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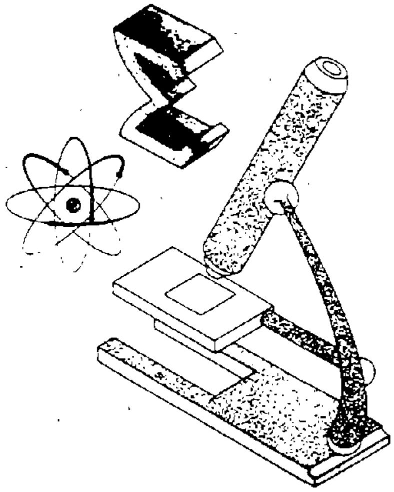
NEW AND INNOVATIVE METHODS AND MATERIALS FOR PAVEMENT SKID RESISTANCE



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FOREWORD

This report presents the findings of an investigation to locate, evaluate, and classify various skid resistant pavement surfaces in use in the Pacific Coast area. It will be of interest to highway engineers concerned with the design, construction, and maintenance of skid resistant pavements.

In addition to a questionnaire survey, skid tests and texture profiles were made on 45 pavement surfaces considered to have satisfactory wear characteristics. The surfaces were rated based on a composite index of skid-number, skid number-speed gradient, and surface texture. The non-skid treatments considered to be new and innovative were found to be quite expensive compared to successful conventional treatments such as open-graded asphalt concrete, chip seals, and textured cement concrete. The available wet-pavement accident data did not provide any criteria for establishing minimum friction values.

This report is being distributed in sufficient numbers to provide a minimum of one copy to each regional and division office and two copies to each State highway agency. Additional copies of the reports for the public are available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

Charles F. Scheffey

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Director, Office of Research
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16. Abstract

This report describes an evaluation and classification of pavement surfaces with respect to skid resistance. The study was conducted by means of a questionnaire survey of agencies within and adjacent to California, and by testing and examination of 45 existing pavement surfaces. The test program included standard skid tests at two speeds and additional tests with a smooth tire at one speed. Surface textures were measured by stereophotographs to obtain a "texture profile." The approximate cost of the surface, the amount of traffic exposure, and vehicle accident data were included in the evaluation.

The pavement surfaces were ranked on the basis of skid number, speed gradient, and texture. Systems which ranked well under heavy or medium traffic included open-graded asphalt concretes with and without epoxy modification, textured cement concretes, and expoxy chip seals. Conventional and rubberized chip seals were found suitable for medium or light traffic. Dense-graded epoxy-asphalt concretes generally ranked about the same as the control section of asphalt concrete. The corrective surface treatments considered new and innovative were all quite expensive compared to conventional treatments. Wet pavement accident data did not provide any criteria for establishing minimum levels of skid resistance.

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Pavement surface texture, skid resistance, pavement maintenance, stereoscopic photography

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We wish to thank Mr. Charles Seim of Caltrans for making data from sixteen test sections on the San Francisco-Oakland Bay Bridge available for this report. A special thanks is extended to Mr. John Apostolos for his work in the early stages of this study, especially for his effort in developing the photogrammetric technique that was used for texture evaluation.

Mr. Gene Stucky performed the skid tests and took the stereo photographs of the pavement surfaces for this project. The texture profiles were obtained from the stereo photographs under the direction of Mr. Dick Burns in the Office of Geometronics. Mr. Burns was very instrumental in developing the photogrammetric techniques.

The helpful suggestions and contributions made by the contract manager, Mr. James M. Rice, are also appreciated.

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INTRODUCTION

One of the goals of a highway program is to provide a satisfactory level of pavement skid resistance for reasonable vehicle maneuvers. While most pavements have sufficient skid resistance when dry, they lose some skid resistance when wet. The magnitude of the reduction varies considerably depending upon numerous factors such as vehicle speed, tire pressure, tire tread depth, water depth, and the surface texture of the pavement. Therefore, it is important to provide a pavement surface having a gritty texture to develop skid resistance and drainage channels to maintain this skid resistance in the presence of water. It is not enough to construct a pavement surface with a coarse, gritty surface texture. The surface must be capable of resisting the polishing action of traffic, especially truck traffic, which can significantly reduce skid resistance. Also, the bonding agent or binder must be capable of retaining the aggregates within the pavement surface or the resultant surface will provide poor skid resistance qualities.

The objective of Phase I of this investigation was to locate and classify the various skid resistance treatments currently in use in the State of California, adjacent states, and by other public agencies, and to evaluate their potential for reducing skidding-type accidents. Also, selections and recommendations were required for surfaces investigated in NCHRP Project 1-12(3), "Guidelines for Skid Resistance Highway Pavement Surfaces". Surfaces deemed worthy of further evaluation could then be constructed at a later date if Phase II of the project is undertaken.

A primary goal in classifying and evaluating pavement surfaces is to select criteria that relate to the effectivneess of the surface performance. In addition to the ability of the surface to remain in place under traffic, three parameters that have been selected as criteria for evaluating pavement surfaces in this report are:

1. Skid Number
2. Speed Gradient
3. Surface Profile

Based upon numerous informal studies of accident reports, the adoption of a minimum skid number would classify many pavement surfaces as substandard or inferior even though the wet pavement accident rates are low. This indicates that additional parameters are involved. Since skid number alone often does not correlate well with wet pavement accidents, it is not appropriate to try to require a specific minimum level in every case. For the purpose of this evaluation, it was assumed that a higher skid number is preferable.

A speed gradient, G, is a measure of the sensivity of skid resistance to speed. It is the ratio of the change in skid number for the corresponding change in test speed. A speed gradient of 0.6 is not as desirable as a speed gradient of 0.1. Occasionally, low speed gradients are obtained from relatively smooth textures (both low and high speed skid resistance is low) and, more frequently, a moderately high speed gradient is obtained from a rather rough texture and, therefore, speed gradient values by themselves may be misleading. By considering the skid number <u>and</u> the speed gradient together, a better evaluation of the pavement surface can be made.

This can be achieved by looking at the SN and G values for each surface, or the values may be incorporated into a single quantitative value, percent normalized gradient, PNG. The relationship between percent normalized gradient and texture has been utilized by other researchers(1) and will be considered in this report.

The third parameter utilized in this project is the surface profile or texture roughness. A good texture should provide adequate drainage channels for the surface water to escape and permit the vehicle tires to make contact with the roadway surface. From a stereo photograph profile, a "T" value is used to classify surface texture. Generally, the larger the value of T, the rougher the texture. For this evaluation it is assumed that the larger the T value, the better the surfacing for skid resistance. Additional information on the stereo photographic equipment and the development of the T value is provided in the report, "Pavement Texture Evaluation by Photogrammetric Techniques"(2), and a summary is included in Appendix F.

Other criteria that are provided to assist in an evaluation of the surface treatments are wet pavement accident statistics and service life. One element of the wet pavement statistics to be considered is the percent of time that the pavement is wet. In California this is determined by accumulating the hours that have 0.01 inch (0.25 mm) or more rainfall from hourly precipitation data published by the U.S. Department of Commerce. The percent of wet time is based on an eleven year weather record (1957-1967). Values range from a low of one percent in the arid areas to eleven percent in a heavy rainfall area, though more typically the upper limits are about six to eight percent.

Although accident data is listed as pertinent criteria, it should be pointed out that due to the nature of accident reports and the short length test patches of some of the surfacings evaluated, the accident frequency data should be used with discretion. What might appear to be a relatively high "after treatment" rate may in fact represent a substantial improvement if the "before treatment" rates could be compared. In many cases, a valid "before treatment" accident rate was not available.

PROCEDURE

An inquiry was sent to adjacent States, Hawaii, and local agencies within California regarding the type of pavement surfaces that they use for special pavement treatments. Both new construction and modification to existing pavements were of interest. The response is summarized in Appendix A. Also listed in Appendix A are some innovative surfaces that have been investigated for airport runways in New Mexico(3,4).

After reviewing the responses from the other Western states and local agencies, it became evident that samples of all the surface types listed existed in California and, therefore, only California pavements are included in this report. Further, it appeared that most of the "innovative" surfaces used were placed as test patches on the San Francisco-Oakland Bay Bridge. Several of these surfaces were discussed in a 1974 report on epoxy asphalt surfaces on California Toll Bridges(5). Several of the other surfaces included in this project are under study on other ongoing research projects at the Caltrans Transportation Laboratory.

Skid tests were performed on innovative surfaces considered to have acceptable performance characteristics. Also, a dense graded asphalt concrete surface is included as a standard for comparison purposes. Towed trailer skid testers that comply with ASTM E274-70 standards were used to test the surfaces in the outer wheel track at 40 and at 50 or 55 mph (64 and 80 or 88 km/h). Because of the traffic conditions at several locations, tests were not made at other speeds. In this report, the speed gradient G was determined by the following formula:

$$G = \frac{SN_{40} - SN_{55}}{15} \quad \text{or} \quad G = \frac{SN_{40} - SN_{50}}{10}$$

and percent normalized gradient, $PNG = G \times 100/SN_{40}$

In addition to the ribbed tire, smooth test tires were used whenever they were available and the subscript S is used in the figures to denote a smooth tire test value. In all cases, a preliminary test was made to scrub the surface before performing the recorded skid resistance tests. This was done to minimize the effects of any existing contaminants that might contribute to test value variation.

A stereo photograph of each tested surface was taken for the purpose of measuring and recording the surface texture profile. Three profiles of each surface were plotted from each photograph to provide a visual record. The middle profile has approximately 300 readings within the 110 mm length and the vertical scale has been amplified five times for the plot. From the middle profile, a surface texture value T has been obtained by dividing the length of the existing profile in millimetres by 110 millimetres (which is the horizontal distance that the profile covers). The top and bottom profiles of the pavement surface are plotted without vertical amplification to provide a visual concept of the uniformity of the pavement surface.

These plots are shown in Appendix B along with a summary of pertinent surface information such as the age of the surfacing, cost, type and amount of materials, wet pavement accident data, visual appearance, skid number, speed gradient, and the surface texture value. Estimated vehicle passes are given to the date when skid tests were taken. The date when the stereo photograph was taken is shown in the lower left corner of each figure.

Two additional parameters that are important to the effectiveness of these surfaces are aggregate gradation and mineral composition. Both of these properties are tabulated in Appendix C.

DESCRIPTION AND EVALUATION OF SPECIFIC SURFACES

As stated in the introduction, the primary criteria used to evaluate the pavement surfaces included in this project are skid number, speed gradient and texture profile. Attempts were made to relate these quantitative values for the surface types to desirable or undesirable accident reduction characteristics. Greater detail is provided in the discussion but a limited accident history did not establish any criteria for a meaningful classification. Therefore, a system that utilized all three parameters was used to present the surface types in a preferential order. Each surface type was ranked in preference for each of these parameters. The sum of the ranked values for each surface provided a value that was used to list the surface types in the order presented in Appendix B. The ranked values for each parameter and their summation are tabulated in Appendix D. This order provides for a relative comparison of the surface types; however, it is not specific enough to convey, for example, that the surfacing represented by Figure 5 is necessarily preferable to that represented by Figure 6 or 7. It is reasonable to conclude that the surface types listed in the first third of the group will have better skid resistance characteristics than those listed in the last third.

The resulting order appears to be a reasonable classification for the skid resistance properties, but there is no consideration of the lasting effects of the surface types. If any of the surfaces are being compared for a specific application, the traffic history listed in the respective figures in Appendix B should be considered. These surfaces have not experienced tire chain or studded tire traffic. Vehicle passes and truck passes accumulated up to the date that skid tests were performed have been provided for each surface. It was assumed that eighty percent of the trucks travel in the outside lane and twenty percent in the next lane for these calculations.

The three parameters used to rank the surface types may not include enough information to provide for an effective evaluation of skid resistance characteristics. Therefore, three additional parameters are included to provide additional information. These are Percent Normalized Gradient, SN_{40} - SN_{40S} and SN_{40S}.

Since the wet pavement accident history did not provide sufficient guidelines to establish any minimal values the following values were selected as maximum or minimum for evaluating available friction of a pavement surface in this report.

Friction Available	Speed Gradient	Percent Normalized Gradient	SN_{40}- SN_{40S}	Texture	SN_{40}	SN_{40S}
High	0.2	0.2	4	1.10	50	40
Moderate to High	0.3	0.3	5	1.09	49	39
	0.5	0.6	7	1.05	40	36
Moderate to low	0.6	0.7	8	1.04	39	35
	0.7	0.9	12	1.03	35	30
Low	0.8	1.0	13	1.02	34	29

It should be understood that a surface with a high Speed Gradient, SN_{40}, and SN_{40S} friction available rating may not necessarily have a high Percent Normalized Gradient or SN_{40} - SN_{40S} rating.

The pavement surfaces will be discussed in the order that they were ranked in Appendix B for each of the three surface classifications used in this report. However, since the chip seal and overlay surfaces shown in Figures 1, 4, 8, 13, 15, 18, 19, 20, 21, 22, 23, 26, 27, 28, 29, 30, 39, 40, 43, 44 and 45 exist on the San Francisco-Oakland Bay Bridge, the background information is presented here prior to discussions by ranking and surface type.

Most of the deck surface upon which the innovative surfaces were placed was a polished coal tar modified epoxy asphalt overlay. All but five surface treatments cover the right lane -- number 5 -- of the structure for approximately 200 feet (61 m). Figures 21 and 22 represent the surfacing placed on lanes one and five of the upper deck of the structure in 1976, and Figures 15, 18 and 26 represent approximately 600 feet (183 m) of surfacing placed in lanes five, four and one, respectively, on the lower deck in 1969. This structure has daily traffic volumes of approximately 170,000 vehicles. Six percent of this traffic is trucks and most of these travel in the outer lanes so that of the 17,000 vehicles per day over the surfaces in the number five lane approximately 4,250 are trucks. The traffic speed on the surfaces is approximately 55 mph (88 km/h) and there are moderate frictional demand levels that result from routine traffic accelerations and lane changes.

The mild coastal climate does not subject these surfaces to temperature extremes and neither studded tires nor tire chains were used on any of the surfaces evaluated. Records of accidents in this area before the surface placement in September 1971 were not coded to show the primary location of the collision, so only accident data after the surface placement can be related to the outer lane (A few of the recorded accidents for the 200 feet (61 m) test sections may be attributed to the wrong area because of the short length. However, the accident frequency was very low for these areas, and a detailed analysis of each accident would not be reliable.). The bridge deck is considered to be wet about five percent of the time and a five year average wet pavement accident ratio for this county is twenty percent of the total accidents.

The following is a description of the different surface types that were studied for this project.

Chip Seals

Epoxy Chip Seal with Calcined Bauxite (Figures 1 and 4). The grittiness of the calcined bauxite provides a very high initial skid resistance value that may be satisfactory for high skid resistance demand areas such as intersections. The binder must be exceptional to retain the aggregate because of high stresses developed by the vehicle tires. To obtain a good bond with the existing surface, the practice has been to sandblast or grind the surface before the binder application. The coal tar modified epoxy asphalt was sandblasted prior to the chip seal applications on the bridge deck. These surfaces appear to have several years of quality service life remaining.

At another location, the asphalt concrete surface was ground before application of the calcined bauxite chip seal on a 285 foot (87 m) radius curve connecting two freeway routes. An irregular surface profile left by the grinding operation was desired to provide additional lateral resistance for the surface bond. Traffic conditions prohibited obtaining a stereo photograph of this area so the data is presented as

1a with Figure 1. The curve is posted with an advisory speed of 35 mph (56 km/h). The 1971 ADT was 19,000 and the vehicle count has increased approximately 1,000 each year. Reported accidents have been infrequent before and after this corrective treatment, but the visual appearance of the guardrail indicates that there have been fewer contacts since the surface treatment. Furthermore, these guardrail dents and scratches indicate that vehicle contact is now almost out of the curve whereas before the corrective treatment it was near the beginning of the curve. Apparently, if the errant vehicle is operational, then the accident is not reported.

This chip seal surface is experiencing some bond failure and approximately three or four additional years is all that may be expected at this high skid resistance demand location. An estimated 62 million vehicle passes can be inferred as a maximum service life from these findings.

This type of surface is satisfactory for areas subject to high friction demand. A questionnaire response indicated that it is not acceptable for studded tire traffic.

<u>Asphalt Chip Seal with Streambed Aggregate (Figures 3 and 10).</u> Visual observation of this project revealed more macrotexture between the wheel paths than in the wheel paths. This phenomenon is not unusual and is attributed to a combination of chip loss, chip depression into the asphalt matrix, chip reorientation to a flatter surface, and some chip polish. The chip loss became so significant that an overlay was placed before the winter rains in 1976. Smooth tires were not on hand when the skid tests were made in 1975 and the overlay was placed before a complete series of tests were scheduled so smooth tire data are not available for this surfacing.

This chip seal surface provided two years of service life for about six million vehicle passes. A five to seven year service life is normally expected from a good asphalt chip seal. The life of the wearing surface is dependent on the aggregate, traffic conditions, and construction procedures. The specific reason for the short life is not known but some common problems with chip seals are discussed later in a general discussion.

Although the measured parameters indicate that this type of surfacing would be acceptable for high friction demand areas, the high potential for chip loss and the short life suggest its use should be limited to moderate or low friction demand areas.

Epoxy Chip Seal with Watsonville Granite (Figures 8, 20 and 27). This aggregate is desirable for chip seal application because of the durability, surface roughness, and the cubical shape that the crushed aggregate possesses. The rather large variation in values of texture and percent normalized gradient suggest that construction procedures are important. This type of surface appears to be acceptable for moderate to high friction demand areas.

These surfaces appear to have several years of service life remaining.

Rubberized Chip Seal with Crushed Igneous Aggregate (Figures 11 and 24). This surfacing is performing satisfactorily under an extremely high percentage of high speed truck traffic in a rural area. Wheel track depressions are apparent but the overall appearance of the surfacing is good.

The ribbed and smooth tire skid test results indicate acceptability in areas of high friction demand but the texture and gradient parameters indicate that the surface should be limited to areas having moderate friction demand.

Epoxy Chip Seal using Bear River Quartz (Figures 13 and 19). This aggregate is a very durable aggregate; however, experience indicates that the surface texture will eventually polish after a very large number of vehicle passes. Most of the skid resistance will be developed from the macrotexture. This surface type appears to be acceptable for moderate to high friction demand areas.

Epoxy Chip Seal with Copper Slag (Figure 23). Because this is a crushed product, this material is very angular. It is considered to be a satisfactory surface treatment for moderate friction demand areas.

