%	
1	%	
2	%	

TESTED BY Jasik

DATE TEST COMPLETED 4-1

122-
Rev.


INDIAN SCHOOL ROAD
N
55th AVE.
① 2.25' X 656' (Backslope Only)
② 8' X 670'
③ 8' X 674'
④ 8' X 674' & 8' X 40'
⑤ 8' X 674'
℄ CLARENDON
NOT TO SCALE

CITY OF PHOENIX
ENGINEERING DEPARTMENT
MATERIALS SECTION

EXPERIMENTAL PROJECT: Use of Various Asphalt-Rubber Compositions in Open Graded Mixes and Surface Treatments.

INITIAL REPORT

EXPERIMENT NO. 120-A PROJECT NO. A-71168.00(B) (Change Order #1)

DATE OF EXPERIMENT 11-15-71

LOCATION:

Sky Harbor International Airport, Phoenix. See attached sketches for details.

LOCATION and/or CHARACTER OF UNTREATED CONTROL:

Heater scarified and slurry sealed adjacent sections in northwest T-Hanger area (Sketch No. 5). Untreated area shown on sketch No. 2 and comparative performance between all of the experiments shown on the sketches.

PURPOSE OF THE EXPERIMENT:

Further study of various asphalt-rubber compositions as surface treatments and as plant mixes 1/2" in thickness for airports, by way of practical application to areas in need of treatment because of fatigue and/or flexural failure. One of the chief objectives was to eliminate the loose chip problem while retaining the best properties of the asphalt-rubber.

MATERIALS USED:

85-100 penetration grade paving asphalt; kerosene; Atlos ground tire rubber, designation TP .044 (#16-#25 mesh); Atlos chopped whole tire rubber, designations WTS-4 and WTA; Johns-Manville "Asbaltic Asbestos"; 1/4" nominal sized aggregate chips (used in all mixes - grading attached); plaster sand. See Table No. 1 for individual mixes, percentages, etc. by item number and Table No. 2 for asphalt-rubber-kerosene composition, etc. See sketches No. 1 through No. 5 for geographical placement.

TESTING CONSTRUCTION METHODS:

Step 1 Item No. 4 Taxiway "C" - A conventional 1/4" open graded plant mix, of attached grading, containing 3 percent asphalt was placed and rolled utilizing standard hot plant mix placement procedures.

Step 2 Item No. 5 Northwest T-Hangers - A previously heater scarified and slurry sealed area (see sketch) was shot with an asphalt-rubber-kerosene mixture at an average rate of 0.26 gallons per square yard. This area was then sanded with plaster sand (grading attached).

Step 3 Item No. 4 Taxiway "C" - Following completion of Step 2 the asphalt distributor, containing the asphalt-rubber-kerosene mixture, was routed to shoot the 1/4" open graded plant mix laid in Step 1. An average of 0.33 gallons per square yard was applied. The area was then sanded to prevent pick up.

Step 4 Item No. 3 Taxiway "C-6" - A 1/4" open graded plant mix, containing 2-1/2 percent Johns-Manville "Asbaltic Asbestos", was placed and rolled utilizing standard hot plant mix placement procedures. The asbestos was introduced to the mix at the plant weigh hopper while weighing out the aggregate.

Step 5 Item No. 1 Taxiway "C-6" - The asphalt distributor was moved to the asphalt plant and attached so as to by-pass the plant's asphalt pump, allowing the distributor to pump the fully reacted asphalt-rubber-kerosene mixture directly to the plant scales. A 1/4" open graded plant mix was then batched, the mix being placed and rolled utilizing standard hot plant mix placement procedures.

Step 6 Item No. 2 Taxiway "C-7" - A 1/4" open graded plant mix containing 2-1/2 percent Atlos TP .044, a ground tire tread rubber (-#16, +#25 mesh) was placed and rolled utilizing standard hot plant mix placement procedures. The rubber was introduced to the mix at the weigh hopper, as was the asbestos in Step No. 4.

Step 7 Item No. 2A Taxiway "C-7" - A 1/4" open graded plant mix containing 5 percent Atlos WTS-4, a chopped whole tire rubber and cord (nominal -3/8", +#16 mesh) was batched. Introduction of the rubber and placement of the mix was the same as in Step No. 4.

Step 8 Item No. 2A-W Taxiway "C-7" - A 1/4" open graded plant mix containing 5 percent Atlos WTA, a chopped-shredded whole tire rubber and cord (nominal -1/2" +#16 mesh) was batched. Introduction of the rubber and placement of the mix, again being the same as in Step No. 4. This mix was also utilized on the "fuel farm" road. See Sketch No. 4.

WERE PHOTOGRAPHS TAKEN?

Yes. Before and during construction.

Charles H. McDonald

Charles H. McDonald
Engineering Supervisor

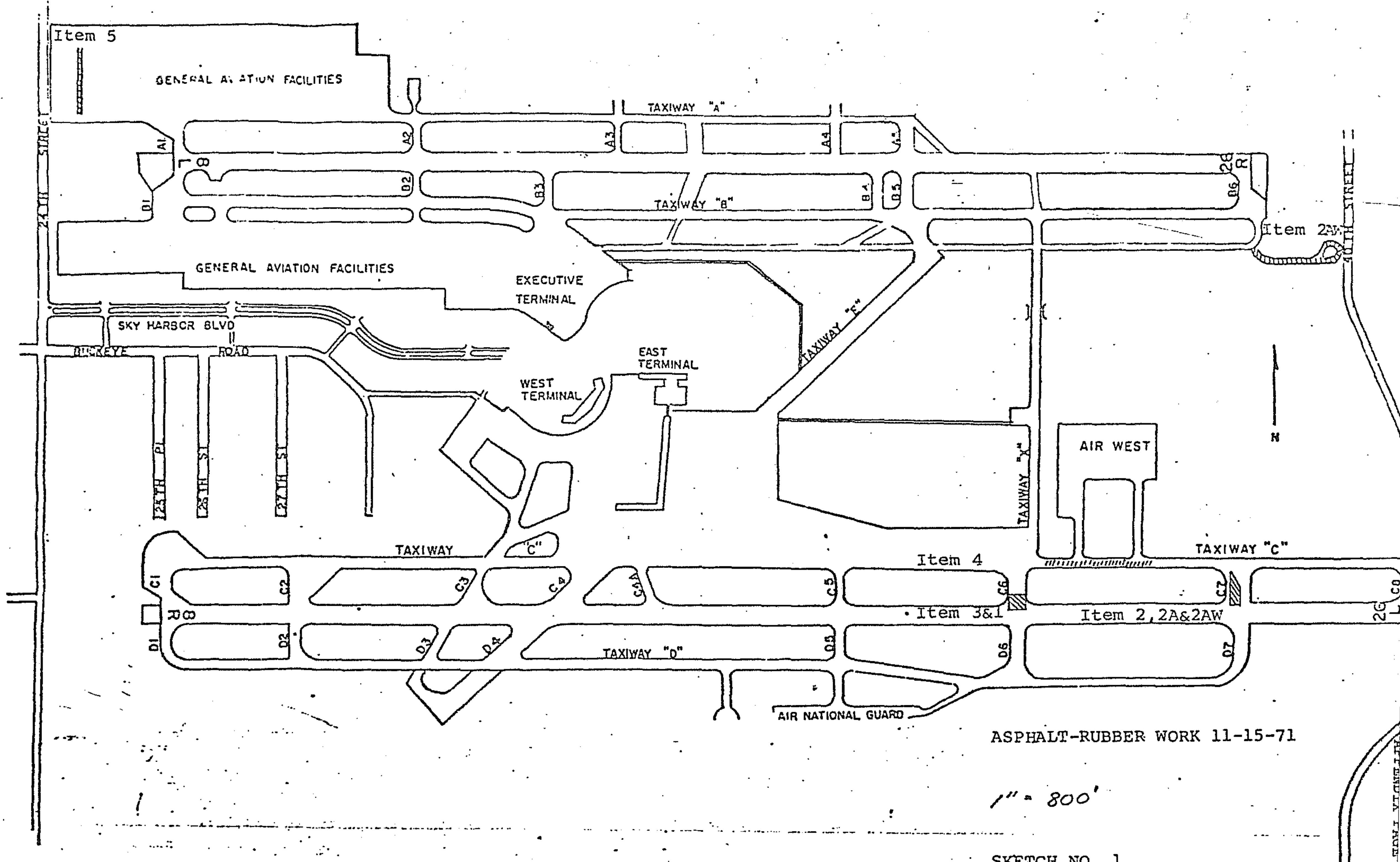
[illegible]	% of Aggregate	% of Rubber	% of Asphalt	Kerosene % by volume of Asphalt-Rubber.	(Actual) --- Mix Temp. in °F at Plant	(Objective)---	Grade of Rubber	Asphalt Grade	Aggregate Gradation	Asbestos %	Pugmill Mix Cycl. (Seconds)	Placing Sequence	Time of Placement	Temperature at Placement in °F	Ambient Temperature at Placement	Square Yards Covered	Tonnage Placed	Pounds per Square Yard	Gals. of Asphalt-Rubber	Gals. p.s.y. of Asphalt-Rubber	REMARKS
1	89½	2½	8*		225 230 220	230 ±20	-#16, +#25 mesh; ground tire rubber	85-100	¾" Nominal open graded		Dry 3 Wet 30	Fifth	1:45p.m. to 2:30p.m.	240° to 270°	65° 65°	C 412 C-6 972	34.8	50.3			Temperatur mix in dis butor 230° 185°F
2	90	2½	7½		225 235 240	210	-#16, +#25 mesh; ground tire rubber	85-100	"		Dry 15 Wet 30	Sixth	2:30p.m. to 3:30p.m.	250° to 285°	65° 65°	C-7 1,089	44.9	82.5			High appli cation rat to materia being used repair are
2A 2AW	85	5	10		250 240 240 260	210	Atlos WTS-4 Nominal -3/4", +#16, chopped whole tire (rubber and cord) Atlos WTA	85-100	"		Dry 30 Wet 30	Seventh Eighth	3:45p.m. to 5:00p.m.	290° and 320°	65° 64°	C-7 1,089 C-7 175 Fuel Farm 767	27.2	55.8 57.8			
3	90	0	7½		225 205 230	220	None	85-100	"	2½	Dry 10 Wet 30	Fourth	11:15a.m to 12:45p.m	200° 170° 265°	62° 66°	C-6 1,162	38.1	65.6			Used 10 Bin No.
4	97	 22.4	3 77.6	 7.1	250 225 240 225 220 235 280±	240 320	See Remarks This Table	85-100	1/4" Nominal Open Graded Plaster Sand		Dry 8 Wet 30	First Third	8:00a.m to 11:00a.m 11:15a.m to 12:00a.m	285° 280° 290° 275° 275° 260°	52° 62° 62° 63	C 3,495 C 3,202	90.5 21.5	51.8 13.5	 1,300	 0.41	Asphalt- Kerosene (Item No applied face of open gra plant mi
5	0	22.4	77.6	7.1		320	-#16, +#25 mesh; ground tire rubber	85-100	Plaster Sand		-	Second	10:45a.m to 11:00a.m		62° 62°	T 2,048	15.0	14.6	550	0.26	