Permapol Rubber Incorporating Aluminum Oxide Aggregate (Figures 25 and 28). This surfacing was applied with paint rollers on two projects. It appears to be an acceptable wearing surface, but considering the very high cost its use will no doubt be limited to special treatments such as sealing membranes(6). The rather large variation in values of SN_{40} - SN_{40S}, speed gradient, and percent normalized gradient indicate that nonuniformity may be a problem. Because of this and the marginal texture values, this surface is not recommended for areas where high friction demand is expected unless the vehicle speed is limited to 40 mph (64 km/h) or less.

Epoxy Chip Seal with Silicon Carbide (Figure 37). Prior experience with this material has indicated that the angularity of this aggregate provides a high initial skid resistance value. The aggregate lacks a gritty surface texture so the skid resistance is developed from macrotexture. The low smooth tire test results and the high percent normalized gradient suggest that this surfacing should be limited to moderate to low friction demand areas.

This surface was placed primarily for the purpose of providing color contrast for delineation to another primary highway route. It is subjected to a high traffic volume and a high percentage of truck traffic. The expected service life is estimated to be approximately 60 million vehicle passes because some ravelling and bond failure have developed between the wheel paths.

Epoxy Seal with Monterey Sand (Figure 40). This subangular to rounded sand is durable; however, excluding areas having tire chain traffic, aggregates high in silica usually polish instead of wear under heavy traffic. With the fine gradation there is minimal macrotexture to maintain a high skid number as the exposed surface polishes. This surface exhibits low SN_{40} - SN_{40S} and high percent normalized gradient values.

Therefore, this type surface is not recommended for areas where high friction demand is probable.

Epoxy Seal with Bear River Sand (Figure 41). A 25 foot (7.6 m) section of this surfacing was placed as part of a research study(7) completed in June, 1965. In the Sacramento Valley climate -- hot summers and cool winters -- this surface has performed very satisfactorily in the absence of tire chain and snowplow action. This surface should provide several more years of skid resistant service. It is acceptable for areas having moderate to low friction demand.

Overlays

Open Graded Asphalt Concrete (Figures 2 and 5). This surfacing was a part of new construction that was completed in December 1965. It was placed over 0.33 foot (100 mm) dense graded asphalt concrete.

The ADT of the four lane facility has increased from 9200 in 1966 to 14,900 in 1974. This traffic consists of 3.7 percent trucks. It is assumed that the truck traffic in the outer lane is the primary reason for the difference in the test values for the two lanes. The visual appearance and the test values indicate the existing surface will provide several more years of effective service.

This surfacing is satisfactory for mild climates where tire chains, studded tires or snow plows are not used. It is acceptable for areas having high friction demand.

Open Graded Asphalt Concrete (Figure 7). This surfacing was placed in July 1975. It looks very good and should provide many more years of service for the rather high traffic volume. This area has experienced a rather high accident rate for several years. The open graded asphalt concrete surfacing did not reduce the wet pavement rate but the relatively high ranking of this surface and the low percent of wet pavement accidents indicate that skid resistance is not the primary cause of accidents that occurred. This surfacing appears to be satisfactory for all mild climate locations. It is acceptable for areas having high friction demand.

Open Graded Epoxy Asphalt Concrete with Blast Furnace Slag (Figures 15 and 26). The performance of this surfacing has been very good. It was placed as a test installation in an area with a very high frequency of wet pavement accidents. It has provided a substantial reduction in accidents(8) and has provided service for more than nine years. There is evidence of surface polishing and slight raveling in the wheel tracks; however, there appears to be several years of service life remaining.

This surfacing is considered to be satisfactory in mild or hot climates. It is acceptable for areas having moderate to high friction demand.

Open Graded Epoxy Asphalt Concrete with Watsonville Granite (Figure 18). The performance of this surfacing has been comparable to those shown in Figures 15 and 26 using blast furnace slag. This surface is considered satisfactory in mild or hot climates and is also acceptable for areas having moderate to high friction demand.

Dense Graded Epoxy Asphalt Concrete using a combination of Metagraywacke and Expanded Shale (Figures 21 and 22). Although this is a recently placed surfacing, the performance appears to be very good. During a recent rainstorm, only 2 wet pavement accidents were recorded on the upper deck using this surface while 11 were recorded on the lower deck. Prior to the placement of this surface, the accident rates on the upper and the lower decks were nearly equal.

A better evaluation can be made after several years of traffic exposure but it appears that this surfacing is acceptable for moderate to high friction demand areas.

Dense Graded Epoxy Asphalt Concrete using Blast Furnace Slag (Figures 29 and 30). This epoxy asphalt concrete surface exhibits a uniform appearance with no signs of spalling or bond problems. Macrotexture appears to be minimal for this surface so the skid resistance must be developed from aggregate grittiness and angularity.

This surfacing had 0.8 percent less epoxy asphalt binder than the recommended design percentage, however, there is ample binder for the mix. The speed gradient and skid number indicate that this is probably an acceptable surface for moderately high friction demand areas but the texture values are low and moderate respectively. The smooth tire skid numbers indicate that these surfaces differ even more than the texture measurements. Presumably this difference results from construction procedure variation. Therefore, this surface type should be limited to moderate to low friction demand areas.

Dense Graded Asphalt Concrete (Figure 33). As a typical standard thin blanket overlay, this surfacing has performed satisfactorily. Values for texture and SN_{40} - SN_{40S} on this surface are low but the skid number and speed gradient values indicate that an adequate surfacing exists for moderate to high friction demand areas. Therefore, this surfacing is considered to be acceptable for areas experiencing low to moderate friction demand.

Dense Graded Epoxy Asphalt Concrete with Expanded Shale (Figures 39 and 44). There is minimal macrotexture for this surfacing so the skid resistance must be developed from the aggregate grittiness. This surface had 1.5 percent less epoxy asphalt binder than the recommended 11.5 percent by design. However, the slight richness of the surface indicates there is sufficient binder in the mix. So far there is no visual evidence of any ravelling or bonding problems with this surfacing.

The SN_{40} values are desirable for moderately high to high friction demand areas but the smooth tire skid test values the texture values and the SN_{40} - SN_{40S} values indicate that this surface should be limited to low friction demand areas. It is probably an acceptable surface for moderate to low friction demand areas.

<u>Dense Graded Epoxy Asphalt Concrete with Watsonville Granite (Figures 43 and 45).</u> This surface has a uniform appearance with no signs of spalling or bond problems. The mix was placed with 0.4 percent more epoxy asphalt binder than the recommended design value of 6.3 percent. A bleeding or flushing condition resulted immediately, so the surfaces were sandblasted to obtain satisfactory skid resistance values. The speed gradient and SN_{40} values are desirable for a moderately high friction demand area but the smooth tire skid test values, the texture values, the percent normalized gradient and the SN_{40} - SN_{40S} values indicate that this surface should be limited to low friction demand areas.

This surface appears to have a high potential for skidding accidents but is probably an acceptable surface for low to moderate friction demand areas. Due to the need to sandblast, the surface cannot be considered "typical" of this type of construction.

Portland Cement Concrete

The PCC surfaces listed are part of another current research project to evaluate PCC surface textures. Additional information on the performance of these textures will be reported in "Surface Texture for PCC Pavements", by B. F. Neal, D. E. Peck, J. H. Woodstrom, and D. L. Spellman at a later date. These textures are so new that it is impossible to evaluate their effectiveness or service life at this time.

Transverse Metal Tines (Figures 6, 12 and 14). The transverse texturing was performed in California with metal tines spaced at 1/4, 1/2, and 3/4 inch (6, 13, and 19 mm) without any prior texturing. The 1/4 inch (6 mm) tine spacing was visually considered unacceptable and only a very short section was constructed.

Longitudinal Metal Tines (Figures 9 and 16). The longitudinal tine texturing was constructed at 1/2 inch (13 mm) and 3/4 inch (19 mm) spacings. The appearance of the longitudinal tine texturing on 3/4 inch (19 mm) centers has resulted in California adopting this finish for several projects. Prior to the tine texturing, a burlap drag is used to distribute surface water and to give some initial texture between the grooves.

Transverse Bristle (Figure 17). This texture was provided with a double row of polypropylene bristles.

Longitudinal Burlap Drag (Figures 31 and 35). A burlap drag texture was provided on this project which also has research test sections using the aggregate-seeding procedure. Figure 31 represents the normal texturing procedure and Figure 35 represents a section that the use of additional water during finishing was prohibited.

Aggregate Seeding (Figures 32, 36 and 38). An attempt to provide a long wearing texture was made by spreading durable aggregate after the paver. A roller, a pipe float and a burlap drag were used to imbed the aggregate and to provide an initial texture. As the mortar wears, the aggregate should provide acceptable texture and skid resistance. The crushed gravel surface is represented by Figure 32, the blast furnace slag surface by Figure 36, and the lightweight aggregate surface by Figure 38.

Artificial Grass Drag (Figure 34). This texture was developed with an artificial grass (such as Astroturf) drag which resembles that obtained with a broom.

Longitudinal Broom (Figure 42). This texture is considered to be light for a broom finish. Heavy broom finishes have generated complaints from motorcyclists. Although traffic eliminates this problem by removing the harshness in the first few months, there is a tendency to prefer the lighter finish. Because typical broom finishes were not highly skid resistant nor long lasting, the trend in texturing has been toward the use of a metal tine finish.

DISCUSSION

Accident Criteria

In the description of specific surfaces, an evaluation of the surface treatments was made using skid number, speed gradient, surface texture, and service life. Another parameter that can be useful in evaluating surface treatments is wet pavement accident criteria. All but four of the installations included in this project are in areas of moderate vehicle maneuvers and friction demand so that a low frequency of wet pavement accidents is expected. This low frequency of accident occurrence and the many variations in length, age and traffic will reduce the significance of any observed trends in this data. Specific data on the four surfaces that were placed to reduce the wet pavement accident rate are presented in 1a of Figure 1 and in Figures 15, 18 and 26.

A summary of the accident data is tabulated in Appendix E. The length of the test section, the period of time for which data was collected, the wet pavement and dry pavement accident count, the percent of time that this pavement is expected to be wet and the average percent of wet pavement accidents for the resident county are included in the tabulation.

Accident statistics for the location of the test sections were obtained for a period of time before and after construction in most cases. In some instances, the new surface was placed along with realignment so that a before/after comparison would be misleading. Also, until 1971, the accident data on the San Francisco-Oakland Bay Bridge was not coded to show the primary location of a collision. For these situations, only the after-placement accident data is presented in Appendix E.

Without a "before and after" comparison it becomes necessary to consider statistics such as simply the absence of wet pavement accidents or the ratio of wet pavement to total accidents. Although wet pavement accidents should relate best to skid resistance, the dry pavement accident frequency provides a clue that other factors may be involved. For example, the surface represented by Figure 15 has 15 wet pavement accidents over a six-year period. This frequency might seem high until we see that there were 108 dry pavement accidents for the same period. This condition strongly suggests that geometrics, delineation, speed or some other factor is probably more responsible for accidents than the pavement skid resistance. This implication becomes stronger when weather statistics show that the pavement is wet about five percent of the time.

For the area represented by Figure 15 a very high traffic volume is subjected to a curve on a structure such that the sight distance is limited. If problems develop ahead, driver inattentiveness may result in collisions even though there is adequate skid resistance for normal conditions.

The rather low frequency of accidents for the pavement surfaces included in this project indicate that there are few if any problems. But, in general, locations having wet pavement accident frequencies greater than some specified level or percent are considered by some traffic engineers as potential candidates for corrective treatment. The percentage that one adopts as a "trigger" value usually depends upon experience and the percent of time that a pavement is wet.

In addition to problem sites that are located and reported by highway users and highway personnel such as maintenance men and highway patrolmen, high concentrations of wet pavement accidents are identified on computer printouts and investigated. Usually, to establish that there may be a skid resistance problem, the percentage of wet pavement accidents must be greater than the county average.

Data Correlation

For this study, attempts were made to establish a relationship between the wet pavement accidents and the various measured parameters. The low accident frequency, the variable friction demands on the different surfaces, the short test sections and the different duration of wet pavement time are some of the reasons why good correlations did not exist for this data. Also, attempts were made to relate texture to several other parameters. The correlation coefficients from regression analyses for texture versus skid number, percent normalized gradient, speed gradient and $SN_{40} - SN_{40S}$ were 0.29, 0.47, 0.48 and 0.75 respectively.1/

The relationship between texture measurements and speed gradient and the percent normalized gradient was expected to be stronger than the data correlation coefficient indicates. Therefore, some parameter might be missing from one of the measurements. One important characteristic of skid resistance that texture measurements as obtained do not quantify is grittiness. If a pavement surface is to be evaluated by texture, it appears that some measurement of the grittiness characteristic must accompany the texture measurement.

Some research has been performed in this direction. M. Leu and J. Henry establish a relationship between speed, skid

1/ The best relationship is shown in Figure I.

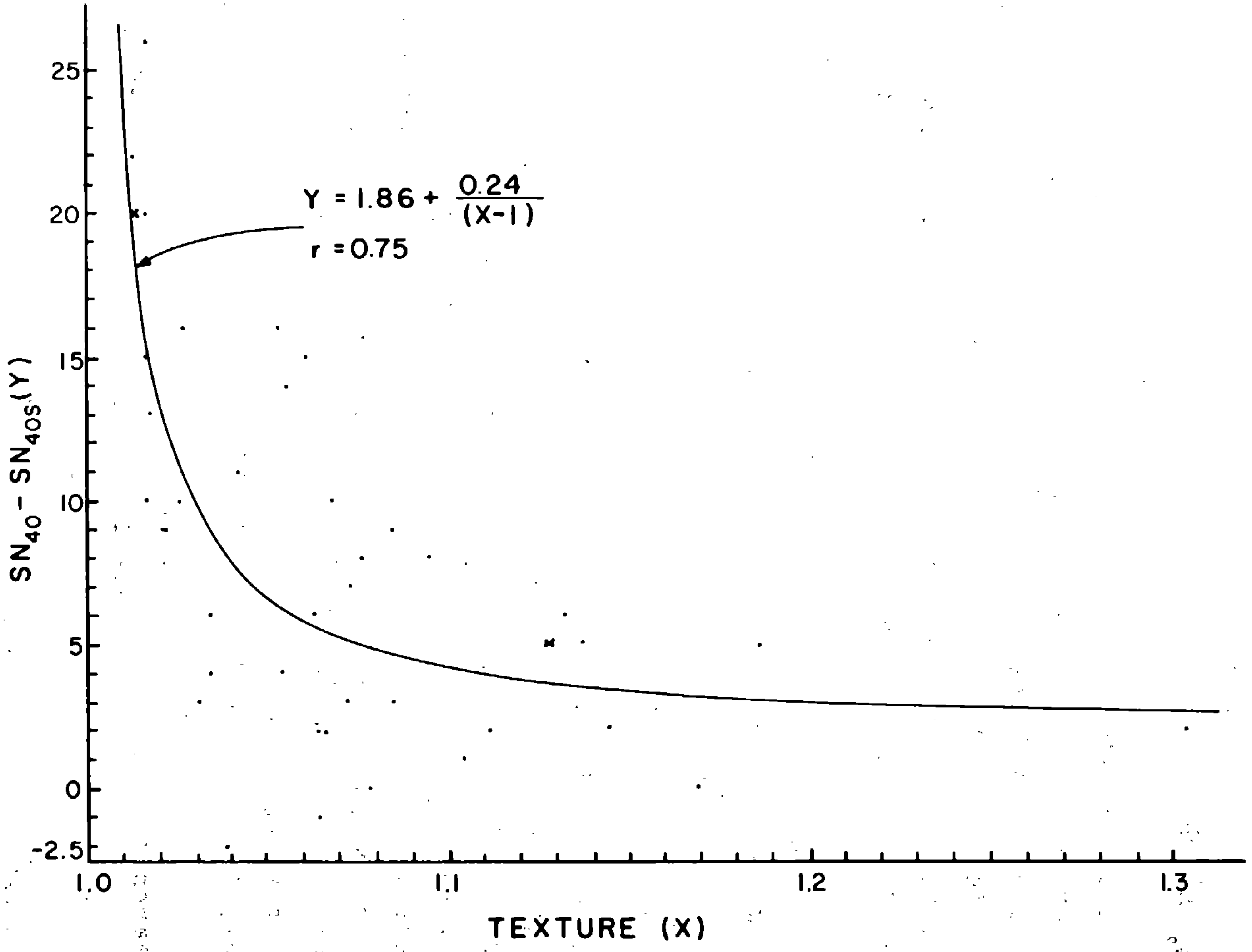

Figure I - RELATION OF PAVEMENT TEXTURE VALUE ON THE DIFFERENCE BETWEEN RIBBED TIRE AND SMOOTH TIRE SKID TESTS.

number, British Portable Number and the sandpatch mean texture depth(9).

The need for a grittiness classification to accompany a texture value for evaluation is illustrated by the following example. The three epoxy chip seals presented below have approximately the same texture value, T.

Aggregate	SN_{40}	T	G*	$(SN_{40} - SN_{40S})$
Watsonville Granite	45	1.054	0.20	4
Silicon Carbide	40	1.056	0.40	14
Monterey Sand	45	1.061	0.53	15

*Speed Gradient

The grittiness of the Watsonville granite is reflected in the speed gradient and the difference between ribbed tire and smooth tire test values. It is probable that a relative value could be approximated by fingertip sensitivity at the time texture measurements are made if one desires to use texture for pavement evaluation.

Although this is only a fair correlation, it appears that surfaces having texture values greater than 1.100 have exceptional drainage characteristics so the difference between skid numbers measured with a ribbed tire and a smooth tire are small. Surfaces with texture values less than 1.020 have very little macrotexture and need aggregate with grittiness to be acceptable even in a moderate demand area. Surfaces with texture values between 1.020 and 1.100 could be classified as very good or as fair depending upon the grittiness characteristics present. The reader should keep in mind that these values were obtained from a curve having a correlation coefficient of 0.75 and therefore should be considered approximate.

At the request of the FHWA contract manager, a correlation coefficient from regression analysis was determined for texture, T, versus percent normalized gradient, PNG, which relates the speed gradient, G, to the level of skid resistance. For this analysis:

$$PNG_{40} = G \times 100/SN_{40}$$

The data plotted in Figure II provide a correlation coefficient r of 0.47 for the linear equation and 0.43 for the hyperbola. While this data does not establish a strong equation, the hyperbola does tend to substantiate the levels of texture obtained in the plot of texture vs. $SN_{40} - SN_{40S}$, namely, $T \leq 1.02$ appear to be unsatisfactory and $T \geq 1.1$ appear to be very desirable. The data plots exhibit considerable scatter, again indicating that these texture measurements alone do not reflect the total skid resistance performance of a pavement.

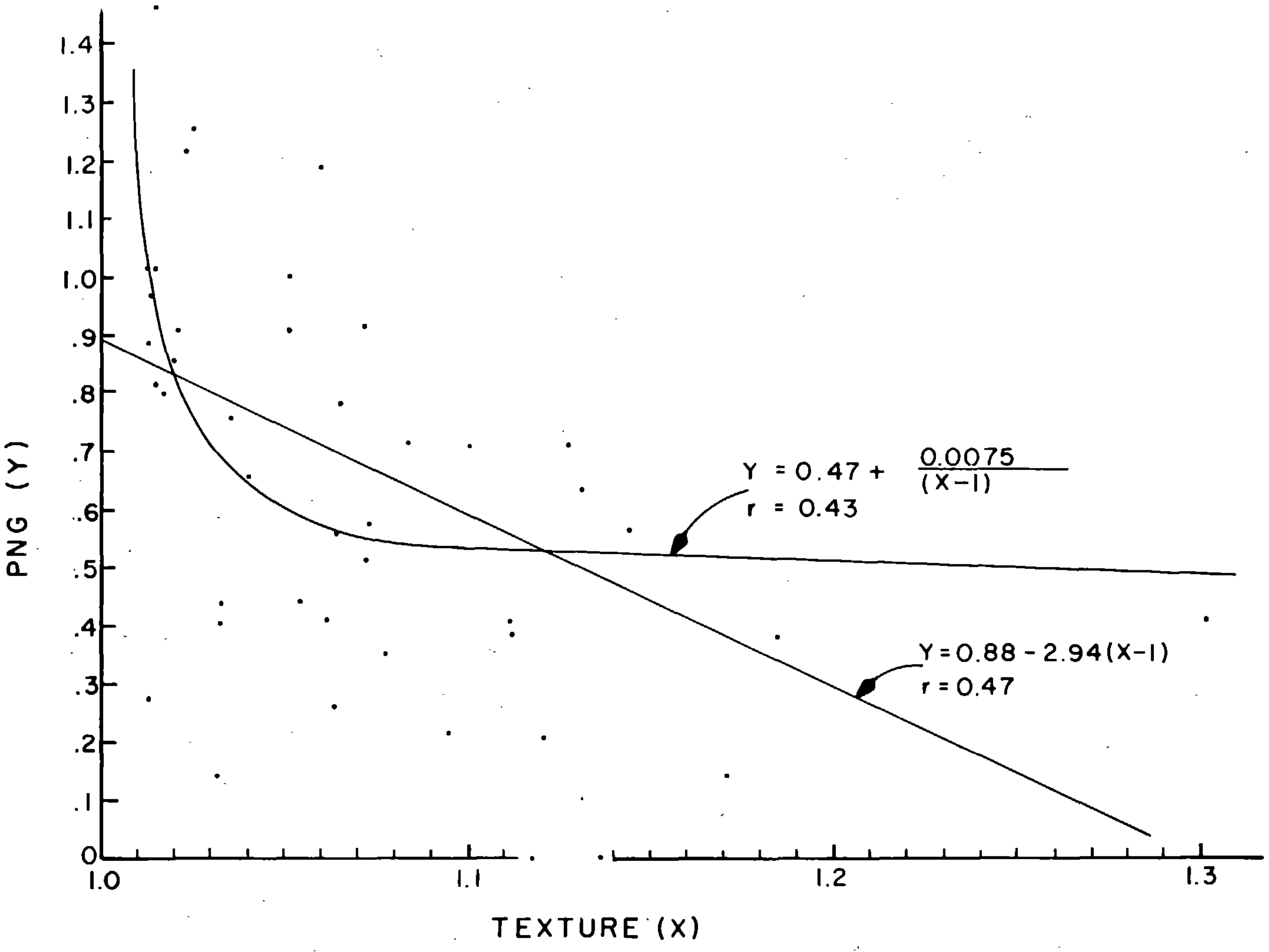

Figure II - RELATION OF PAVEMENT TEXTURE VALUE ON PERCENT NORMALIZED GRADIENT.

Chip Seals

A crushed aggregate is often implied by the term chip seal; however, to minimize classifications, all thin membrane coatings will be discussed as chip seals in this report whether the aggregate is grit, natural sand or a crushed product. In general, properly placed chip seal surfaces have excellent skid resistance characteristics.

Under normal conditions and with good construction practices, maintenance personnel indicate that five or more years may be expected from bituminous chip seals. Projects included in this study show that a longer service life may be expected from resinous epoxy seals in mild climates. When placed over portland cement concrete surfaces in cold climates the thermal characteristics require that epoxies be modified so that they do not create a shear failure within the PCC. Therefore, Coal Tar Modified Epoxy Resin is frequently used for epoxy asphalt chip seals on PCC surfaces. Even then, tire chain and snowplow action and thermal stresses may result in a service life for epoxy-modified asphalt resin chip seals of no more than a year(7). A polyester binder over an epoxy primer has provided approximately three years service life in a nonfreeze-thaw area.

Even though all the surfaces for the epoxy resin seals were cleaned by sandblasting or by grinding prior to applying the binder, three of the eleven placed have started to separate from the original surfaces of epoxy asphalt, asphalt, and portland cement concrete pavement. It is not known whether this bond failure resulted from oil residue, moisture vapor, blisters that eventually burst and peel, or some other phenomenon. Although the service life for the epoxy resin seals in non-chain areas is very good, it appears that this type of bond failure will eventually cause failure of all of the epoxy resin chip seals described in this report. The wearing surface should continue to perform well until bond failure occurs because the intact aggregate displays slight wear, and the bond between the aggregate and the epoxy resin appears excellent.

Both asphalt and epoxy resin chip seals are vulnerable to excessive chip loss when 1) the chips are placed too late for the binder to wet the chips and develop a good bond, 2) high speed traffic is permitted on the chips before an adequate cure, 3) the chips are not clean, or 4) there is insufficient binder for the chip size. These four construction variables must be controlled for a successful chip seal surface. The shape of the aggregate chips is also important to the success of a chip seal treatment, angular chips being better than a nearly spherical shape.

The spread rates for the binder and the aggregate used in the chip seal surfaces described in this report are listed on the profile charts in Appendix B. Also listed for comparison are the approximate costs of the various surfaces. Most of these costs are high and reflect the small jobs and the Contractors' inexperience with the material at the time they were placed.

It is apparent that the cost of chip seals increases significantly as special gritty, polish resistant aggregates bonded with epoxy resin are used to accommodate requirements of high traffic volumes, high vehicle speeds, or special conditions. User savings may offset the apparent high cost if the service life of an epoxy chip seal is two or three times that of an asphalt chip seal.

Overlays

Usually, with overlay treatment, the traffic is on the new surface within a short period of time after construction so it becomes important to maintain good control of the binder content to reduce the probability of a flushing or bleeding condition. A flushing or bleeding condition can be less of a problem for epoxy asphalt surfaces because sandblasting will restore skid resistance. Surfaces represented by Figures 43 and 45 were improved by sandblasting.

Open graded mixes usually provide a rapid surface drainage so that there is less tire-splash than on most other pavement surfaces during and just after rainfall. This is an important safety consideration.

Open graded surfaces are not used in areas of snow and ice in California because the tire chain and snowplow action substantially reduce the service life making surfaces of this type unsuitable.

Generally, good skid resistance properties can be obtained with overlays. An expected skid resistance service life of 10 to 15 years for dense graded and open graded asphalt concrete can be obtained in the absence of chain or studded tire wear, or other severe treatment.

Portland Cement Concrete Texturing

A satisfactory initial skid number and texture roughness can be easily obtained on PCC surfaces; however, the rapid wear and polish in the wheel tracks of the truck lanes have generated a need for improving the durability of the textured surface. Currently a promising approach is to texture the fresh PCC with metal tines. California has investigated tined texture in both the transverse and the longitudinal direction. Unfortunately, neither surface type has been subjected to enough traffic to determine its durability at this time. A recent Texas report indicates that there is no significant difference between transverse texturing and longitudinal texturing(10).

National Cooperative Highway Research Program Project 1-12(3)

There were ten systems selected as most suitable for immediate practical application as skid resistant pavement surfaces in the findings of NCHRP Project 1-12(3)(11). These findings from Digest 89, November 1976, are repeated here along with any comments or pertinent findings relative to pavement surfaces observed for this project, "New and Innovative Methods and Materials for Pavement Skid Resistance".

1. Portland cement concrete with sharp, polish-resistant fine aggregate and coarse texture (tined) surface.

There are five projects included in this report that have been textured with metal tines. While these surfaces are too new to form definite conclusions, this type of texturing appears to be very desirable. The initial surface texture is substantial and the adequate skid numbers indicate the presence of a sharp or gritty fine aggregate. A better evaluation of this construction can be made in three or four years. Data for the tined texture PCC surfaces are presented in Figures 6, 9, 12, 14, and 16.

2. Dense-graded asphalt concrete with polish-resistant coarse aggregate.

The dense graded asphalt concrete surface included in this project has been subjected to a high rate of truck traffic for seven years and still exhibits acceptable skid resistance values. Although this aggregate has not been subjected to a polishing test, it is considered to be polish resistant because of its satisfactory performance in local roadways. It is probable that a 3/4 inch (19 mm) maximum size aggregate AC would provide more texture than the 1/2 inch (12.5 mm) size. The availability of polish-resistance aggregate is paramount to the life of this pavement. The texture profile and other data are shown in Figure 33.

3. Open-graded asphalt concrete with polish-resistant coarse aggregate.

With the exception of mountainous climates, the open graded surface has been utilized as a skid resistant surface in California for more than fifteen years. A number 3 or 1/4 inch (6.3 mm) maximum open graded surfacing is represented in Figures 2 and 5 of this report. Although the 3/8 inch (9.5 mm) and the 1/4 inch (6.3 mm) maximum gradation has performed satisfactorily, a 1/2 inch (12.5 mm) maximum gradation is being tried because the sizes are more compatible with typical bin storage supplies and therefore, somewhat easier to schedule orders. The cost per ton is less which will help offset the cost of the additional thickness required. This surfacing is included in this report in Figure 7.

4. Gap-graded asphalt concrete with polish-resistant coarse aggregate.

None of the agencies responding to our questionaire indicated that they used a gap grading.

5. Asphalt concrete with rolled-in, precoated, polish-resistant chips.

None of the agencies polled indicated that they used this procedure; however, in areas where polish resistant aggregate is lacking and/or expensive it should be tried. If a uniform appearance is not important this procedure may be appropriate for restoring texture to a bleeding or flushing pavement surface if the pavement is heated prior to rolling.

6. Epoxy-modified asphalt concrete with polish-resistant coarse aggregate.

There are eight surfaces included in this study having dense graded aggregate and epoxy-modified asphalt binder. Two of these have utilized a blend of two aggregates with different wear rates (Figures 21 and 22). The other six surfaces (Figures 29, 30, 39, 43, 44 and 45) consist of three different aggregates at thicknesses of 1/2 inch (12.7 mm) and 1 inch (25.4 mm). While the wear qualities and durability of the epoxy-modified asphalt concrete surfaces are very good, the texture of the dense graded epoxy asphalt concrete is marginal. It appears that the aggregate blend of metagraywacke and expanded shale have improved the texture somewhat but it may be due to the difference in traffic history.

7. Asphalt seal coat with polish-resistant chips.

This is a common skid resistant surface treatment that has realized various degrees of success. Several comments on construction procedures that affect performance are included in the discussion of chip seals earlier in this report. Asphalt chip seal surfaces are included in Figures 3 and 10.

8. Rubberized asphalt seal coat with polish resistant chips.

One surface of rubberized asphalt chip seal coat is presented in Figure 11. Although the rubber is expected to provide greater flexibility and elasticity at cold temperatures which should be helpful in controlling reflection cracking or in sealing fatigue cracks, this treatment has not been widely accepted. One of the reasons is the high chip loss experienced on several projects.

9. Epoxy-asphalt, calcined bauxite chip seal.

The calcined bauxite grit develops a very high skid resistance which requires a strong binding agent such as a two component epoxy resin binder to retain the chips. Data from two locations having an epoxy-asphalt calcined bauxite seal are presented in this report in Figure 1. It should be noted that one agency experienced a bond problem with this type surfacing. Also, the performance of the surfacing under studded tire traffic was unsatisfactory.

10. Sawed longitudinal grooves in existing portland cement concrete.

Longitudinal grooving has been an acceptable corrective treatment for smooth PCC pavements in California for more than 15 years. A "before and after" statewide study shows that grooving has reduced wet pavement accident rates by 69 percent(12), and is a cost effective treatment for PCC pavements. While accident rate decreases are well documented, it should be pointed out that skid resistance as measured does not always show a significant change after grooving.

Summary

The most promising skid resistant surfaces that were evaluated under this project are listed below in the order of ratings shown in Appendix D. This order presents the surfaces having the highest frictional characteristics first so the surfaces listed first would usually be preferable for areas having high friction demand. Surfaces listed last would usually be acceptable for moderate friction demand. It is important to note that some of the PCC surface textures may perform better than some of the surfaces listed.

A. For heavy or medium traffic volume.

1. Epoxy-modified asphalt, calcined bauxite chip seal as shown in Figure 1.

2. Open graded asphalt concrete as shown in Figures 2, 5 and 7.

3. Epoxy resin-calcined bauxite chip seal as shown in Figure 4.

4. Epoxy asphalt, Watsonville granite chip seal as shown in Figures 8, 20 and 27.

5. Open graded epoxy asphalt concrete with blast furnace slag as shown in Figures 15 and 26.

6. Open graded epoxy asphalt concrete with Watsonville granite aggregate as shown in Figure 18.

7. Epoxy asphalt, Bear River quartz chip seal as shown in Figures 13 and 19.

8. Epoxy asphalt concrete with a blend of Metagraywacke and expanded shale aggregate.

B. For medium or light vehicle traffic volume.

1. Asphalt chip seal as shown in Figures 3 and 10.

2. Rubberized chip seal as shown in Figures 11 and 24.

Many of these surfaces have been subjected to sufficient vehicle traffic so that further testing is unnecessary. However, the tined texture and the transverse broom texture of portland cement concrete and the epoxy asphalt concrete with blended aggregates should be observed for several years to better evaluate their service life.

CONCLUSIONS

1. A number of skid resistant surface treatments have been used with reasonable success in climates where tire chain action is not a factor. These surfaces are enumerated in the preceding summary.

2. Those corrective surface treatments considered new and innovative were all found to be quite expensive when compared to successful common surface treatments such as open graded asphalt concrete, conventional chip seals, and diamond blade grooving of polished portland cement concrete pavement. A longer service life may justify this cost in areas where very heavy traffic and/or high friction demand exists.

3. For the vehicle traffic and pavement surface test sections included in this project, the wet pavement accident data did not highlight any criteria that would help to establish minimal values that would be proper if applied on a broad scale.

4. Any pavement surface evaluation by texture criteria should include an appraisal of the grittiness characteristic.

APPENDIX A

Response Summary to Questionnaire Sent to California Districts

1. Please list those pavement skid-resistant treatments tried in your District and note whether their use was on AC or PCC pavement and whether it was placed during the initial construction or as part of a maintenance program.

Responses:

PCC

Grooving - 9 (Maint.)
OGAC overlay - 2 (Maint.)
DGAC overlay - 1 (Maint.)
Minimum water during finishing - 1 (Constr.)
Metal tine long. grooved - 1 (Constr.)

AC

OGAC overlay - 4 (Maint.), 2 (Constr.)
Chip seal - 2 (Constr.)
Resurfacing-thin blanket - 2 (Maint.)
Grooving - 2 (Maint.)
Cinder seal - 1 (Maint.)

2. Please describe any exceptionally successful and/or unsuccessful treatments or new construction methods you have tried.

Responses:

Successful Methods

PCC grooving - 5
OGAC overlay - 4
Chip seal - 1
Burning excess asphalt - 1

Unsuccessful Methods

Chip seal - 3 (lost chips)
Cinder seal - 1 (lost chips)

3. Do you have "before-and/or-after" skid accident data for any of these areas?

> Data is available in the statewide accident files.

4. Are you aware of any local agencies who may have experience with skid-resistant methods and materials?

> Agencies mentioned in this response were sent the Western States and Local Agencies questionnaire.

APPENDIX A

Response Summary to Questionnaire Sent to Western States and Local Agencies

1. How do you measure skid resistance?

ASTM E-274 - 10
MuMeter - 2
James Decelerometer - 1
Calif. Portable - 3
British Portable Tester - 1
Skidding Vehicle - 1

2. Please list those pavement skid-resistant treatments tried by your agency and note whether their use was on AC or PCC pavement and whether it was placed during the initial construction or as part of a maintenance program.

PCC

Grooving - 4 (Maint.)
Crushed rock - 1 (Constr. & Maint.)
Brooming - 3 (Constr.)
Epoxy & calc. baux. - 2 (Maint.)
Volcanic cinder C.S. - 1 (Constr.) (Bridge decks)
Burlap drag - 2 (Constr.)
AC overlay - 1 (Maint.)
Sandblasting - 1 (Maint.)

AC

OGAC - 7 (Maint. & Constr.)
Crushed rock - 1 (Maint. & Constr.)
Chip seal - 10 (Constr. & Maint.)
Plant mix seal - 1 (Maint. & Constr.)
Volcanic cinder C.S. - 1 (Maint. & Constr.)
Sand seal - 2 (Maint.)
Roadmix skin patches - 1 (Maint.)
DGAC-thin blanket - 3 (Maint.)
Kerosene & sand - 1 (Maint.)
Slurry seals - 4 (Maint.)
Heater scarifying - 1 (Maint.)
Long. grooving - 3 (Maint.)

3. Please describe any exceptionally successful and/or unsuccessful treatments or new construction methods you have tried.

Successful Methods

Chip seals - 4
Slurry seal - 2
AC volcanic cinder seal - 1 (light traffic)
PCC grooving - 2
OGAC overlay - 3
Rubberized AC seal coats - 1
Grinding on PCC - 1
DGAC thin blanket - 1
Sandblasting surface - 1
Armor coat treatment - 1

Unsuccessful Methods

Epoxy & calc. Baux. - 2 (bond failure)(not good under studded tire traffic)
Kerosene & sand - 1 (good winter only)
Slurry seals - 1
Disking or scarifying - 1
Chip seals - 1
Rubberized AC seal coat - 1

4. Do you have "before-and/or-after" skid accident data for any of these areas?

Yes - 5

No - 11

5. Do you specify pavement finishing methods and/or special aggregates for skid-resistance reasons on new or remedial construction?