DISTRIBUTOR TRUCK NO. 9 (11-15-71) HOT ASPHALT-RUBBER COMPOSITION

MATERIAL	TIME	TEMP °F	POUNDS	GALLONS	% OF MATERIAL	REMARKS
85-100 Penetration Grade Asphalt	7:35a.m.	360°	20,120	2,682	77.6%	Loaded in Distributc
97 60# Bags of Ground Tire Tread Rubber	Began 7:50a.m. Ended 8:35a.m.		5,820		22.4%	Weight by Bag Count
			259.40	3,459		
Total Asphalt-Rubber		305°			100%	
Kerosene Added	Began 9:50a.m. Ended 9:55a.m.			245	7.1%	
Total Mixture		300°				

The desired percentage of asphalt, rubber, and kerosene was 75 percent, 25 percent, and 7.5 percent respectively. The resultant percentages were due to the truck overflowing before the desired percentages could be met.

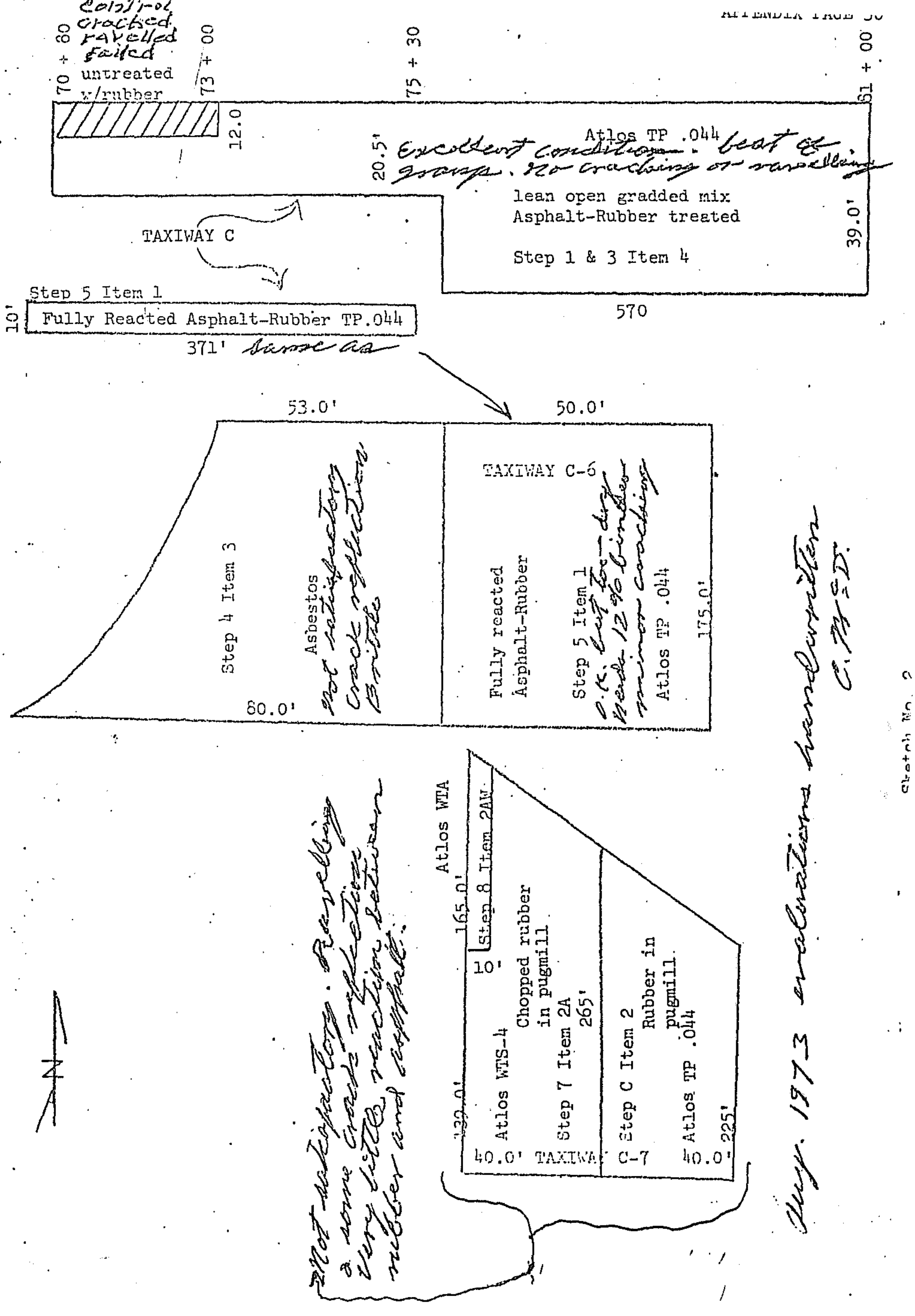
TABLE NO. 2

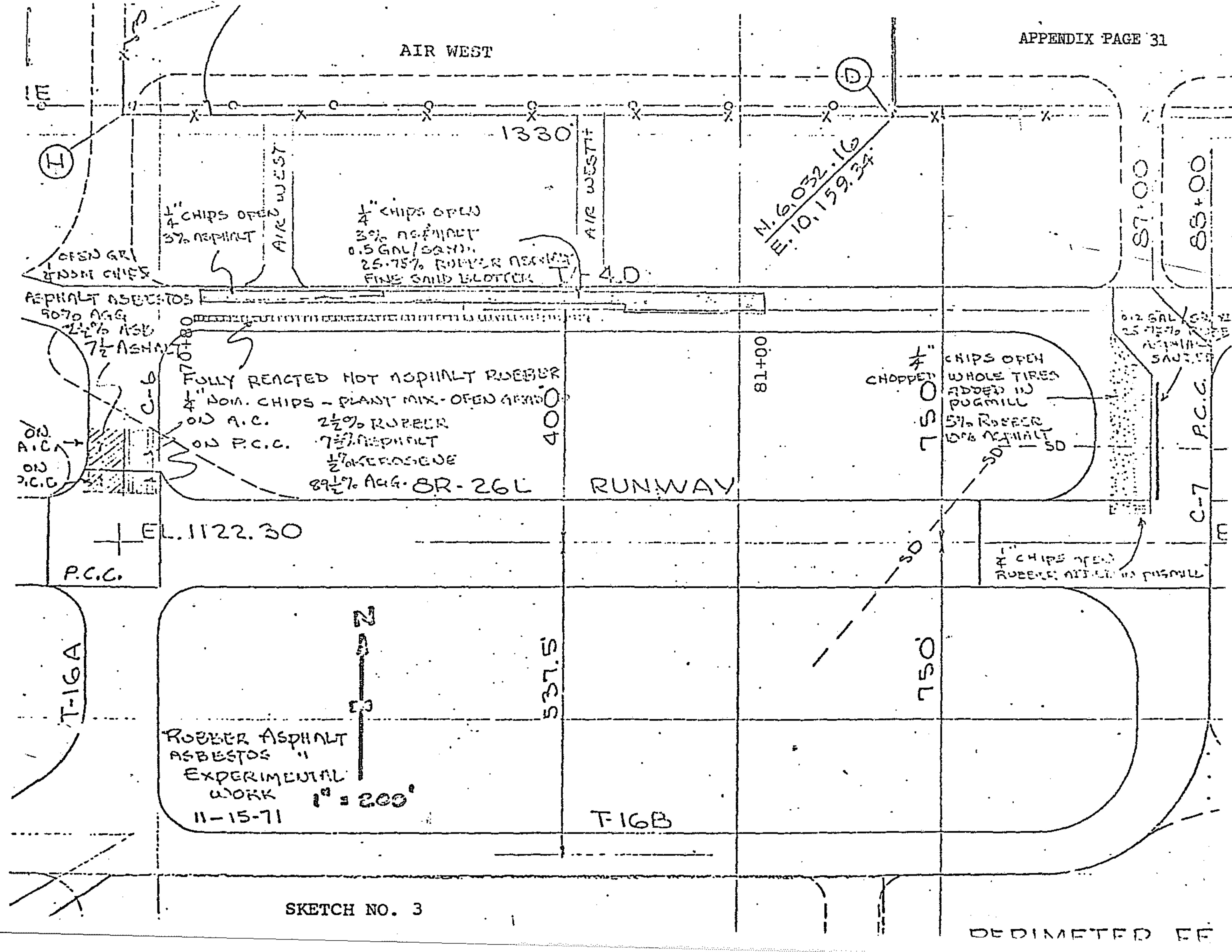


ASPHALT-RUBBER WORK 11-15-71

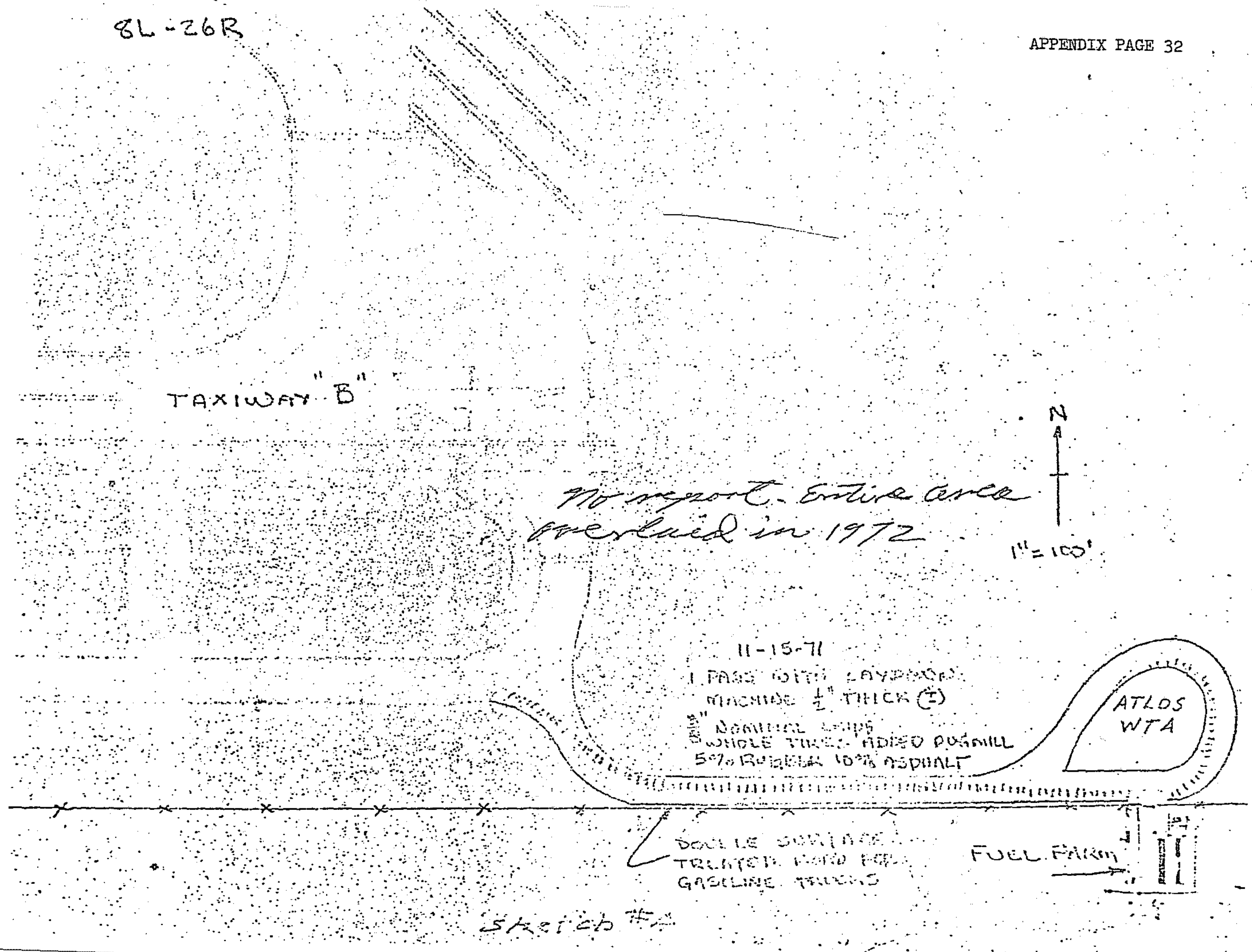
1" = 800'

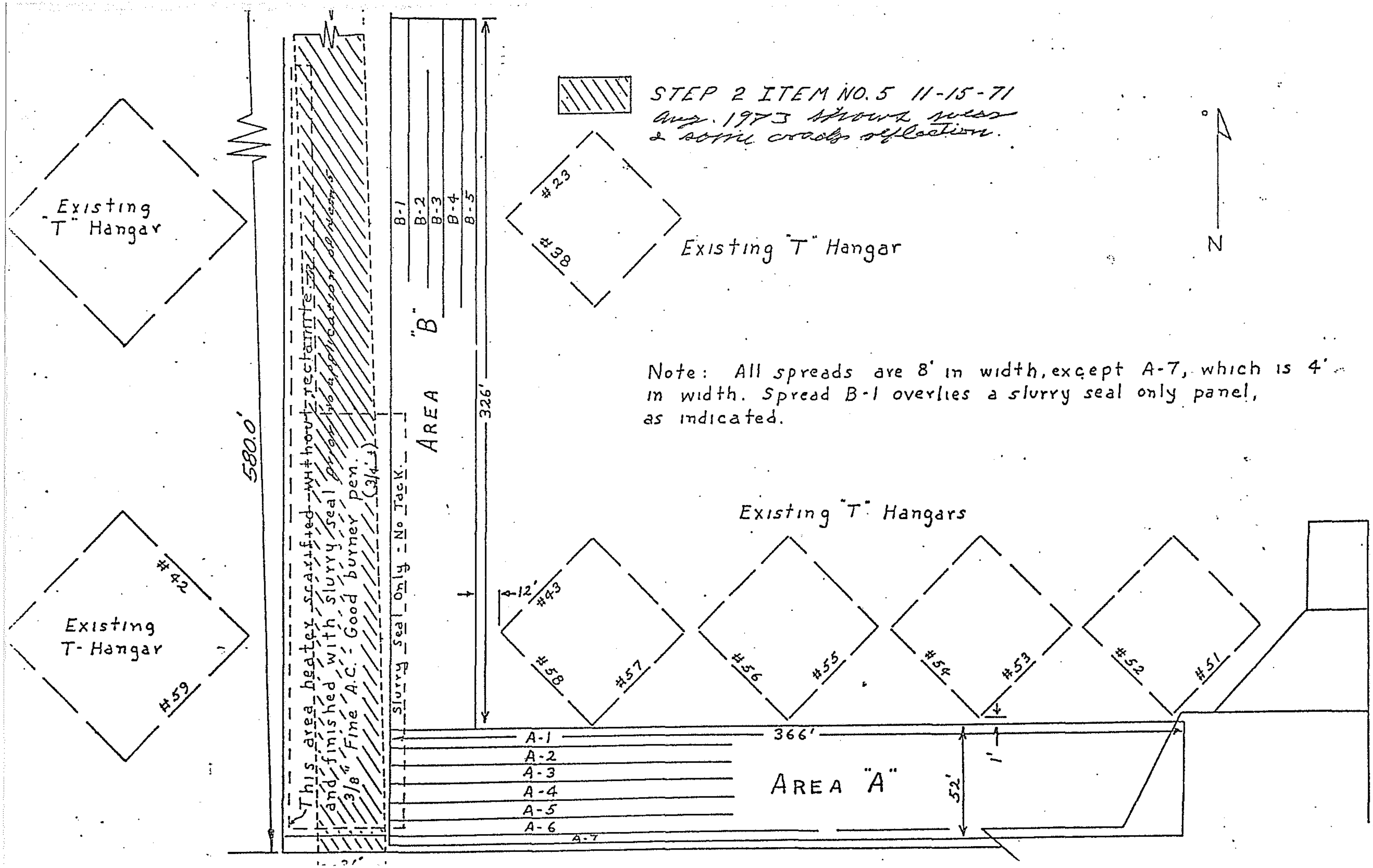
SKETCH NO. 1


Control cracked ravelled failed
untreated w/rubber
70 + 80
73 + 00
75 + 30
61 + 00
12.0
20.5'
Atlos TP .044
Excellent condition. best of group. No cracking or ravelling
lean open gradded mix
Asphalt-Rubber treated
Step 1 & 3 Item 4
39.0'
570
TAXIWAY C
Step 5 Item 1
10'
Fully Reacted Asphalt-Rubber TP.044
371' Same as
53.0'
50.0'
TAXIWAY C-6
Step 4 Item 3
Asbestos
not satisfactory crack reflection brittle
80.0'
Fully reacted Asphalt-Rubber
Step 5 Item 1
Atlos TP .044
O.K. but too dry. Needs 12% binder. minor cracking
175.0'
Aug. 1973 evaluations handwritten C.M.D.
Sketch No. 2
Atlos WTA
Step 8 Item 2AW
165.0'
10'
Chopped rubber in pugmill
Step 7 Item 2A
265'
Atlos WTS-4
130.0'
Step C Item 2
Rubber in pugmill
Atlos TP .044
225'
40.0' TAXIWAY C-7 40.0'
Not satisfactory. Ravelling & some crack reflection. Very little reaction between rubber and asphalt.
N


AIR WEST
D
H
1330'
AIR WEST
AIR WEST
N. 6,032.16
E. 10,159.34
1/4" CHIPS OPEN
3% ASPHALT
1/4" CHIPS OPEN
3% ASPHALT
0.5 GAL/SQ.YD.
25.75% RUBBER ASPHALT
FINE SAND BLOTTER
T-4.D
OPEN GR
1/4" NOM CHIPS
ASPHALT ASBESTOS
90% AGG.
2 1/2% ASB.
7 1/2 ASPHALT
70+80
C-6
FULLY REACTED HOT ASPHALT RUBBER
1/4" NOM. CHIPS - PLANT MIX - OPEN GRADED
ON A.C.
ON P.C.C.
2 1/2% RUBBER
7 1/2% ASPHALT
1/2% KEROSENE
89 1/2% AGG.
ON A.C.
ON P.C.C.
400'
8R-26L RUNWAY
81+00
1/4" CHOPPED
CHIPS OPEN
WHOLE TIRES
ADDED IN
PUGMILL
5% RUBBER
10% ASPHALT
750'
SD
87+00
83+00
P.C.C.
C-7
EL. 1122.30
P.C.C.
1/4" CHIPS OPEN
RUBBER ADDED IN PUGMILL
N
T-16A
537.5
750'
RUBBER ASPHALT
ASBESTOS "
EXPERIMENTAL
WORK
1" = 200'
11-15-71
T-16B
PERIMETER