PCC

Long. text. metal tines - 1
Crushed Aggregate - 1
Transverse text. - 2
Normal long. text. - 3
Coarse nylon broom - 1

AC

Crushed aggregate - 1
Proper mix design - 2
OGAC blanket - 2
Screened chips - 2
Sand seals - 1
Avoid polish susceptible aggregate - 1

6. Do you blend aggregate types to improve skid resistance?

Yes - 1

No - 14

APPENDIX A

Surfaces tested by the Air Force Weapons Laboratory(3),(4).

Slurry seal
Grooved slurry seal
Palmer Pavetread
Emulsified asphalt porous friction surface
120-150 penetration grade asphalt with 5% rubber additive porous friction surface

APPENDIX B

Page 1 of 3

SUMMARY OF APPENDIX B

Figure	Surface Type	Aggregate or Texture	Million Vehicle Passes	Date Placed	SN_{40S}	SN_{40}	G	T
1	ECS	No. 6 Max Calcined Bauxite	29	9/71	51	56	0.00	1.137
	ECS	No. 6 Max Calcined Bauxite	34	3/72	49*	45*	--	--
2	OGAC	No. 3 Max Streambed	16	12/65	51	56	0.20	1.186
3	CS	1/4" Max Streambed	3	7/74	--	50	0.00	1.118
4	ECS	No. 6 Max Calcined Bauxite	29	9/71	65	67	0.27	1.111
5	OGAC	No. 3 Max Streambed	16	12/65	47	52	0.20	1.128
6	PCC	Transverse Metal Tines @ 1/2"	2	4/75	56	56	0.20	1.078
7	OGAC	1/2" Max Metasandstone	7	7/75	52	54	0.30	1.144
8	ECS	No. 4 Max Watsonville Granite	29	9/71	47	47	0.07	1.169
9	PCC	Longitudinal Metal Tines @ 3/4"	2	6/75	46	48	0.20	1.304
10	CS	1/4" Max Streambed	3	7/74	--	48	0.10	1.122
11	RCS	3/8" Max Crushed Igneous	1	11/74	56	59	0.30	1.072
12	PCC	Transverse Metal Tines @ 1/2"	2	4/75	55	56	0.40	1.104
13	ECS	No. 4 Max Bear River Quartz	29	9/71	48	50	0.13	1.064
14	PCC	Transverse Metal Tines @ 3/4"	2	4/75	53	56	0.40	1.085
15	OGEA	1/4" Max Blast Furnace Slag	43	11/69	38	46	0.10	1.095
16	PCC	Longitudinal Metal Tines @ 1/2"	2	6/75	41	47	0.30	1.132
17	PCC	Transverse Bristle	2	4/75	44	50	0.20	1.034

*SN_{30} Values Measured at 30 mph (1 mph = 1.6 km/h)

SUMMARY OF APPENDIX B

Figure	Surface Type	Aggregate or Texture	Million Vehicle Passes	Date Placed	SN_{40S}	SN_{40}	G	T
18	OGEA	1/4" Max Watsonville Granite	43	11/69	42	48	0.20	1.063
19	ECS	No. 4 Max Bear River Quartz	29	9/71	50	49	0.27	1.064
20	ECS	No. 4 Max Watsonville Granite	32	9/71	42	47	0.33	1.128
21	EAC	3/8" Max Metagraywacke & Expanded Shale	2	11/76	50	52	0.40	1.066
22	EAC	3/8" Max Metagraywacke & Expanded Shale	2	11/76	47	54	0.50	1.073
23	ECS	No. 10 Max Copper Slag	32	9/71	38	46	0.27	1.076
24	RCS	3/8" Max Crushed Igneous	1	11/74	55	53	0.40	1.038
25	RCS	Aluminum Oxide Grit	2	11/71	39	55	0.50	1.053
26	OGEA	1/4" Max Blast Furnace Slag	43	11/69	39	48	0.50	1.085
27	ECS	No. 4 Max Watsonville Granite	32	9/71	41	45	0.20	1.054
28	RCS	Aluminum Oxide Grit	29	9/71	38	41	0.06	1.031
29	EAC	No. 4 Max Blast Furnace Slag	32	9/71	27	47	0.13	1.014
30	EAC	No. 4 Max Blast Furnace Slag	32	9/71	41	45	0.20	1.034
31	PCC	Longitudinal Burlap Drag	5	6/75	37	50	0.40	1.018
32	PCC	"Seeded" 1/2" Max Crushed Gravel	5	6/75	35	46	0.30	1.042
33	DGAC	1/2" Max Streambed	29	6/69	34	49	0.40	1.017
34	PCC	Longitudinal Artifical Grass Drag	2	4/75	42	52	0.50	1.017

SUMMARY OF APPENDIX B

Figure	Surface Type	Aggregate or Texture	Million Vehicle Passes	Date Placed	SN_{40S}	SN_{40}	G	T
35	PCC	Longitudinal Burlap Drag	5	6/75	28	47	0.40	1.021
36	PCC	"Seeded" 5/8" Max Slag	5	6/75	39	49	0.60	1.026
37	ECS	No. 8 Max Silicon Carbide	45	7/64	26	40	0.40	1.056
38	PCC	"Seeded" 1/2" Max Lightweight	5	6/75	32	48	0.60	1.027
39	EAC	No. 4 Max Expanded Shale	32	9/71	24	50	0.73	1.017
40	ECS	No. 16 Max Monterey Sand	32	9/71	30	45	0.53	1.061
41	ECS	No. 8x16 Bear River Sand	56	6/65	33	43	0.60	1.068
42	PCC	Longitudinal Broomed	2	4/75	35	44	0.40	1.022
43	EAC	No. 4 Max Watsonville Granite	32	9/71	26	46	0.47	1.017
44	EAC	No. 4 Max Expanded Shale	32	9/71	25	45	0.40	1.014
45	EAC	No. 4 Max Watsonville Granite	32	9/71	24	46	0.47	1.013

CS - Chip Seal (Asphalt Binder)
DGAC - Dense Graded Asphalt Concrete
EAC - Epoxy Asphalt Concrete
ECS - Epoxy Chip Seal
OGAC - Open Graded Asphalt Concrete
OGEA - Open Graded Epoxy Asphalt
PCC - Portland Cement Concrete
RCS - Rubberized Chip Seal

Sieve Designation

mm	Equivalent
19.0	3/4"
16.0	5/8"
12.5	1/2"
9.5	3/8"
6.3	1/4" or No. 3
4.75	No. 4
3.35	No. 6
2.36	No. 8
2.00	No. 10
1.18	No. 16

CHIP SEAL

		1a
Date Placed	9/71	3/72
Average Daily Traffic (1974)	170,000	19,000
Vehicle Passes to 5/76	29,000,000	34,000,000
Truck Passes	6,000,000	Neg.
Unit Bid Cost Per Sq. Yd. (m^2)	$5.80 ($6.94)	$9.50 ($11.36)
Aggregate - Calcined Bauxite No. 6 (3.35mm) Max. Spread Rate Per Sq. Yd. (m^2)	15.6# (8.5kg)	12.5# (6.8kg)
Binder - Epoxy Asphalt (Adhesive Engineering) Spread Rate Per Sq. Yd. (m^2)	0.38Gal. (1.7 litre)	0.31 Gal. (1.4 litre)
Mild coastal climate-	looks good	some spalling

No wet pavement accidents from 9/71 to 9/76.

SN_{40} = 56	SN_{30} = 45
SN_{55} = 56	SN_{30S} = 49
SN_{40S} = 51	07-LA-11/05
G = 0.00	NB 1 of 1 Lane

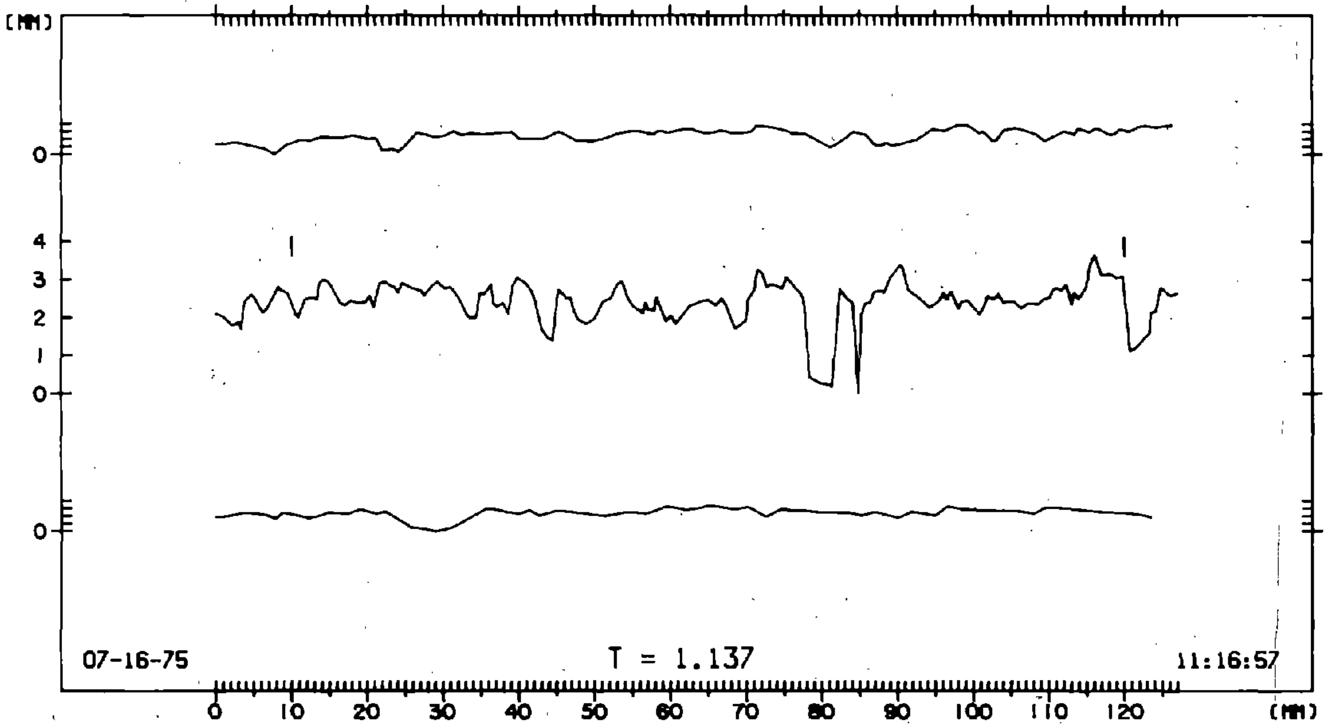

Fig. 1 - 04-SF-80-8.46/8.5 WB 5 of 5 Lanes

OVERLAY
OPEN GRADED ASPHALT CONCRETE

Date Placed - December 1965

Average Daily Traffic (1974) - 14,900

Vehicle Passes to 2/77 - 16,000,000

Truck Passes - 182,000

Cost Per Sq. Yd. (m^2) - \$0.17 (\$0.20)

Aggregate - American River Streambed No. 3 (6.3mm) max.

Binder - 5.8 to 6.0% 85-100 Penetration Paving Grade Asphalt

Hot summers, cool winters, no chain or studded tire traffic; looks good. No wet pavement accidents from 1/74 to 1/77.

$SN_{40} = 56$
$SN_{50} = 54$
$SN_{40S} = 51$
$G = 0.20$

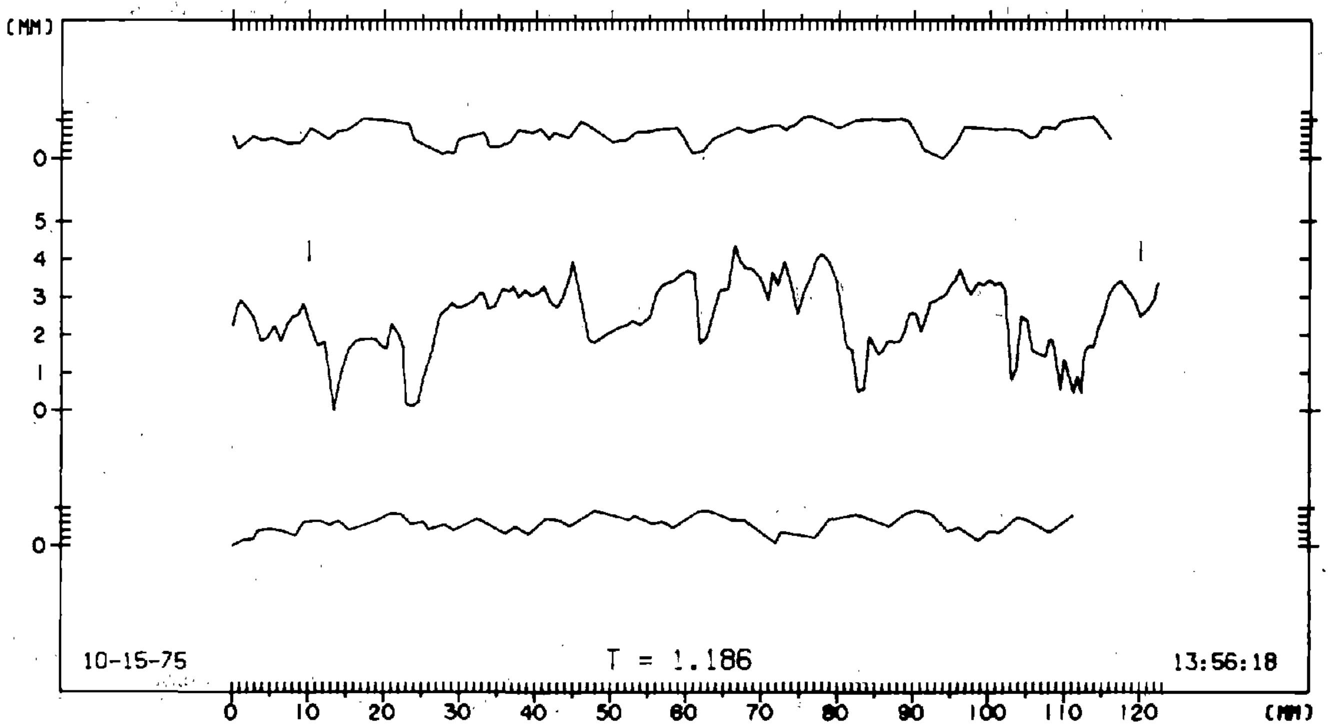

Fig. 2 - 03-Sac-50-18± WB 1 of 2 Lanes

CHIP SEAL

Date Placed - July 1974

Average Daily Traffic (1974) - 9,300

Vehicle Passes to 7/76 - 3,000,000

Truck Passes - 200,000

Cost Per Sq. Yd. (m^2) - \$0.20 (\$0.24)

Aggregate - Yuba River Streambed 1/4 inch (6.3 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 14 pounds (7.6 kg)

Binder - CRS2 Rapid Setting Emulsion
Spread Rate Per Sq. Yd. (m^2) - 0.20 gallon (0.9 litre)

The chip loss and chip depression in the wheel tracks became significant and a dense graded blanket was placed before the winter of 1976. Hot summers, cold winters, no chain or studded tire traffic. One wet pavement accident from 7/74 to 1/77.

$SN_{40} = 50$

$SN_{50} = 50$

$G = 0.00$

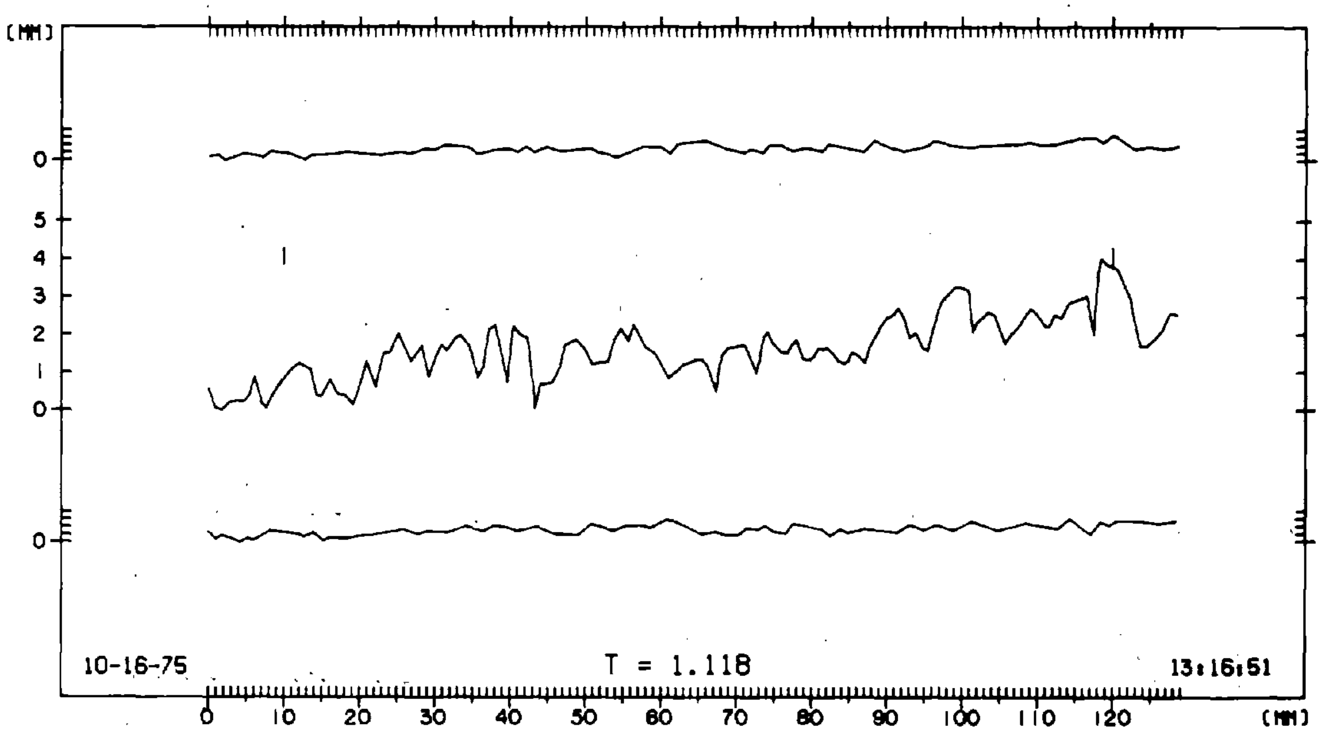

Fig. 3 - 03-Sut-99-38± NB 1 of 1 Lane

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 5/76 - 29,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - $7.10 ($8.50)

Aggregate - Calcined Bauxite No. 6 (3.35 mm) Max
  Spread Rate Per Sq. Yd. (m^2) - 16.4 pounds (8.9 kg)

Binder - Fast Setting Epoxy Resin,
  California Spec. 701-80-47
  Spread Rate Per Sq. Yd. (m^2) - 0.30 gallon (1.4 litre)