SKETCH NO. 3


8L-26R
TAXIWAY "B"
N
No report. Entire area overlaid in 1972
1" = 100'
11-15-71
1 PASS WITH LAYDOWN
MACHINE 1/2" THICK
WHOLE TIRES
5% RUBBER 10% ASPHALT
ATLOS WTA
DOUBLE SURFACE
TREATED ROAD FOR
GASOLINE TRUCKS
FUEL FARM
SKETCH #4



STEP 2 ITEM NO. 5 11-15-71
Existing "T" Hangar
Existing "T" Hangar
Existing T-Hangar
Existing "T" Hangars
#23
#38
#42
#59
#43
#58
#57
#56
#55
#54
#53
#52
#51
580.0'
326'
366'
52'
1'
12'
N
AREA "B"
B-1
B-2
B-3
B-4
B-5
AREA "A"
A-1
A-2
A-3
A-4
A-5
A-6
A-7
Slurry Seal Only - No Tack.
and finished with slurry seal
3/8" Fine A.C. - Good burner pen.
(3/4"±)
Note: All spreads are 8' in width, except A-7, which is 4' in width. Spread B-1 overlies a slurry seal only panel, as indicated.

JOINT EXPERIMENTAL PROJECT OF THE
ARIZONA HIGHWAY DEPARTMENT AND
THE
CITY OF PHOENIX
ENGINEERING DEPARTMENT
MATERIALS TESTING SECTION

EXPERIMENTAL PROJECT

Combination Levelling Course and Asphalt-Rubber Treatment

Initial Report

EXPERIMENT NO. 144

DATE OF EXPERIMENT October 25 and 26, 1973

LOCATION

The central 30 feet of Madison Street between Fourth Street and Sixth Street which consists of a concrete pavement (see sketch).

LOCATION and/or CHARACTER OF UNTREATED CONTROL

Control not required, as past experience has proven that the joint cracks would reflect thru a thin untreated material layer over concrete in less than six months.

PURPOSE OF THE EXPERIMENT

To determine if a thin (1"±) open-graded levelling course, treated with a penetrating application of asphalt-rubber, is capable of preventing crack reflection when placed directly on rough concrete pavement, or any rough surface.

MATERIALS USED

Diluted SS-1h emulsified asphalt, 1/4" nominal open-graded mix containing three percent (3½ percent would have been better) 60-70 penetration grade asphalt, asphalt-rubber (75 percent 120-150 and 25 percent ground tire rubber #16 - #25 mesh), sand, Petromat, non-woven fiberglass.

CONSTRUCTION METHODS

The surface was tacked with .05 to 0.1 gallon per square yard of diluted SS-1h, Petromat and fiberglass mats were laid over several test joints with SS-1h tack (see sketch for details), and 91.1 pounds per square yard of the open-graded mix was laid in under two hours the night of October 25. The asphalt-rubber was placed in less than one hour the morning of the 26th and sanded. The asphalt-rubber application was as follows:

North ten-foot strip	0.51 G.S.Y.
Middle ten-foot strip	0.38 G.S.Y.
South ten-foot strip	0.32 G.S.Y.

The sand application was 15 pounds per square yard which could have been reduced to between five and ten pounds for the purpose.

Experiment # 144 Madison - from 4th to 6th St.
Vertical Scale 1" = 20'
Horizontal Scale 1" = 100'

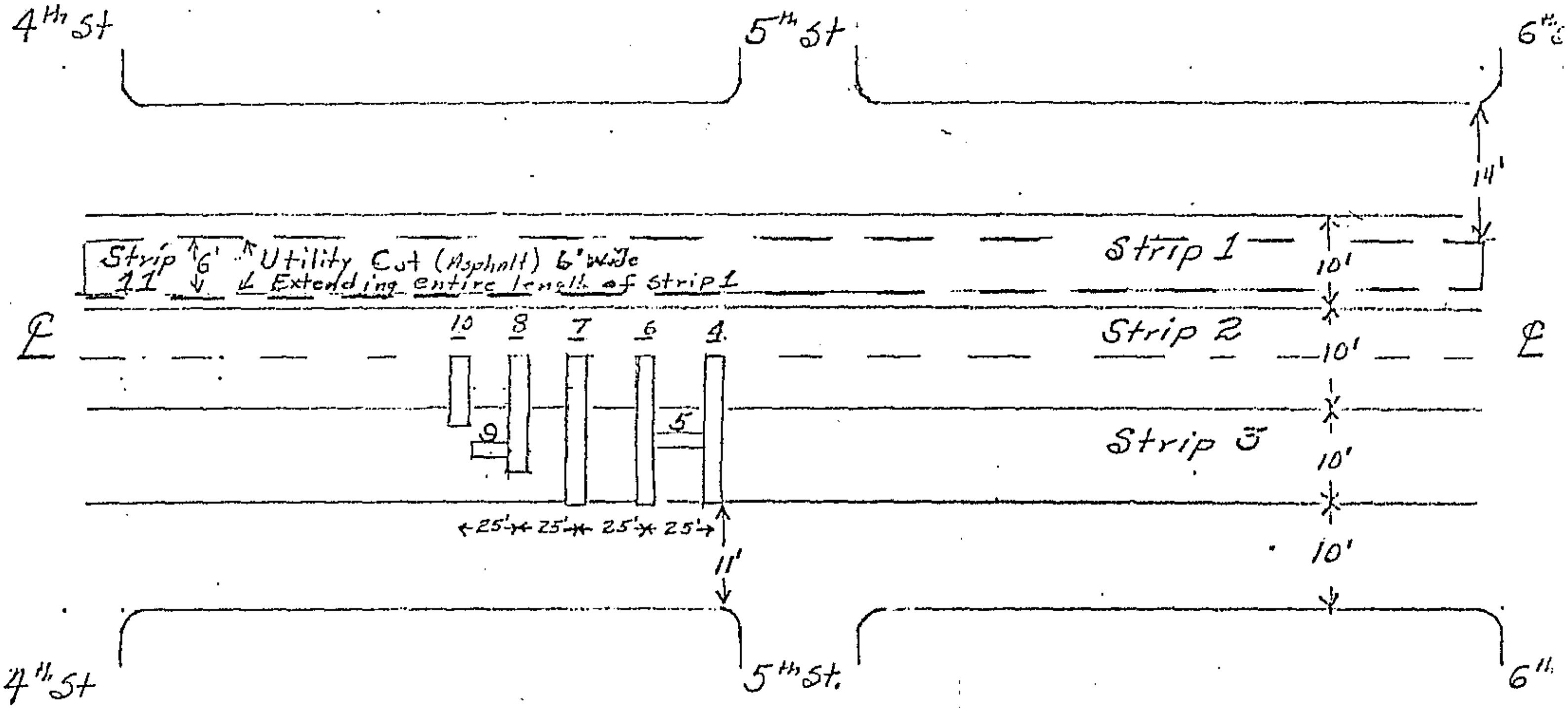


PHOTO NO. 1

Typical example of fatigue cracking.