Mild coastal climate; looks good.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 67$
$SN_{55} = 63$
$SN_{40S} = 65$
$G = 0.27$

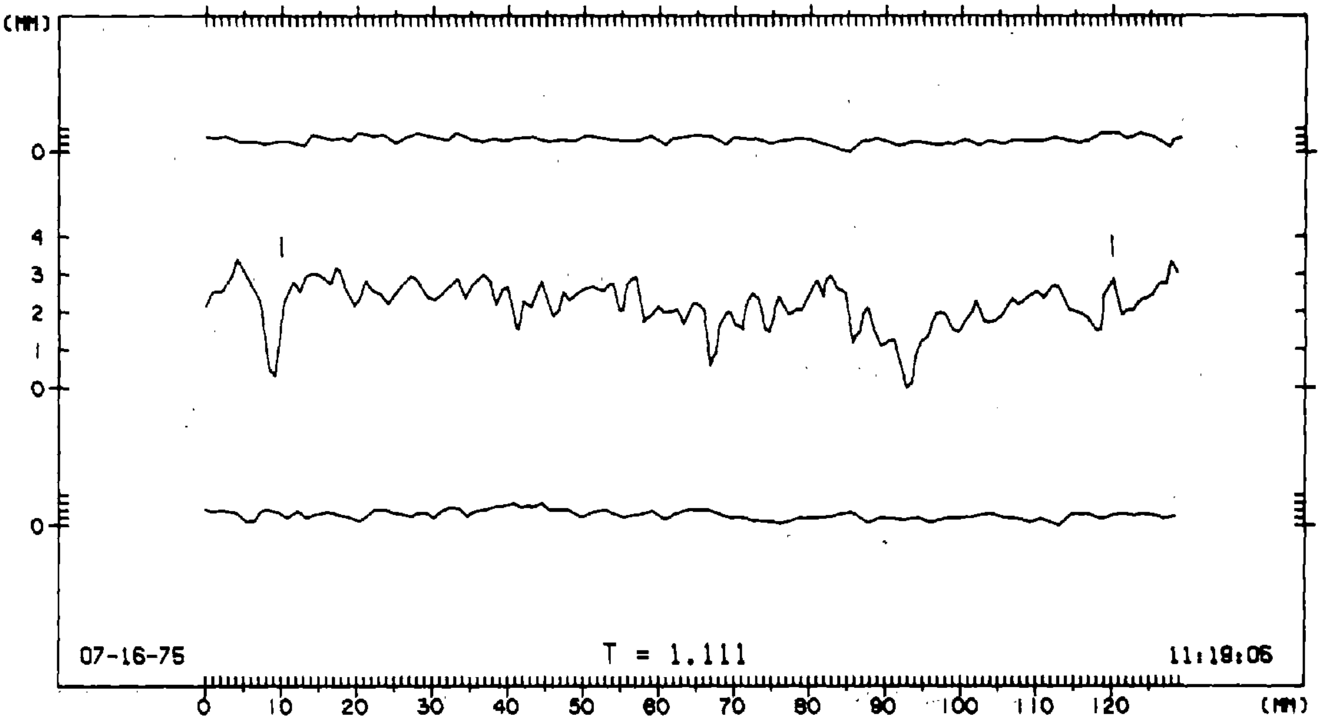

Fig. 4 - 04-SF-80-8.42/8.46 WB 5 of 5 Lanes

OVERLAY
OPEN GRADED ASPHALT CONCRETE

Date Placed - December 1965

Average Daily Traffic (1975) - 15,500

Vehicle Passes to 2/77 - 16,000,000

Truck Passes - 727,000

Cost Per Sq. Yd. (m^2) - \$0.17 (\$0.20)

Aggregate - American River Streambed No. 3 (6.3 mm) Max.

Binder - 5.8 to 6.0% 85-100 Penetration Paving Grade Asphalt

Hot summers, cool winters, no chain or studded tire traffic; looks good.
One wet pavement accident from 1/74 to 1/77.

$SN_{40} = 52$
$SN_{50} = 50$
$SN_{40S} = 47$
$G = 0.20$

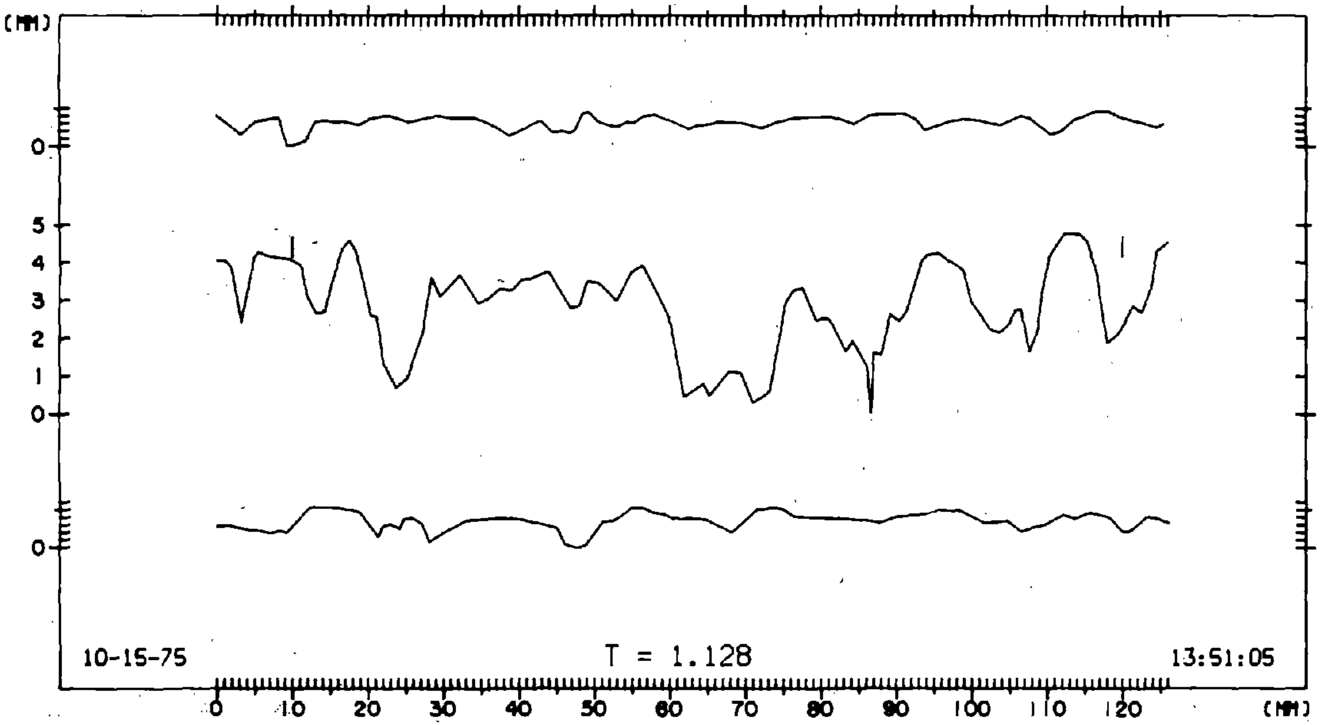

Fig. 5 - 03-Sac-50-18.0 EB 2 of 2 Lanes

PORTLAND CEMENT CONCRETE

TRANSVERSE TEXTURE, METAL TINES AT 1/2 INCH (13 mm)

Date Placed - April 1975

Average Daily Traffic (1975) - 25,000

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 315,000

Tines 5 inches long x 0.126 inch wide x 0.025 inch thick
(127 mm x 3.2 mm x 0.6 mm)

No wet pavement accidents from 5/75 to 1/77.

$SN_{40} = 56$
$SN_{50} = 54$
$SN_{40S} = 56$
$G = 0.20$

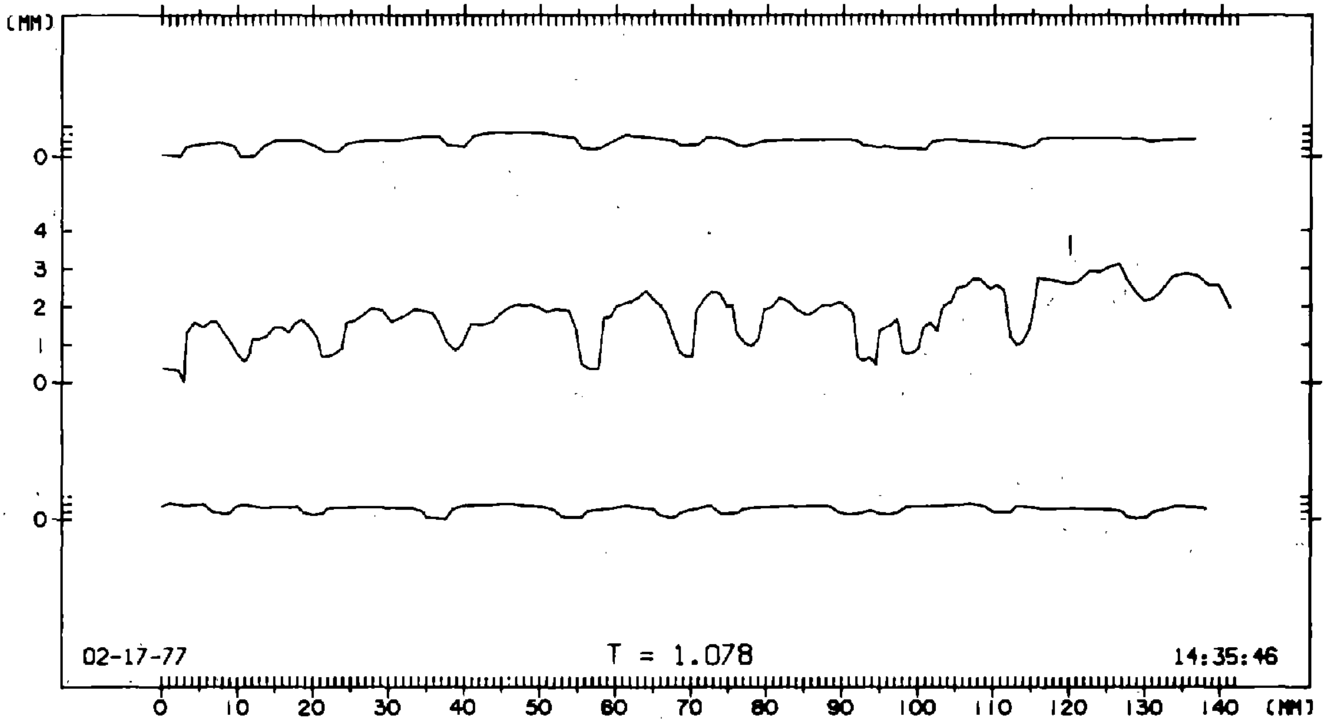

Fig. 6 - 11-SD-805-2.40 NB 4 of 4 Lanes

OVERLAY
OPEN GRADED ASPHALT CONCRETE

Date Placed - July 1975
Average Daily Traffic (1975) - 94,500
Vehicle Passes to 3/77 - 7,000,000
Truck Passes - 739,000
Cost Per Sq. Yd. (m^2) - \$0.60 (\$0.72)
Aggregate - Metasandstone 1/2" (12.5 mm) Max.
Binder - 5.8 to 6.0% AR4000 Paving Grade Asphalt

Mild coastal climate; looks good.

Nine wet pavement accidents from 6/75 to 1/77.

$SN_{40} = 54$
$SN_{50} = 51$
$SN_{40S} = 52$
$G = 0.30$

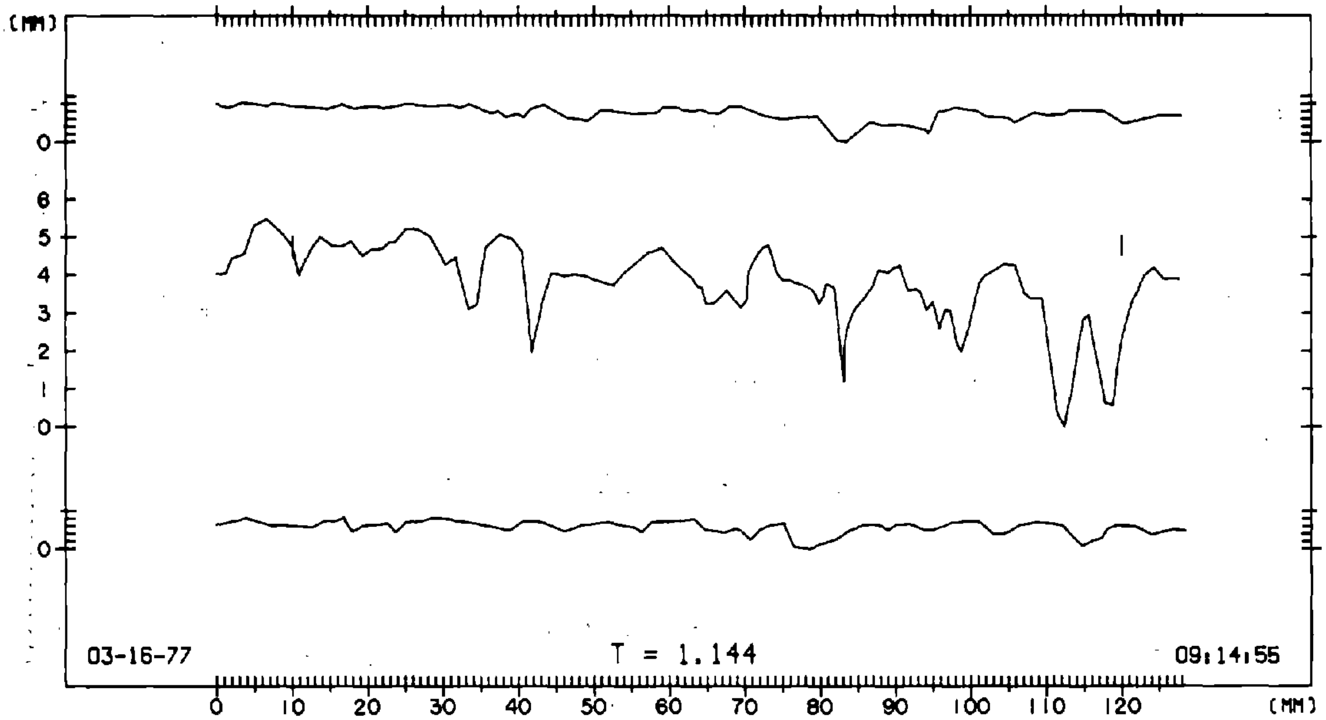

Fig. 7 - 04-Mrn-101 PM 7.80 NB 4 of 4 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 5/76 - 29,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - \$5.80 (\$6.94)

Aggregate - Watsonville Granite No. 4 (4.75 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 13.5 Pounds (7.3 kg)

Binder - Fast Setting Epoxy Resin,
California Spec. 701-80-47
Spread Rate Per Sq. Yd. (m^2) - 0.24 Gallon (1.1 litre)

Mild coastal climate; looks good.
One wet pavement accident from 9/71 to 1/77.

$SN_{40} = 47$
$SN_{55} = 46$
$SN_{40S} = 47$
$G = 0.07$

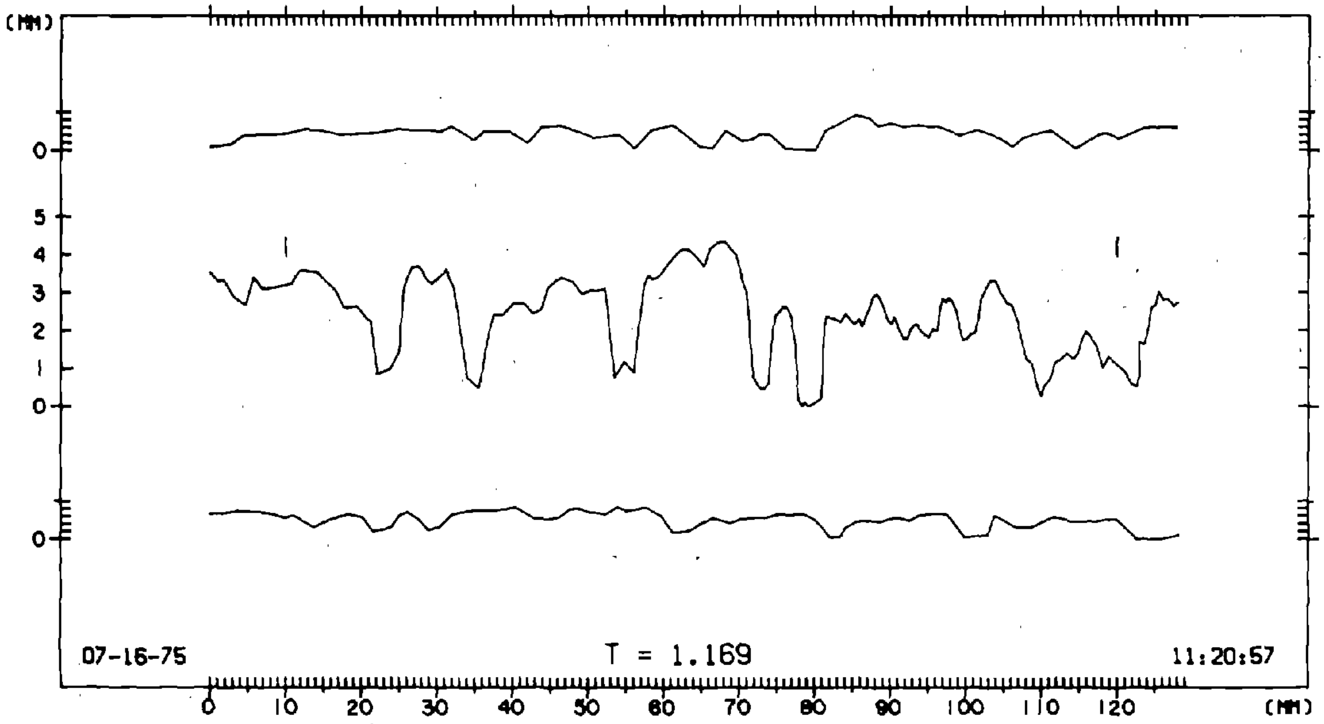

Fig. 8 - 04-SF-80-8.38/8.42 WB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL TEXTURE, METAL TINES AT 3/4 INCH (19 mm)

Date Placed - June 1975

Average Daily Traffic (1975) - 14,400

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 323,000

Straight Double Tines 4 inches long x 0.126 inches wide
x 0.025 inches thick
(102 mm x 3.2 mm x 0.6 mm)

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 48$
$SN_{50} = 46$
$SN_{40S} = 46$
$G = 0.20$

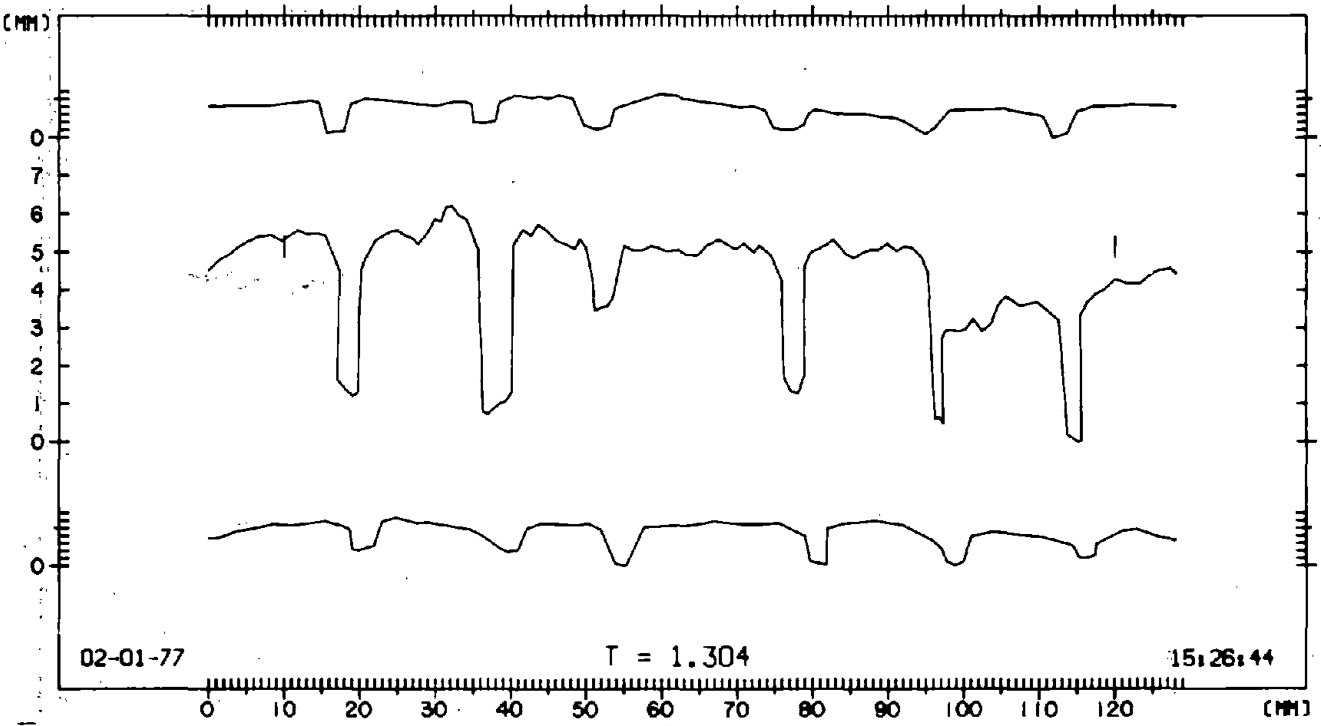

Fig. 9 - 04-Son-101-R42.43 NB 2 of 2 Lanes

CHIP SEAL

Date Placed - July 1974

Average Daily Traffic (1974) - 9,300

Vehicle Passes to 10/75 - 3,000,000

Truck Passes - 200,000

Cost Per Sq. Yd. (m^2) - \$0.20 (\$0.24)

Aggregate - Yuba River Streambed 1/4 inch (6.3 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 14 pounds (7.6 kg)

Binder - CRS2 Rapid Setting Emulsion
Spread Rate Per Sq. Yd. (m^2) - 0.20 gallon (0.9 litre)

Hot summers, cold winters; no chain or studded tire traffic. The chip loss and chip depression in the wheel tracks became significant and a dense graded blanket was placed before the winter of 1976. No wet pavement accidents from 7/74 to 1/77.

$$SN_{40} = 48$$
$$SN_{50} = 47$$
$$G = 0.10$$

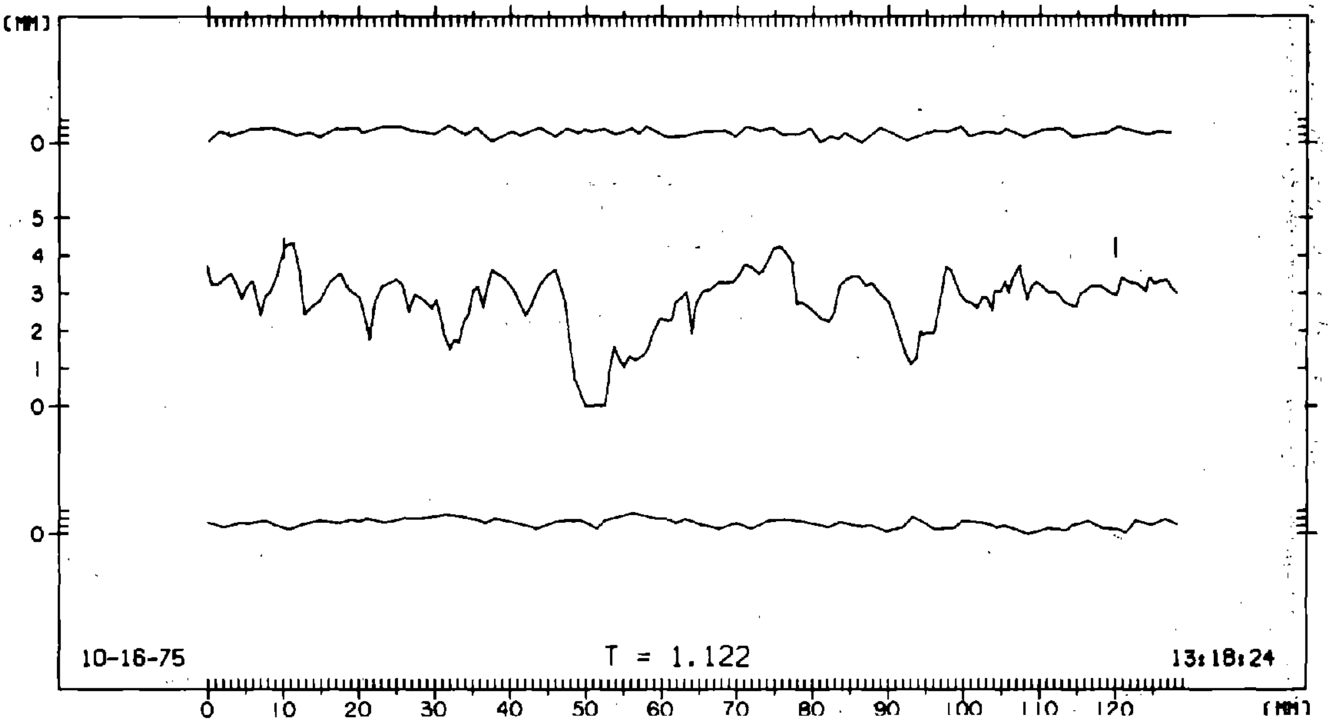

Fig. 10 - 03-Sut-99-38 SB 1 of 1 Lane

CHIP SEAL

Date Placed - November 1974

Average Daily Traffic (1975) - 12,000

Vehicle Passes to 2/77 - 504,000

Truck Passes - 394,000

Cost Per Sq. Yd. (m^2) - $1.40 ($1.67)

Aggregate - Precoated Crushed Igneous 3/8" (9.5 mm) Max.
  Spread Rate Per Sq. Yd. (m^2) - 40 pounds (21.7 kg)

Binder - 75% AR2000 Asphalt, 25% Atlas Rubber Chips and
  6% by volume of solvent
  Spread Rate Per Sq. Yd. (m^2) - 0.48 gallon (2.2 litre)

No wet pavement accidents from 7/72 to 1/77. Very hot climate, slight wheel track depressions.

$SN_{40} = 59$
$SN_{50} = 56$
$SN_{40S} = 56$
$G = 0.30$

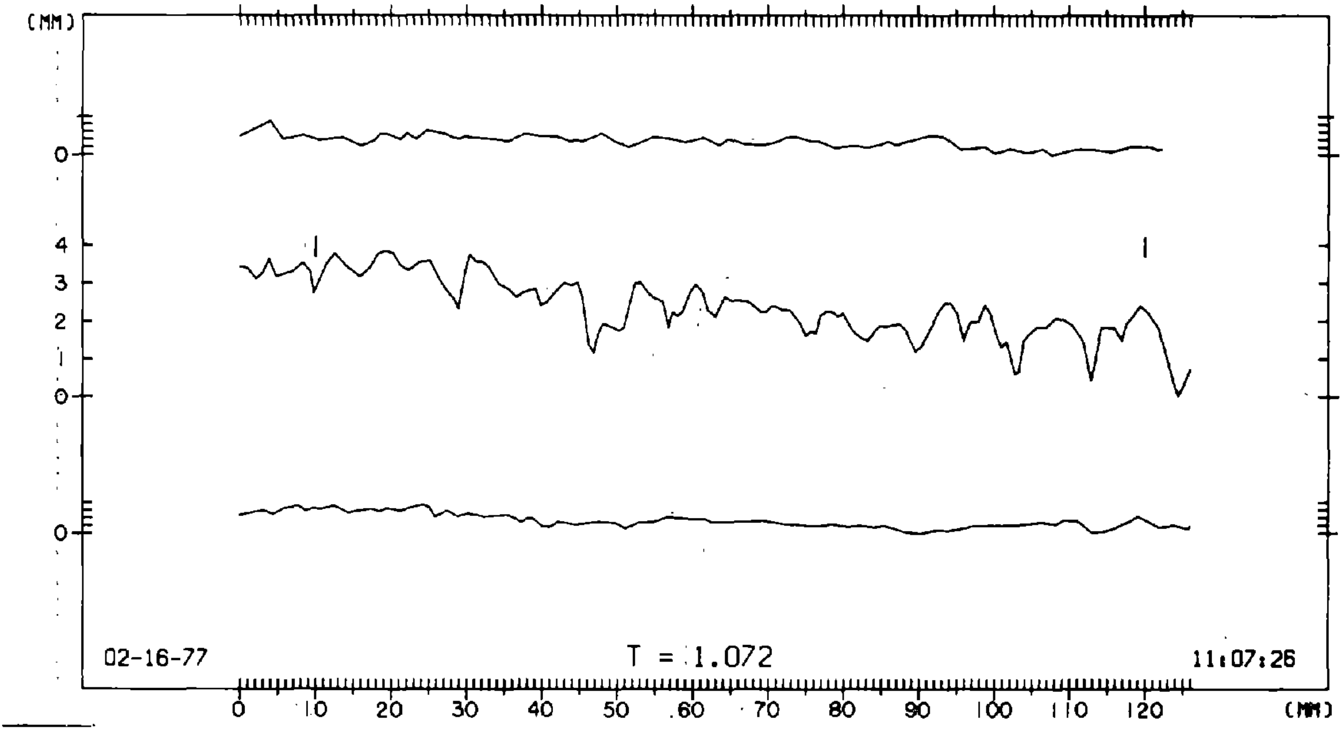

Fig. 11 - 11-Imp-115 PM 23.50 NB 1 of 1 Lane

PORTLAND CEMENT CONCRETE
TRANSVERSE TEXTURE, METAL TINES AT 1/2 INCH (13mm)

Date Placed - April 1975
Average Daily Traffic (1975) - 25,000
Vehicle Passes to 2/77 - 2,000,000
Truck Passes - 315,000
V Shaped Tines 4 inches x 1 inch long x 0.126 inch wide
x 0.025 inch thick
(102 mm x 25 mm x 3.2 mm x .6 mm)
No wet pavement accident from 5/75 to 1/77.

$SN_{40} = 56$
$SN_{50} = 52$
$SN_{40S} = 55$
$G = 0.40$

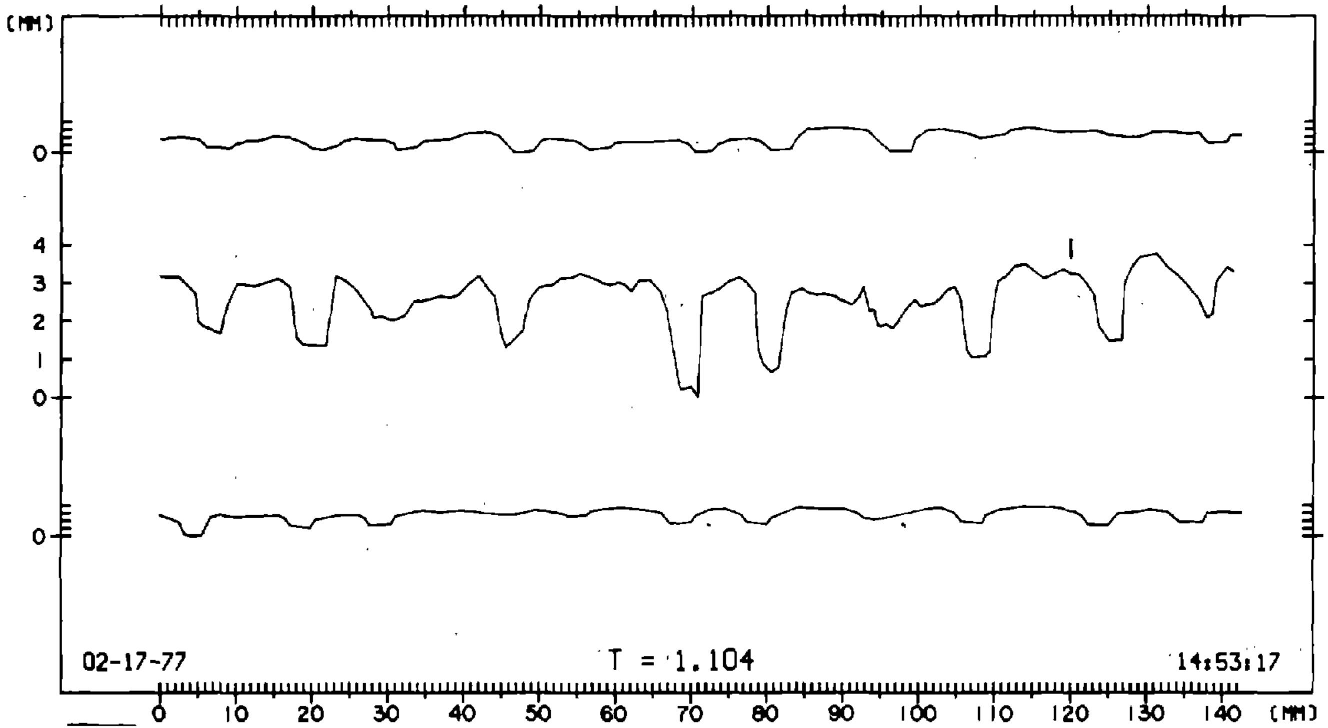

Fig. 12 - 11-SD-805-3.18 NB 4 of 4 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 5/76 - 29,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - $5.70 ($6.82)

Aggregate - Bear River Quartz No. 4 (4.75 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 18 pounds (9.8 kg)

Binder - Polyester Resin
(SF-6827-2 Polylite -- Reichold Chemical)
Spread Rate Per Sq. Yd. (m^2) - 7.16 pounds (3.9 kg)

Mild coastal climate; good appearance.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 50$
$SN_{55} = 48$
$SN_{40S} = 48$
$G = 0.13$

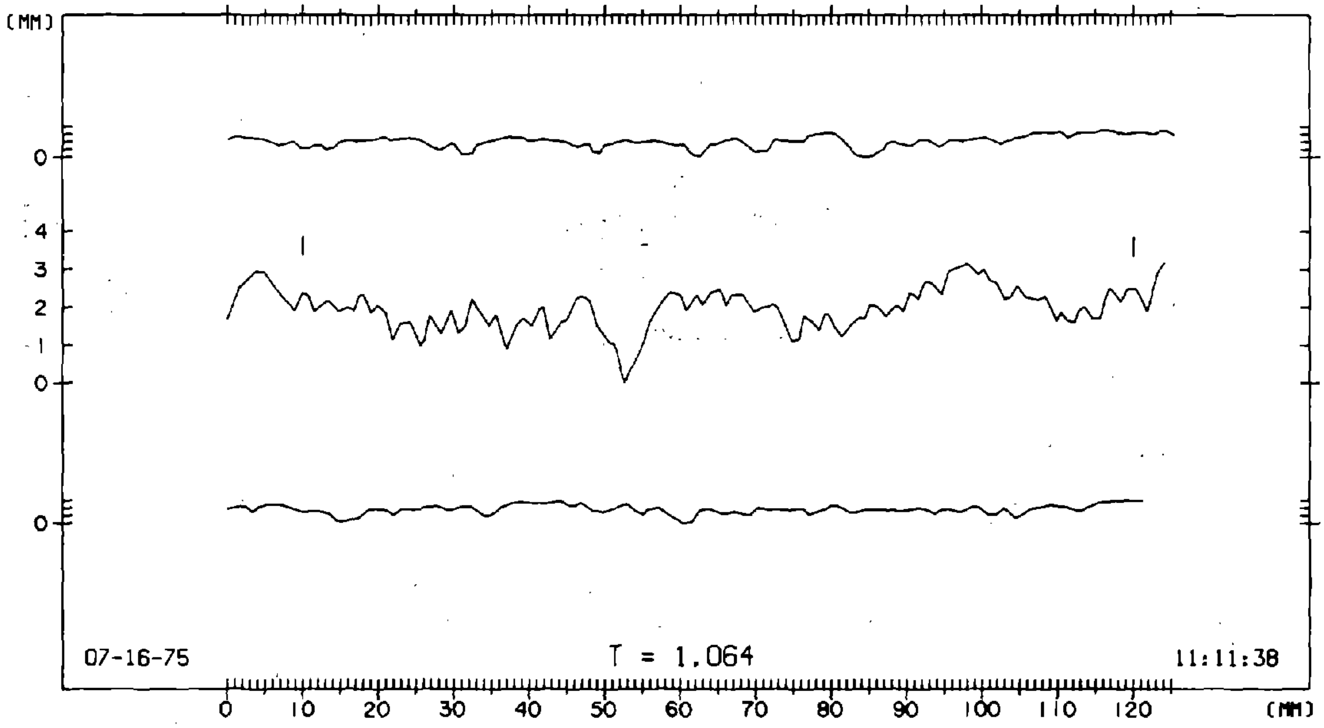

Fig. 13 - 04-SF-80-8.53/8.57 WB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE

TRANSVERSE TEXTURE, METAL TINES AT 3/4 INCH (19 mm)

Date Placed - April 1975

Average Daily Traffic (1975) - 25,000

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 315,000

Straight Tines 3 inches long x 0.083 inches wide x
0.032 inches thick
(76 mm x 2 mm x 0.8 mm)

No wet pavement accidents from 5/75 to 1/77.