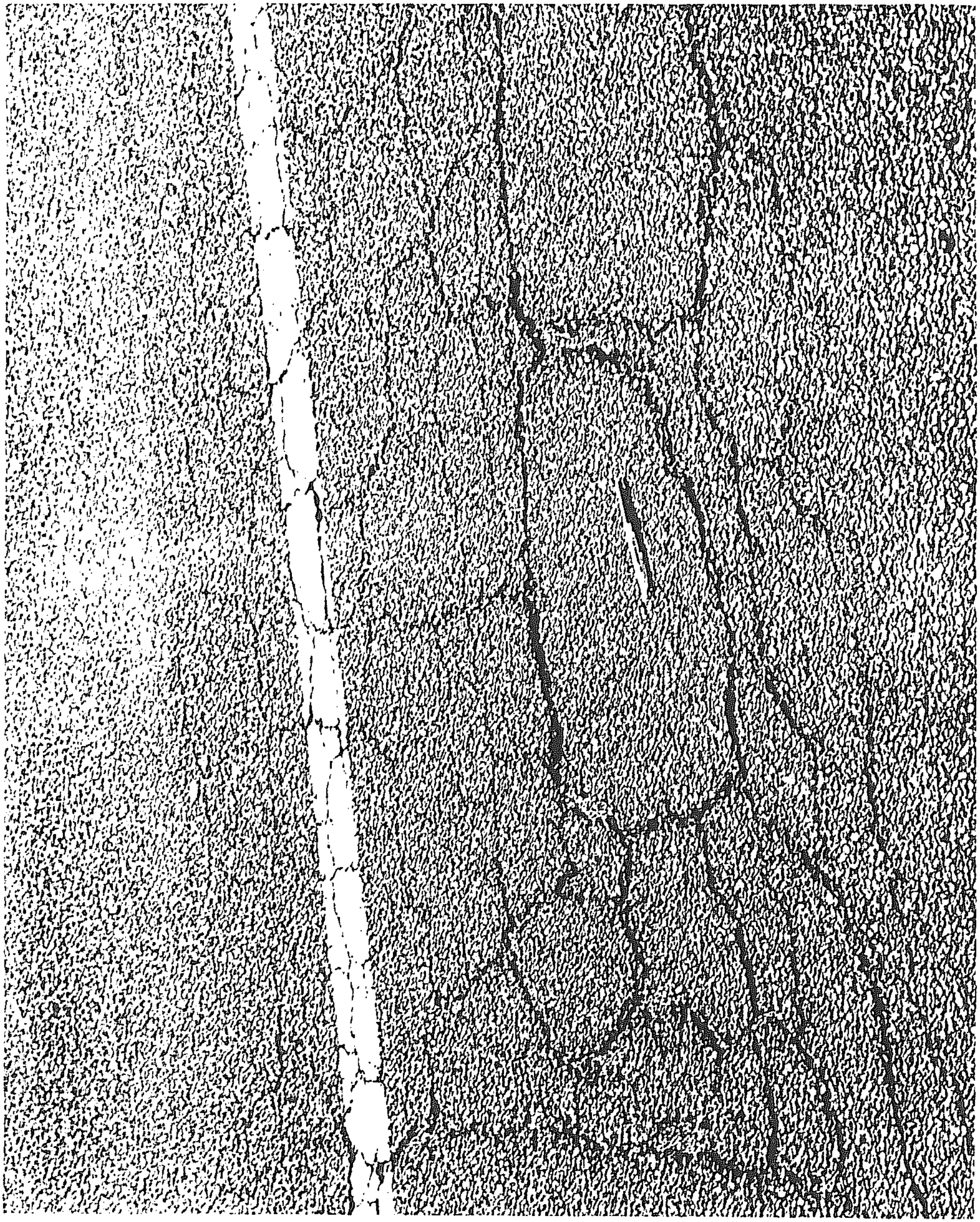


PHOTO NO. 2

Shows poor drainage condition in test
panel area on Seventh Street just south
of Jefferson Street in Phoenix, Arizona.

Mr. C. H. McDonald

PHOTO NO. 2

PHOTO NO. 3

Prefabricated asphalt-rubber, cold "band-aid" type patches placed for testing adhesive systems.

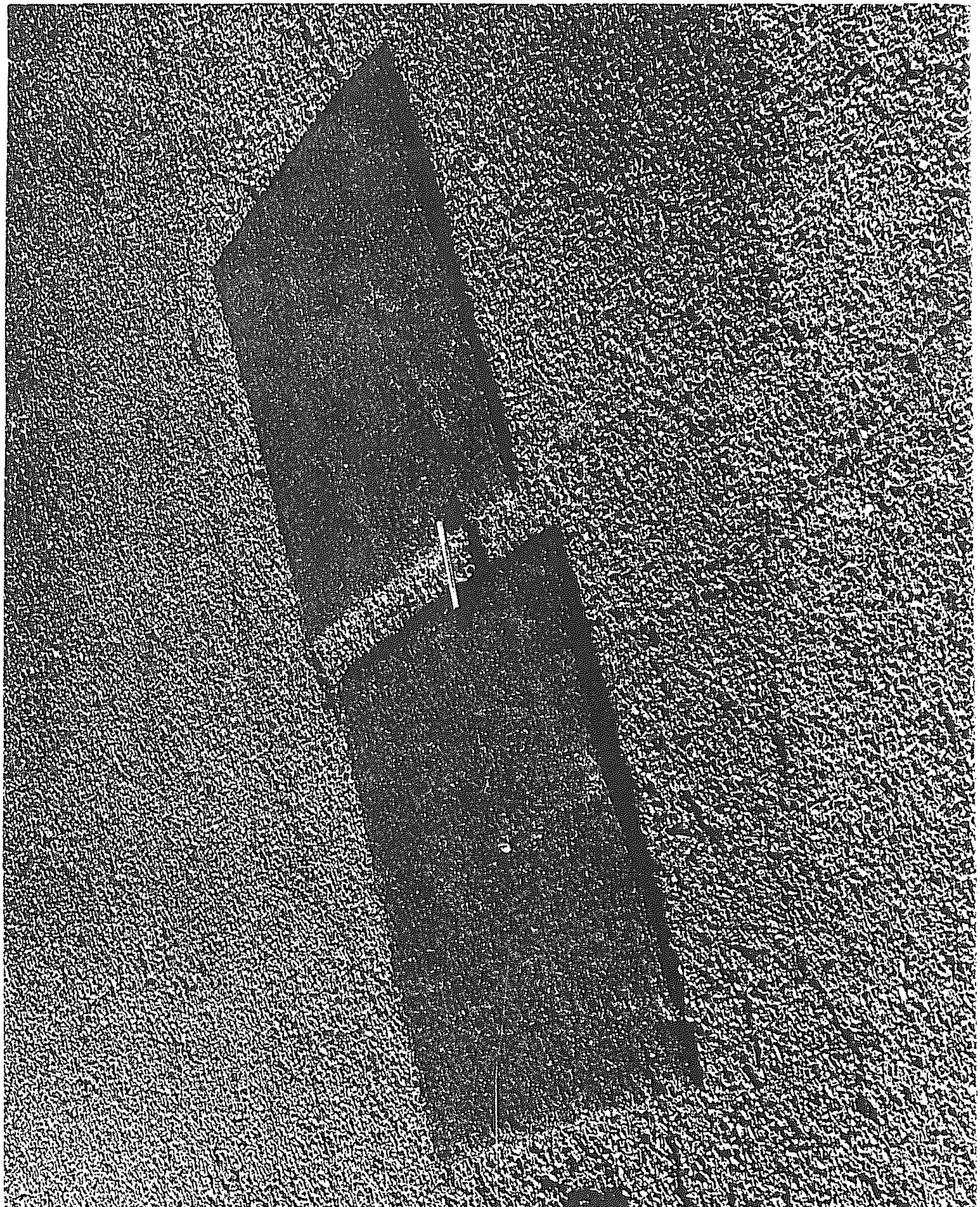


PHOTO NO. 4

Asphalt-rubber treatment placed over five years ago. The broken area in the center reveals the condition of the underlying pavement which was exposed by a "pickup" by a truck wheel at the time of placement. The area looks the same today except that the center exposed portion has been patched.

PHOTO NO. 5

One of the modified distributors used for placing asphalt-rubber.

Mr. C. H. McDonald

PHOTO NO. 5

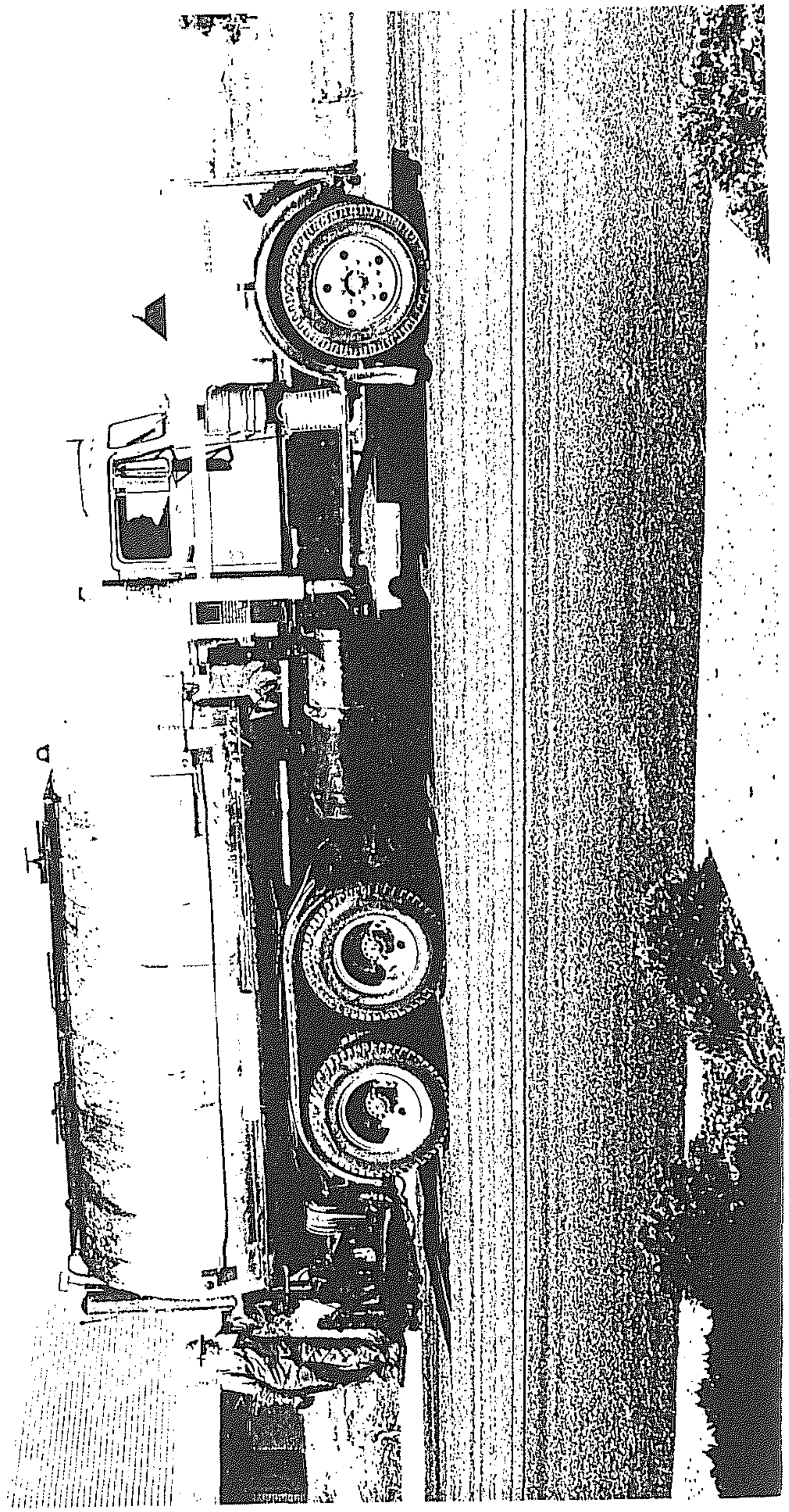


PHOTO NO. 6

Applying crushed gravel chips to the asphalt-rubber application on a major downtown Phoenix, Arizona street.

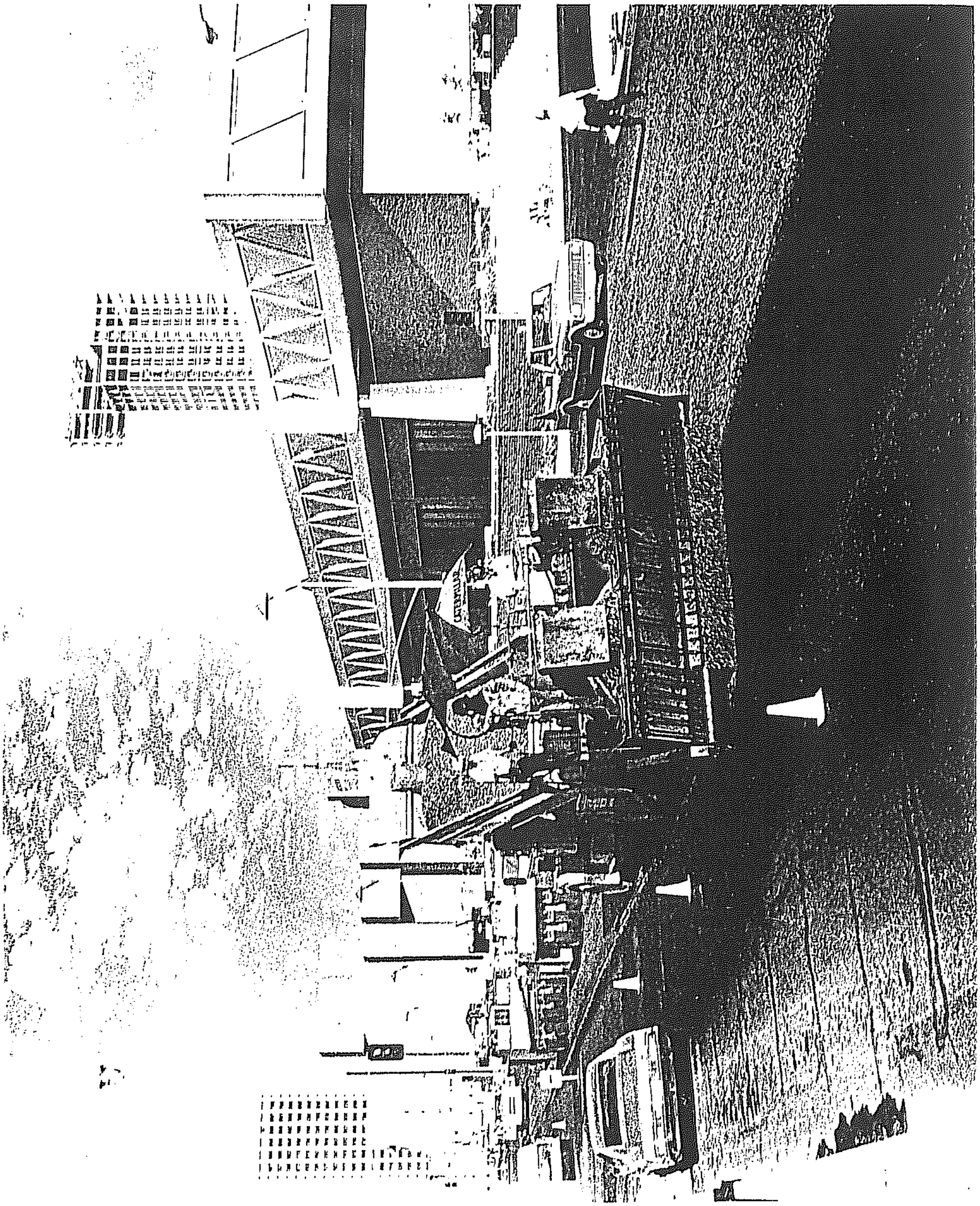


PHOTO NO. 7

Pneumatic rolling the chip application on asphalt-rubber shown in Photo No. 6

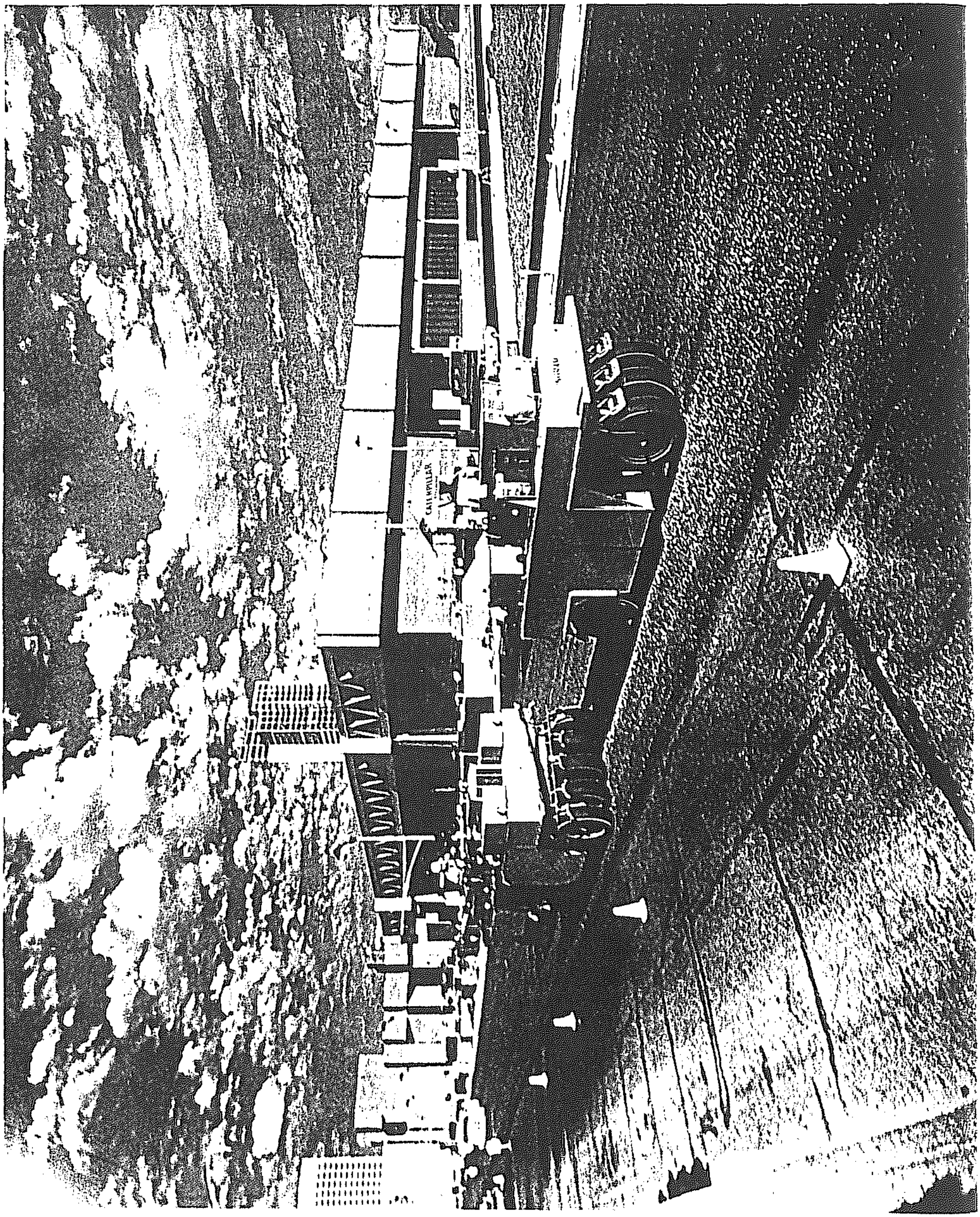


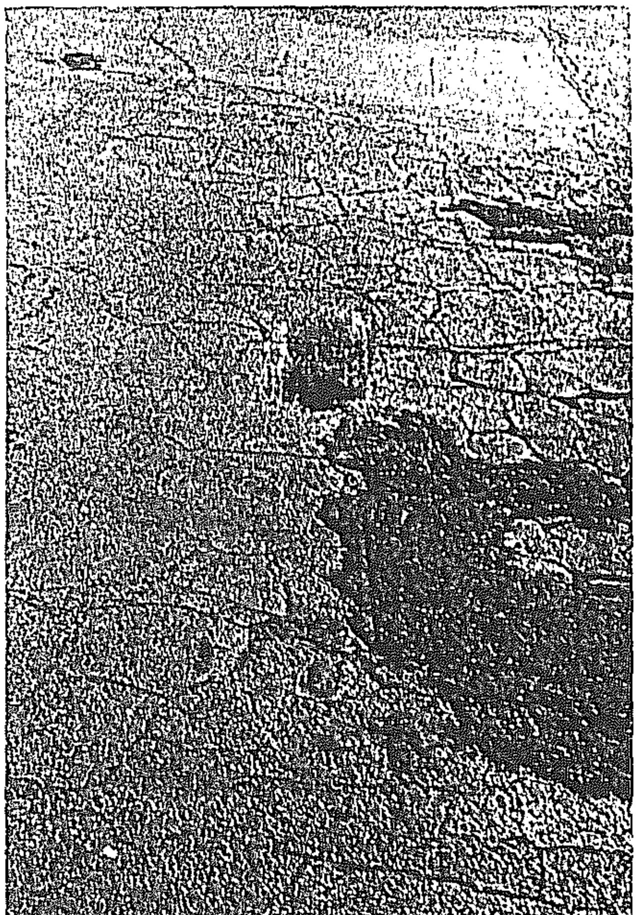
PHOTO NOS. 8, 9 and 10

Comparative photos on asphalt-rubber special seal test section placed January 1970 on 19th Avenue in Phoenix, Arizona.

Photo #8 was taken just prior to application of asphalt-rubber in January, 1970.