$SN_{40} = 56$

$SN_{50} = 52$

$SN_{40S} = 53$

$G = 0.40$

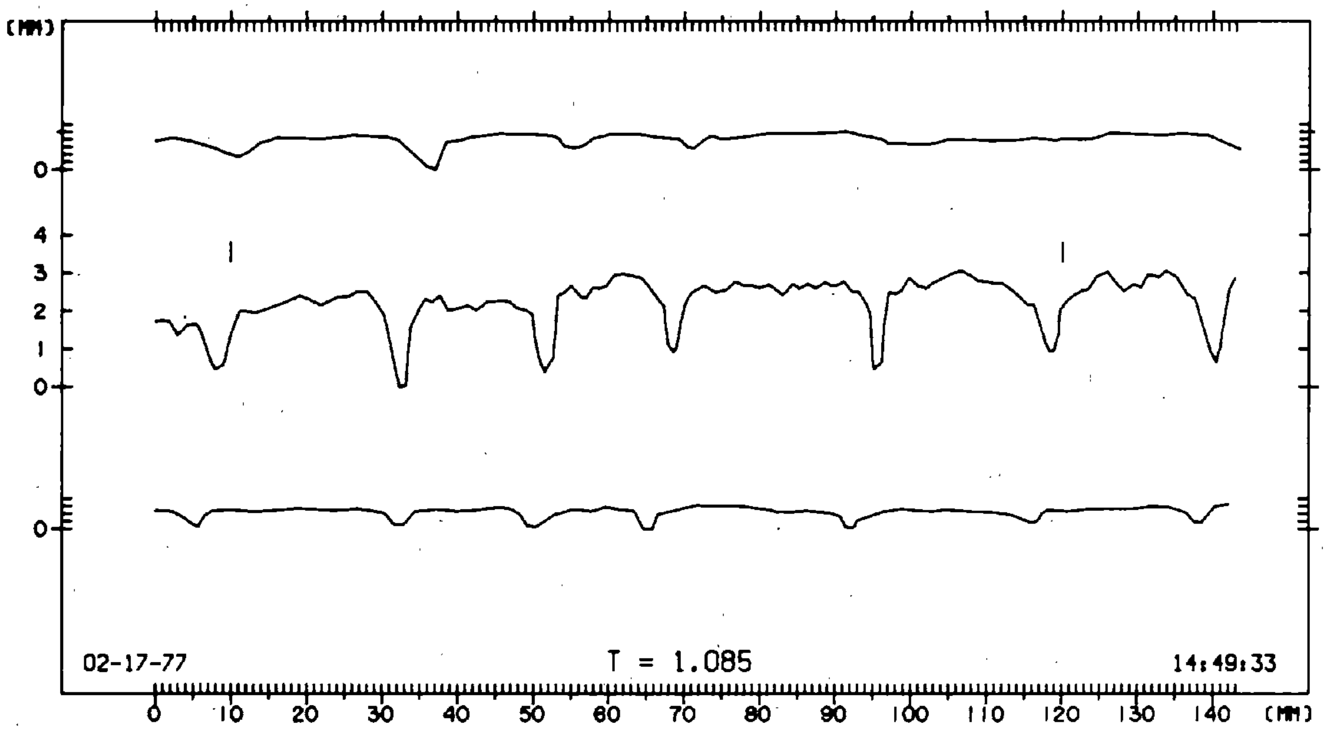

Fig. 14 - 11-SD-805-3.03 NB 4 of 4 Lanes

OVERLAY

OPEN GRADED ASPHALT CONCRETE

Date Placed - November 1969

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 12/76 - 43,000,000

Truck Passes - 9,000,000

Cost Per Sq. Yd. (m^2) - \$8.06 (\$9.64)

Aggregate - Blast Furnace Slag 1/4" (6.3 mm) Max.

Binder - 7.5 % Epoxy Asphalt-Adhesive Engineering

Mild coastal climate; looks good, some polish in wheel tracks. Fifteen wet pavement accidents from 1/71 to 1/77.

$SN_{40} = 46$
$SN_{50} = 45$
$SN_{40S} = 38$
$G = 0.10$

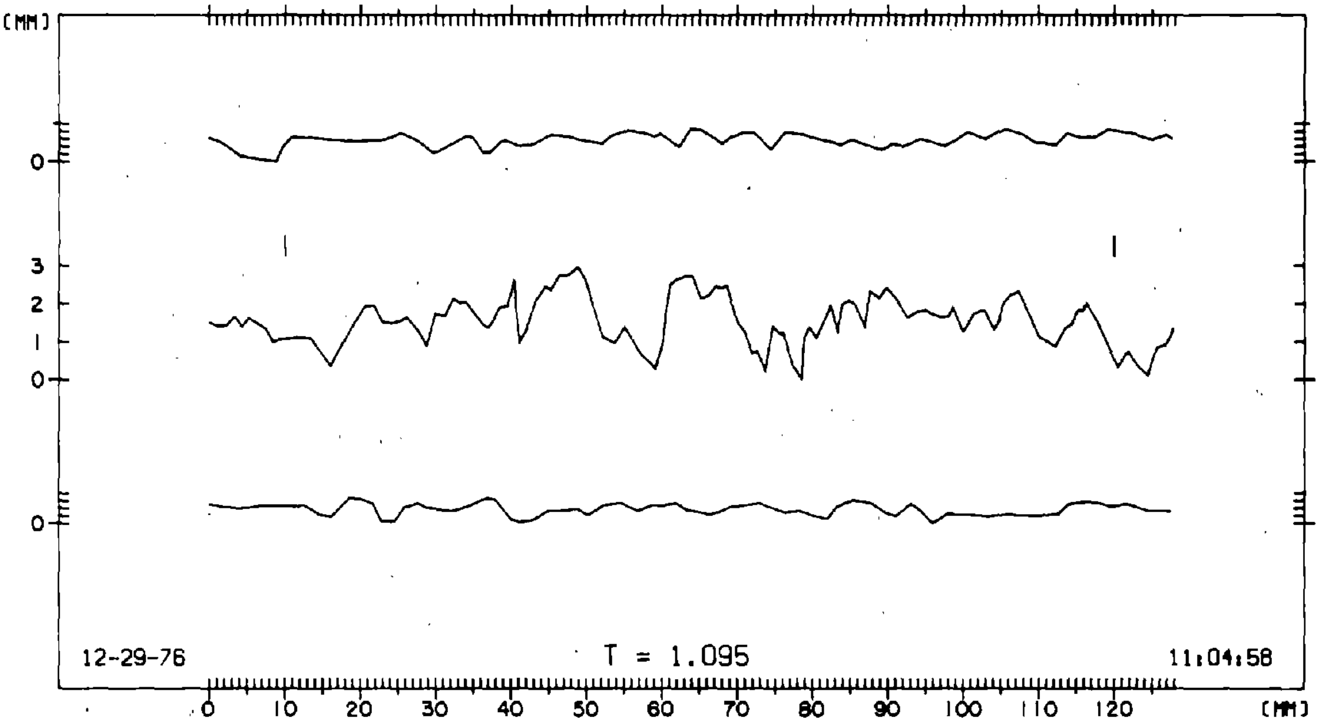

Fig. 15 - 04-SF-80 PM 8.00 EB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL TEXTURE, METAL TINES AT 1/2 INCH (13 mm)

Date Placed - June 1975

Average Daily Traffic (1975) - 14,400

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 323,000

Straight Double Tines 4 inches long x 0.126 inches wide
x 0.025 inches thick
(102 mm x 3 mm x 0.6 mm)

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 47$
$SN_{50} = 44$
$SN_{40S} = 41$
$G = 0.30$

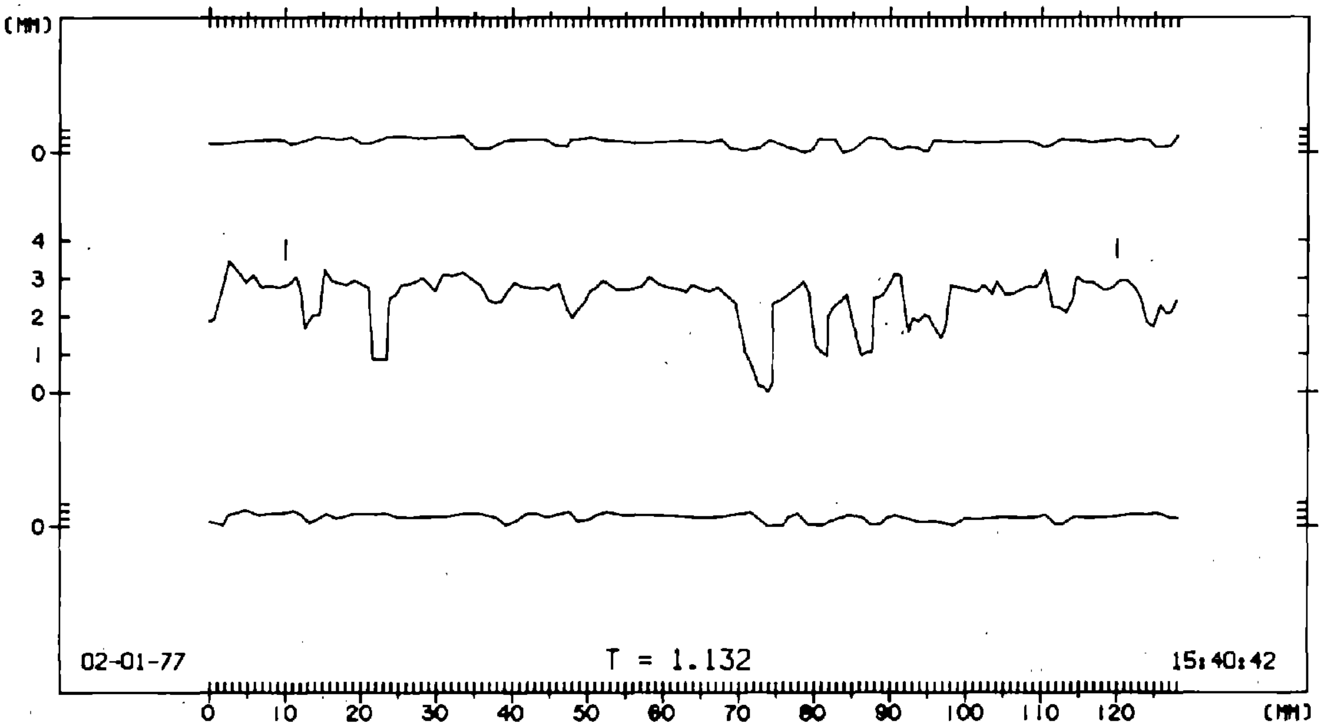

Fig. 16 - 04-Son-101-R45.00 SB 2 of 2 Lanes

PORTLAND CEMENT CONCRETE
TRANSVERSE TEXTURE, POLYPROPYLENE BRISTLES

Date Placed - June 1975

Average Daily Traffic (1975) - 25,000

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 315,000

Seventeen bristles 0.035 inch (0.9 mm) in diameter
x 8 inch (203 mm) long bunched
at 3/4 inch (19 mm) spacing

No wet pavement accidents from 5/75 to 1/77.

$SN_{40} = 50$
$SN_{50} = 48$
$SN_{40S} = 44$
$G = 0.20$

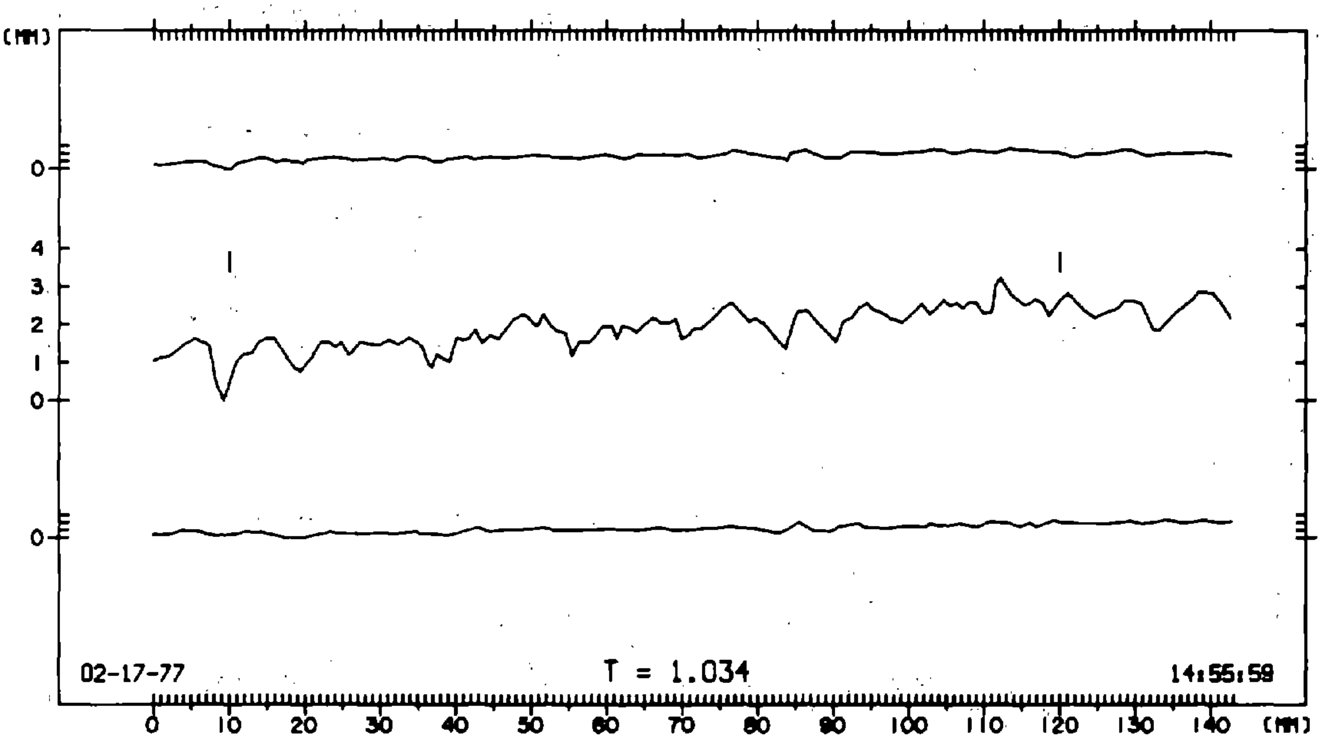

Fig. 17 - 11-SD-805 PM 3.24 NB 4 of 4 Lanes

OVERLAY

OPEN GRADED ASPHALT CONCRETE

Date Placed - November 1969

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 12/76 - 43,000,000

Truck Passes - 2,000,000

Cost Per Sq. Yd. (m^2) - $7.19 ($8.60)

Aggregate - Watsonville Granite 3/8" (9.5 mm) Max.

Binder - 6% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate; looks good, some polish in wheel tracks. Five wet pavement accidents were recorded in this lane from 1/71 to 1/77.

$SN_{40} = 48$

$SN_{50} = 46$

$SN_{40S} = 42$

$G = 0.20$

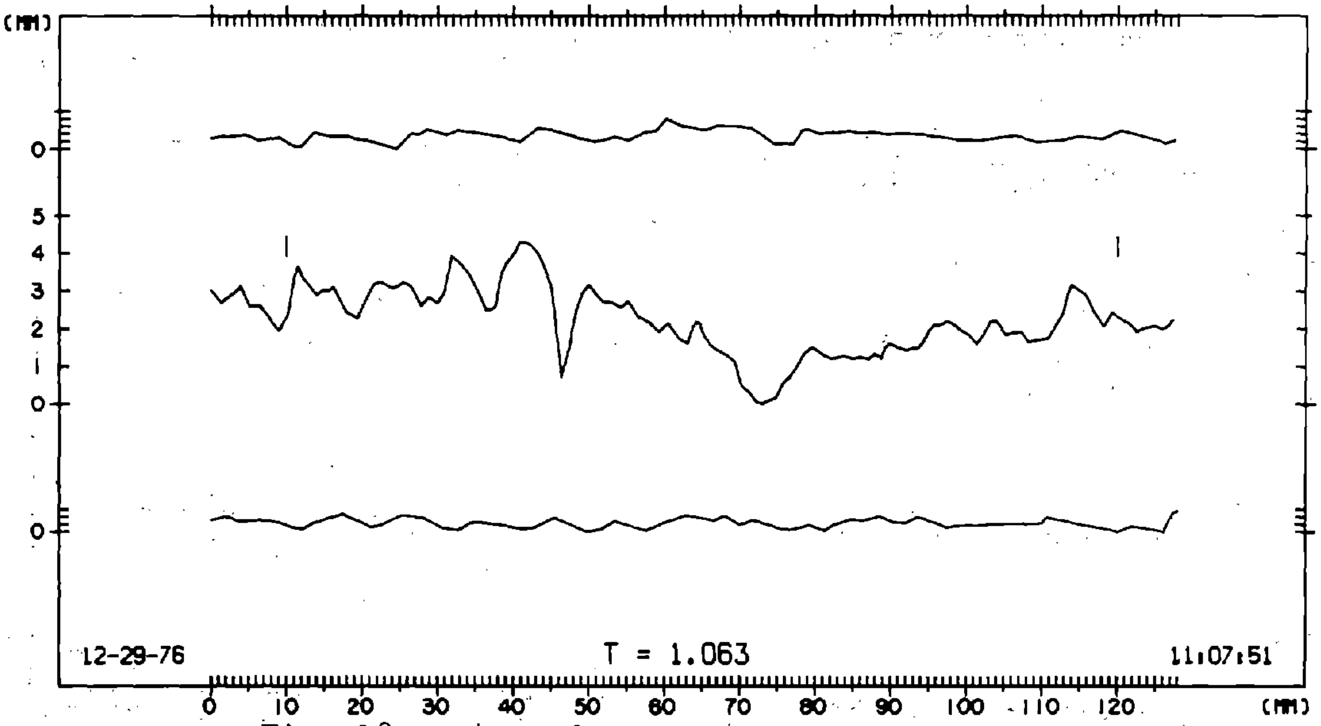

Fig. 18 - 04-SF-80 PM 8.00 EB 4 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 5/76 - 29,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - \$5.60 (\$6.70)

Aggregate - Bear River Quartz No. 4 (4.75 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 12.2 pounds (6.6 kg)

Binder - Fast Setting Epoxy Resin
(California Spec. 701-80-47)
Spread Rate Per Sq. Yd. (m^2) - 0.35 gal. (1.6 litre)

Deterioration results from poor adhesion to the older surface. Portions can be pulled up with fingers. Mild coastal climate.
Two wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 49$
$SN_{55} = 45$
$SN_{40S} = 50$
$G = 0.27$