Photo #9 was taken at the same location approximately one year after asphalt-rubber application and shows the "roping" problem we had at that time.

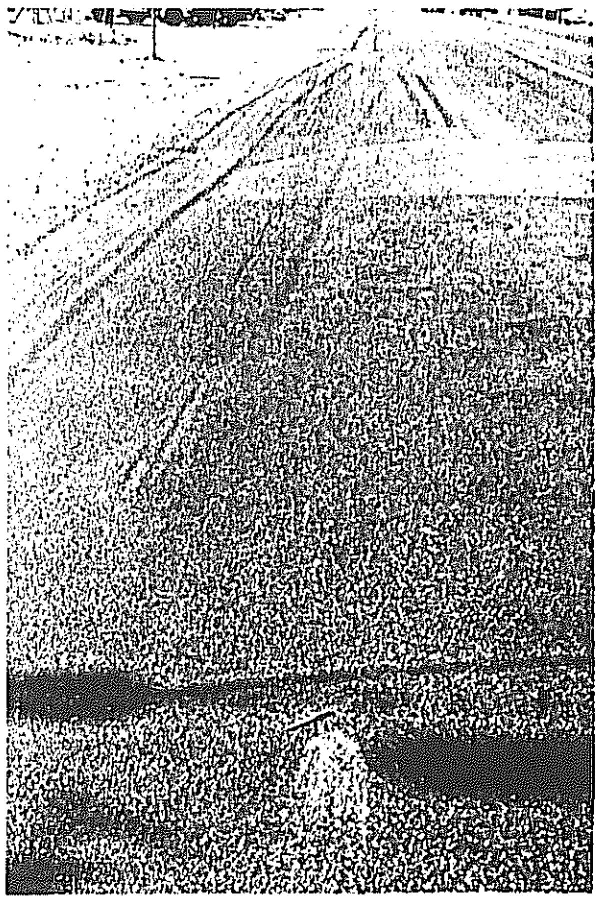
Photo #10 was taken at the same location 3½ years later in July, 1973. It shows no crack re - flection and there is actual improvement in surface texture.



7.0

18-4

PHOTO NO. 9



10-9

PHOTO NO. 11

Principal commercial jet runway at Sky Harbor International Airport in Phoenix, Arizona soon after treating with asphalt-rubber followed by a light emulsified asphalt flush coat to tie down any loose chips after sweeping.

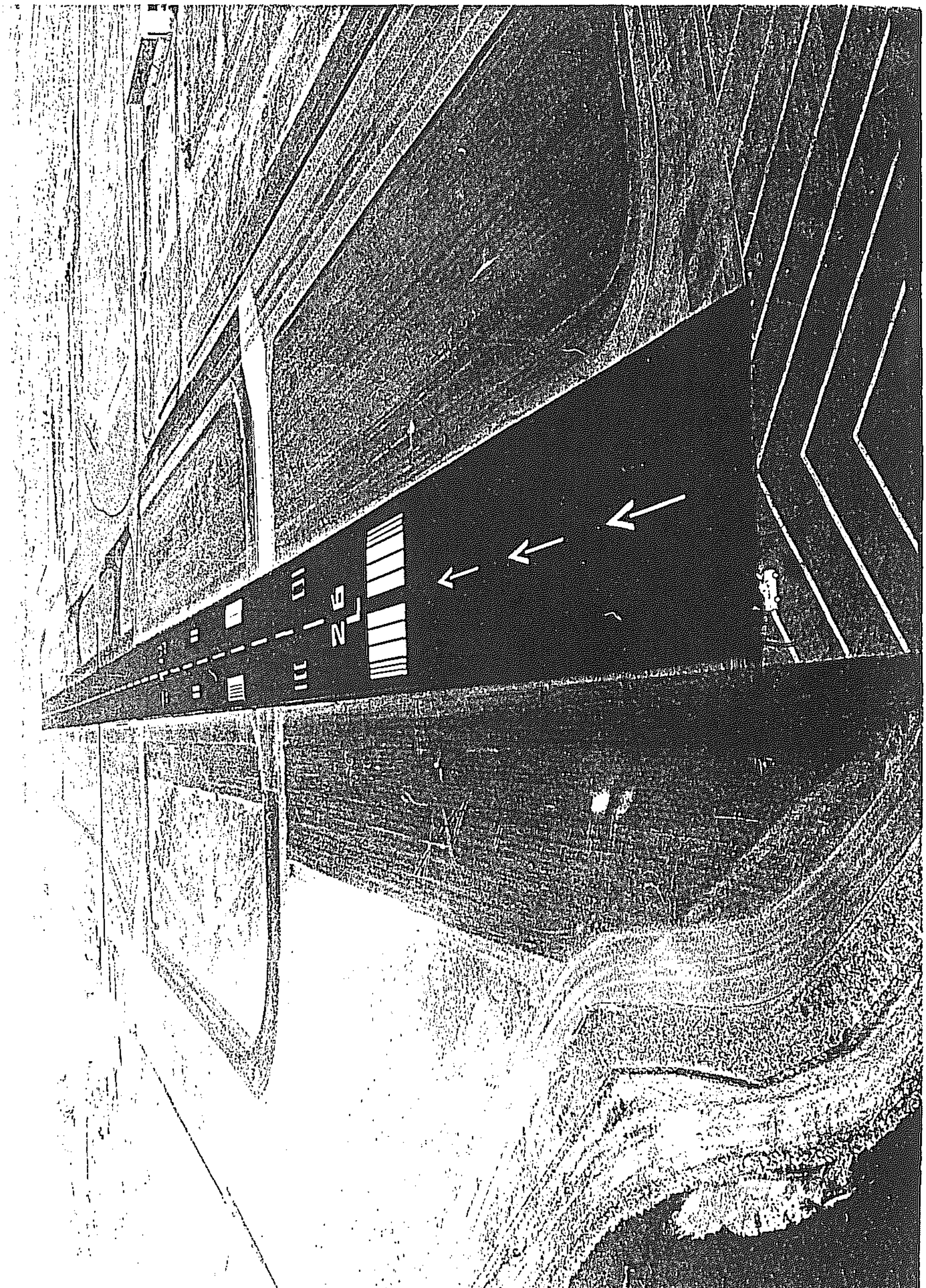


PHOTO NO. 12

Bituminous surface treatment with corrective application of asphalt-rubber on left and none on right.

Placed: May 1971
Photo: July 1973

Air National Guard Runway, Phoenix, Arizona.

Top

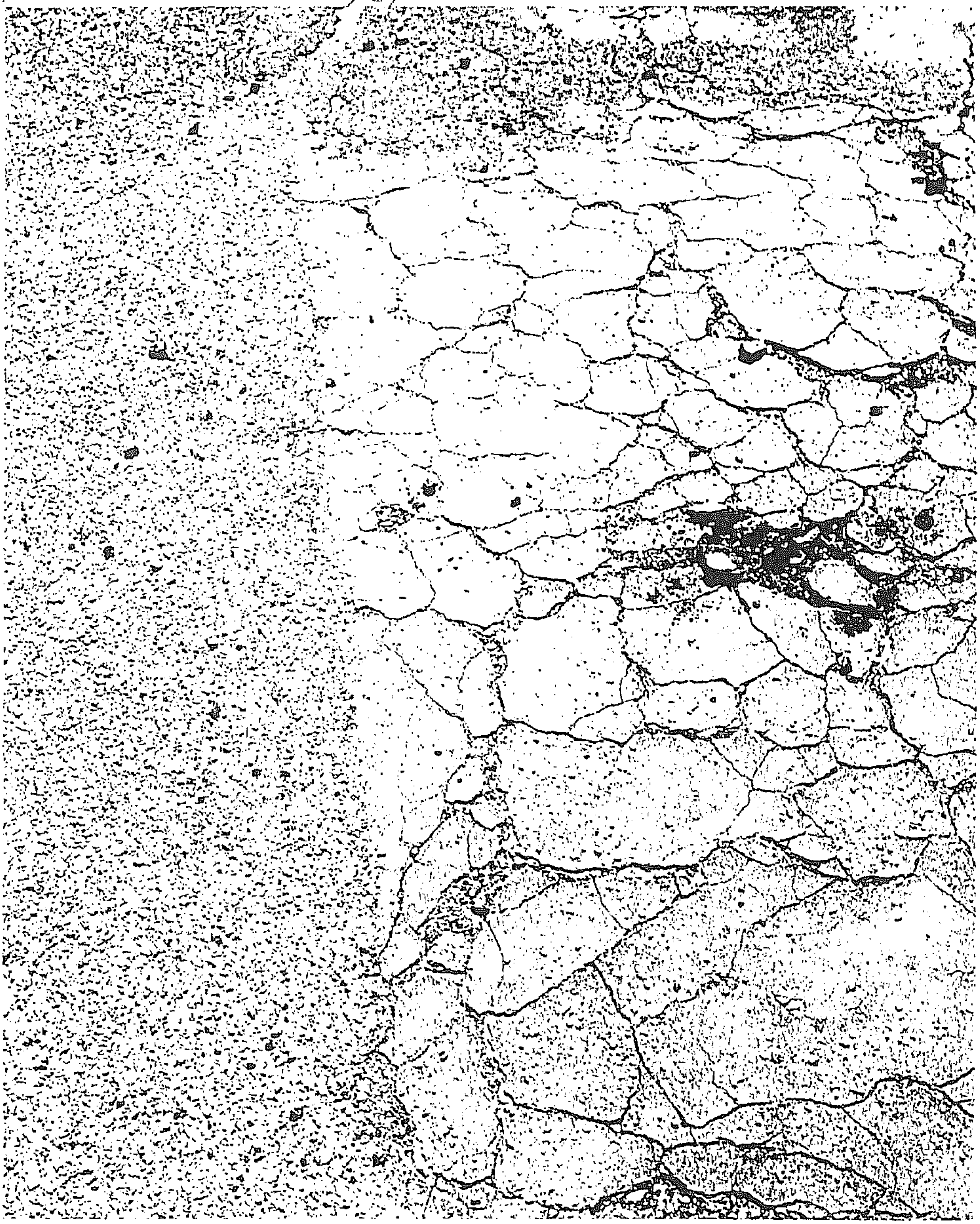


PHOTO NO. 13

Asphalt-rubber treatment placed on primed native clay loam soil April 13, 1971. Photo shows condition after 2½ years of service.

55th Avenue north of Clarendon in Phoenix, Arizona. Asphalt-rubber overlaps old pavement on left.

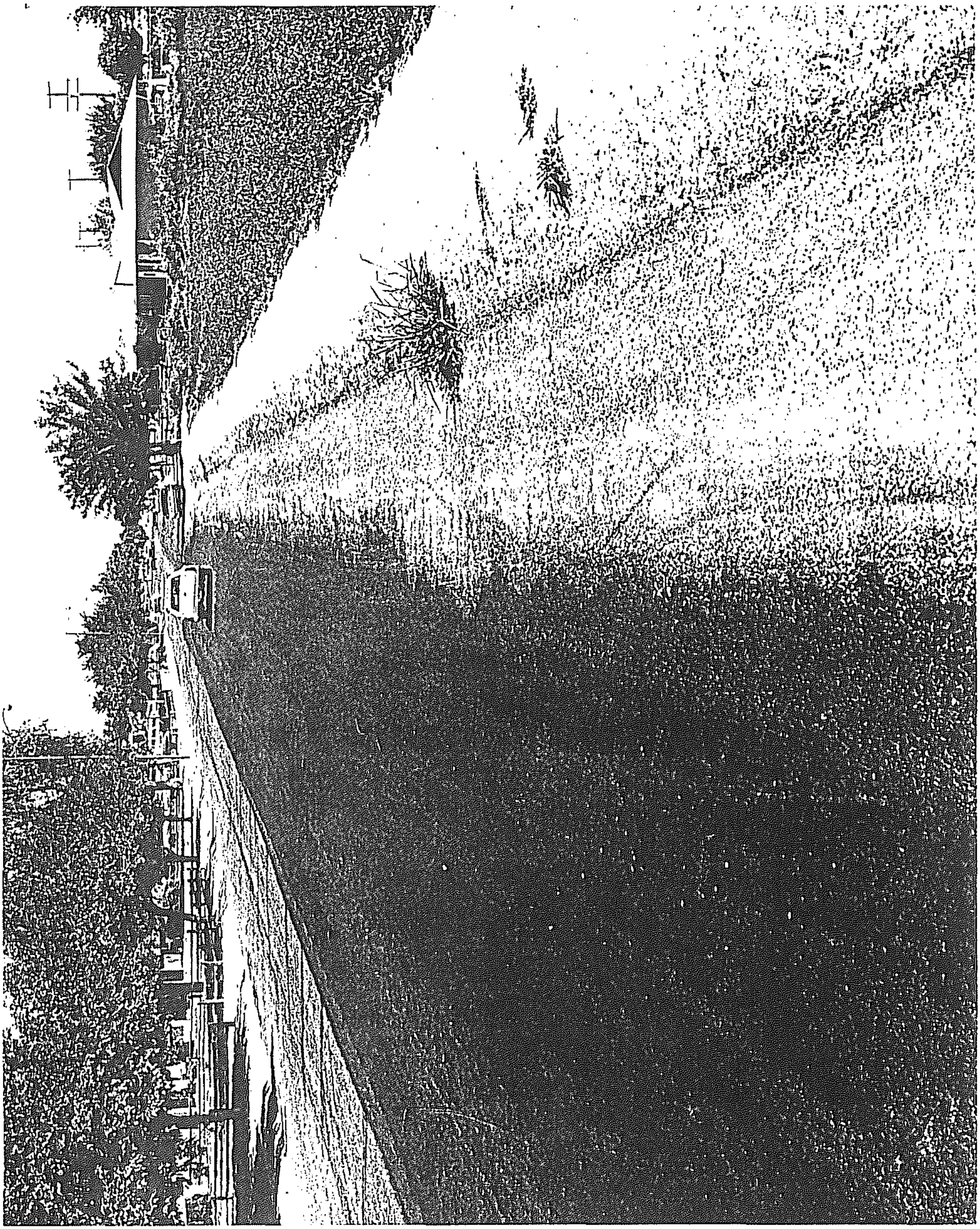


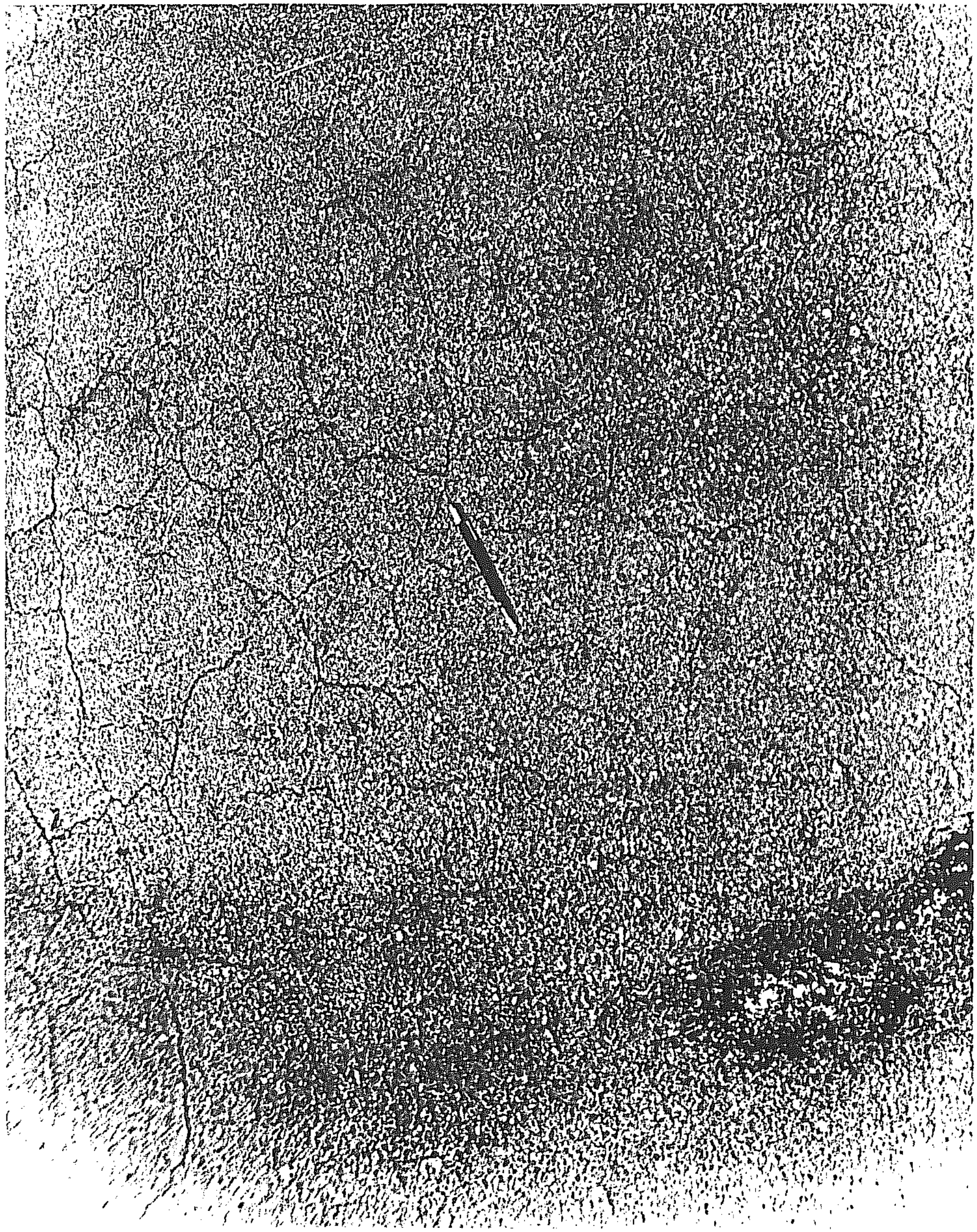
PHOTO NO. 14

Primed subgrade prior to application of asphalt-rubber. Note fatigue failure already developing in prime after one week. Compare with Photo No. 13.

55th Avenue north of Clarendon in Phoenix, Arizona.

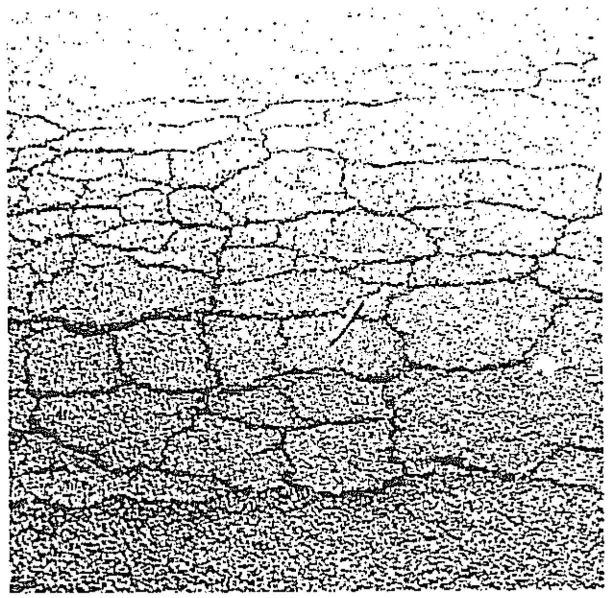
Mr. C. H. McDonald

PHOTO NO. 14



Mr. C. H. McDonald

PHOTO NO. 15



Mr. C. H. McDonald PHOTO NO. 16