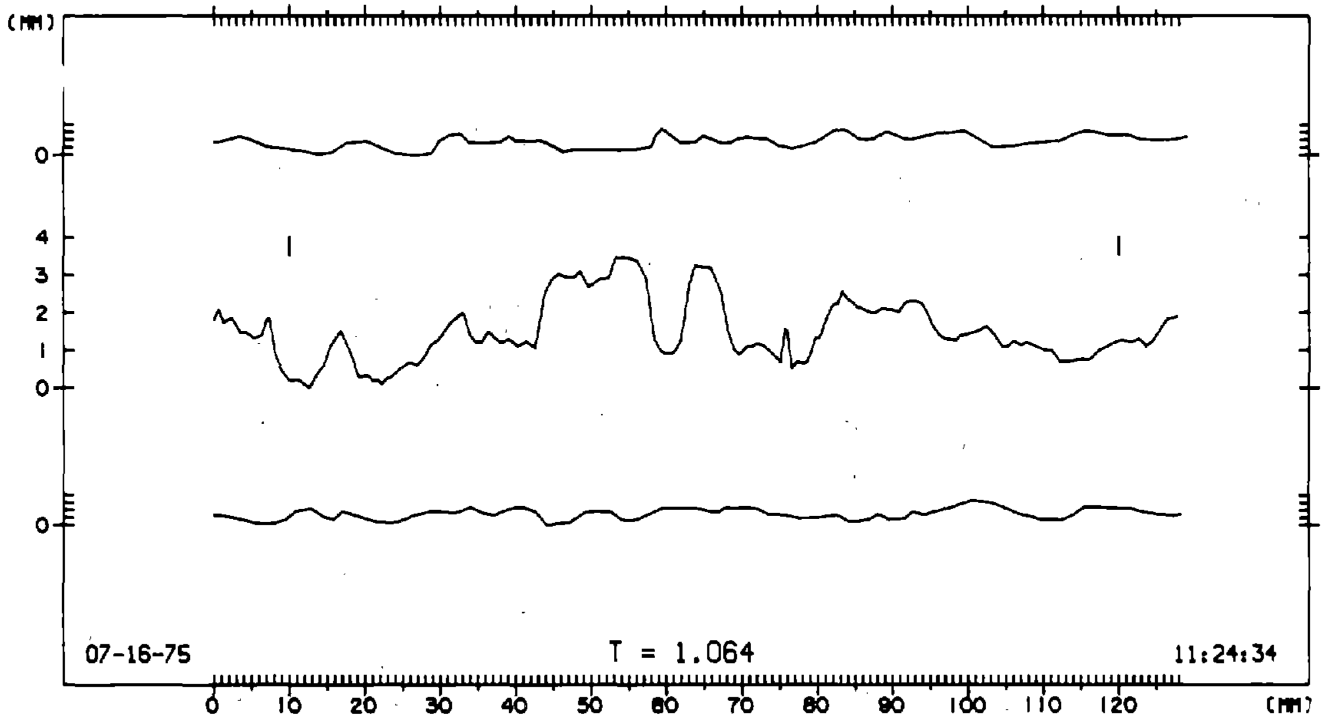

Fig. 19 - 04-SF-80-8.35/8.38 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - \$5.85 (\$7.00)

Aggregate - Watsonville Granite No. 4 (4.75 mm) Max.
  Spread Rate Per Sq. Yd. (m^2) - 19.2 pounds (10.4 kg)

Binder - Epoxy Resin, California Spec. 681-80-28
  Spread Rate Per Sq. Yd. (m^2) - 0.43 gallon (1.9 litre)

Mild coastal climate; looks good. Two wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 47$

$SN_{55} = 42$

$SN_{40S} = 42$

$G = 0.33$

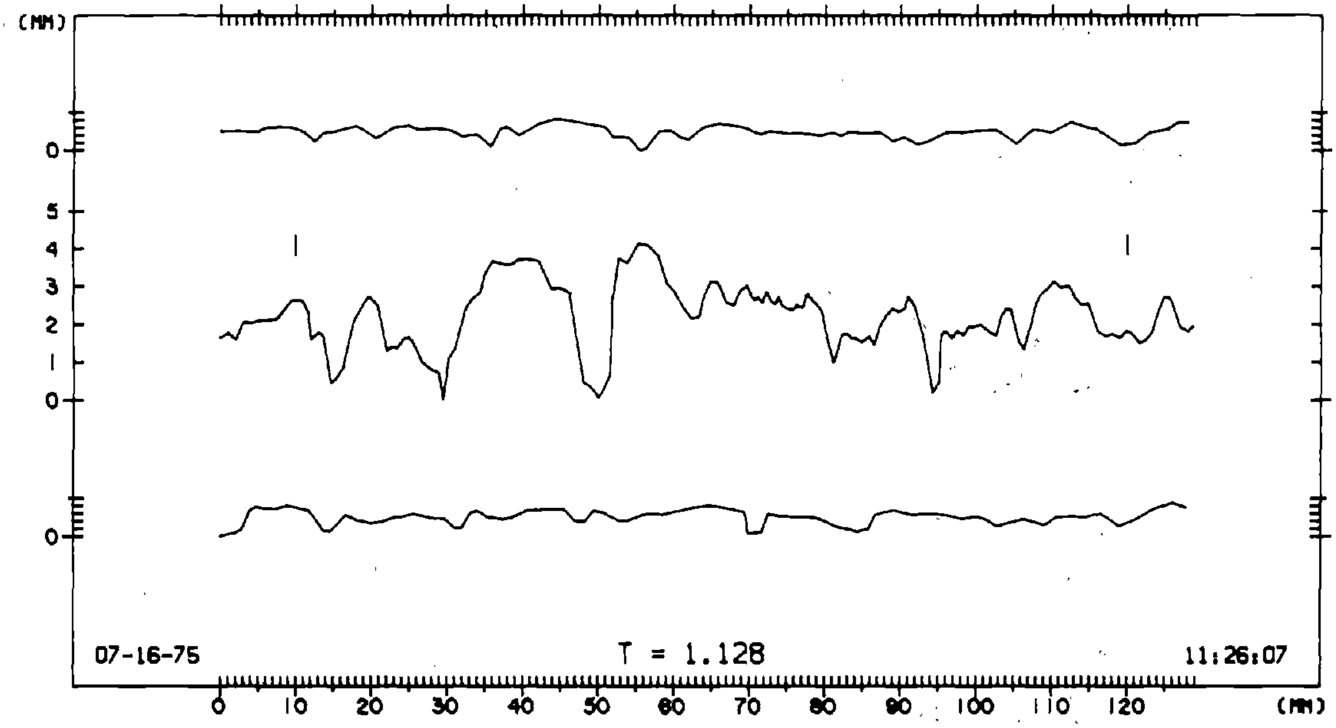

Fig. 20 - 04-SF-80-8.31/8.35 WB 5 of 5 Lanes

OVERLAY
EPOXY ASPHALT CONCRETE

Date Placed - November 1976
Average Daily Traffic (1974) - 170,000
Vehicle Passes to 1/77 - 1,000,000
Truck Passes - Negligible
Cost Per Sq. Yd. (m^2) - $7.09 ($8.48)
Aggregate - Metagraywacke & Expanded Shale 3/8" (9.5 mm) Max.
Binder - 6.5% Epoxy Asphalt-Adhesive Engineering

New surfacing looks good. Mild coastal climate.

$SN_{40} = 52$
$SN_{50} = 48$
$SN_{40S} = 50$
$G = 0.40$

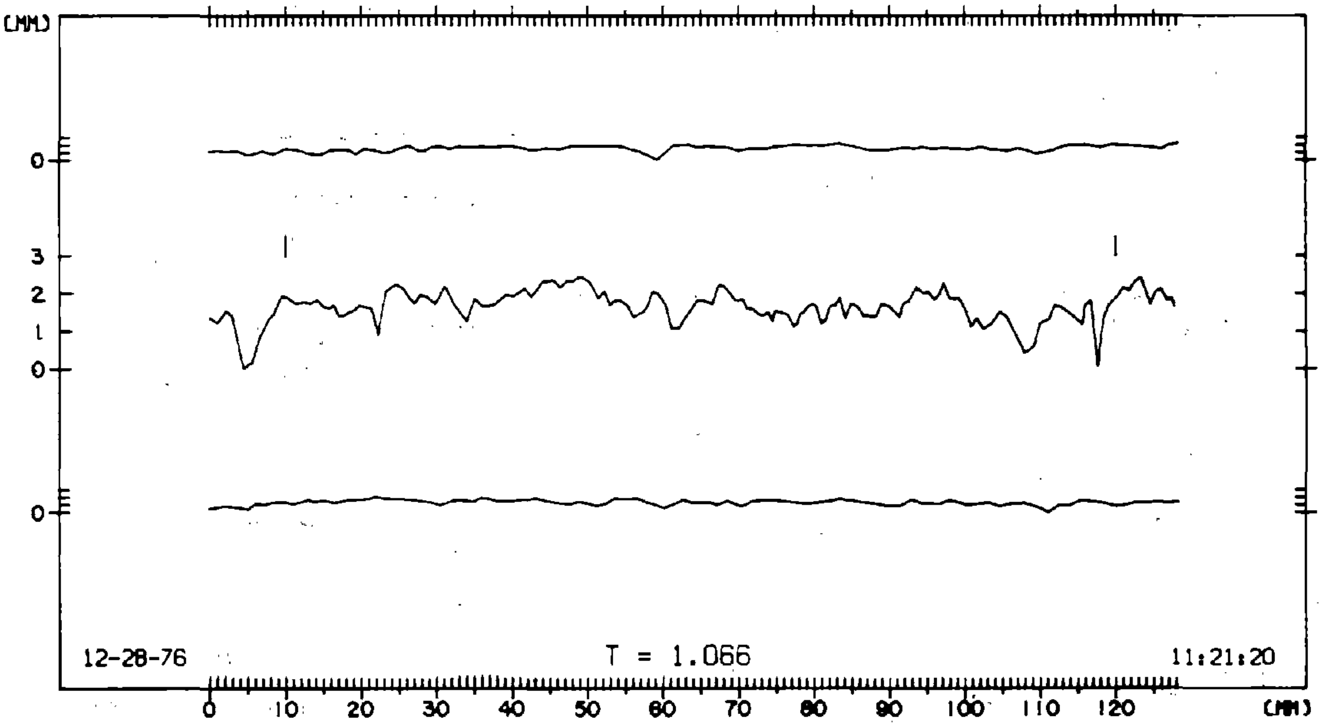

Fig. 21 - 04-SF-80 PM 7.50 WB 1 of 5 Lanes

OVERLAY
EPOXY ASPHALT CONCRETE

Date Placed - November 1976
Average Daily Traffic (1974) - 170,000
Vehicle Passes to 1/77 - 1,000,000
Truck Passes - 363,000
Cost Per Sq. Yd. (m^2) - \$7.09 (\$8.48)
Aggregate - Metagraywacke & Expanded Shale 3/8" (9.5 mm) Max.
Binder - 6.5% Epoxy Asphalt-Adhesive Engineering

New surfacing looks good; mild coastal climate.

$SN_{40} = 54$
$SN_{50} = 49$
$SN_{40S} = 47$
$G = 0.50$

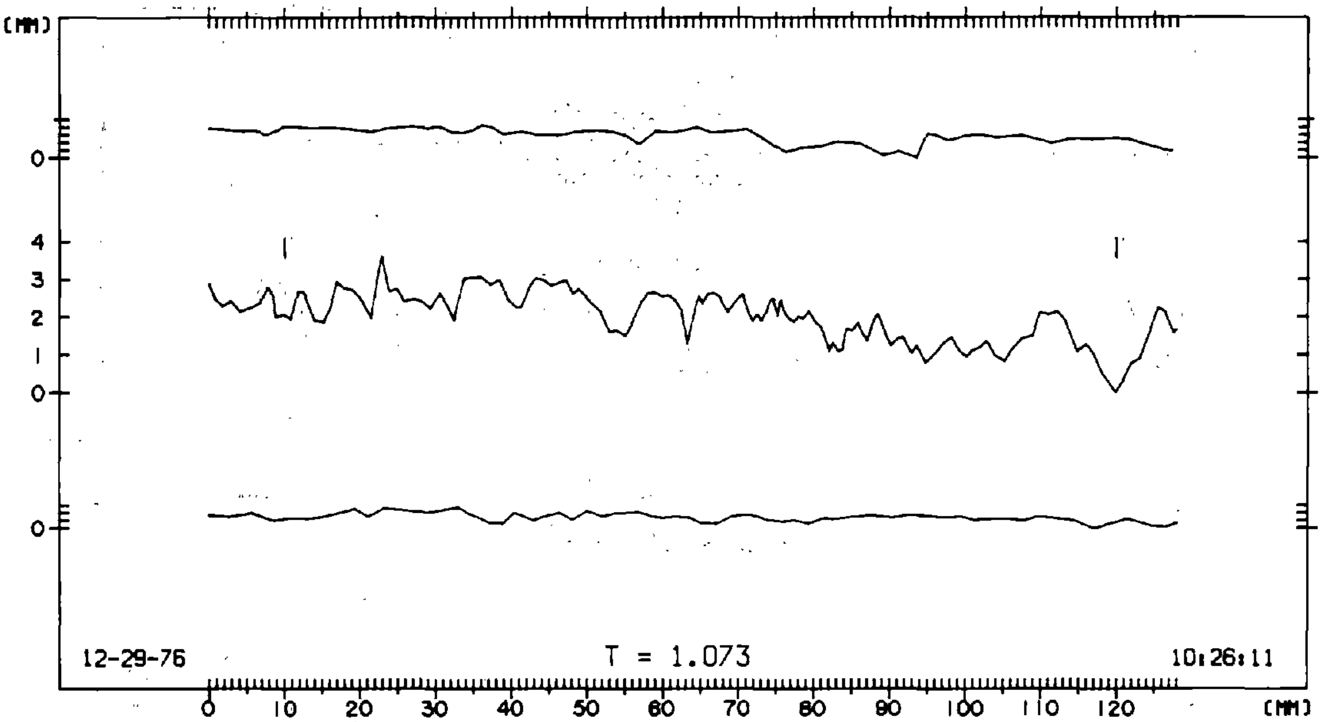

Fig. 22 - 04-SF-80 PM 7.50 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - $5.85 ($7.00)

Aggregate - Copper Slag No. 10 (2 mm) Max.
  Spread Rate Per Sq. Yd. (m^2) - 16.4 pounds (8.9 kg)

Binder - Epoxy Resin (California Spec. 681-80-28)
  Spread Rate Per Sq. Yd. (m^2) - 0.30 gal. (1.4 litre)

Mile coastal climate.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 46$
$SN_{55} = 42$
$SN_{40S} = 38$
$G = 0.27$

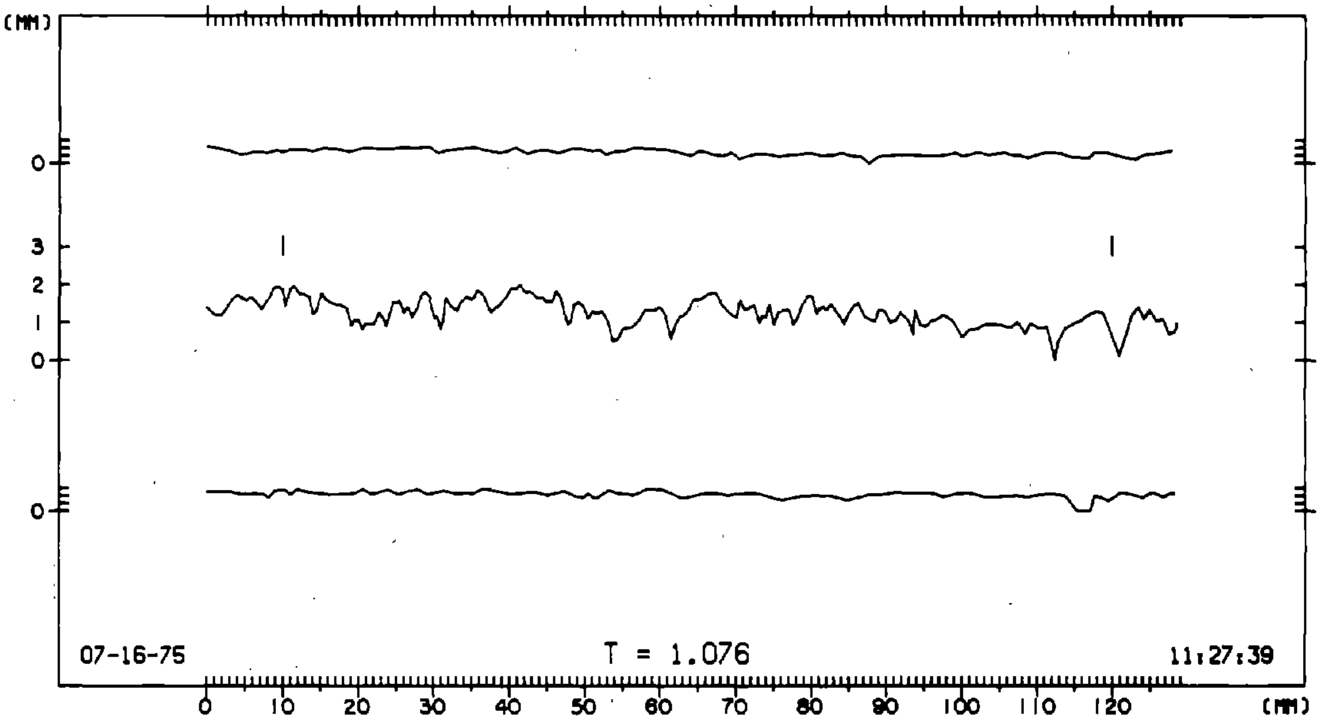

Fig. 23 - 04-SF-80-8.28/8.31 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - November 1974

Average Daily Traffic (1975) - 1,200

Vehicle Passes to 2/77 - 504,000

Truck Passes - 394,000

Cost Per Sq. Yd. (m^2) - \$1.40 (\$1.67)

Aggregate - Precoated Crushed Igneous 3/8" (9.5 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 40 Pounds (21.7 kg)

Binder - 75% AR2000 Asphalt, 25% Atlas Rubber Chips and 6% by volume of solvent
Spread Rate Per Sq. Yd. (m^2) - 0.48 Gallon (2.2 litre)

No wet pavement accidents from 7/72 to 1/77.
Very hot climate -- noticeable wheel track depressions.

$SN_{40} = 53$
$SN_{50} = 49$
$SN_{40S} = 55$
$G = 0.40$

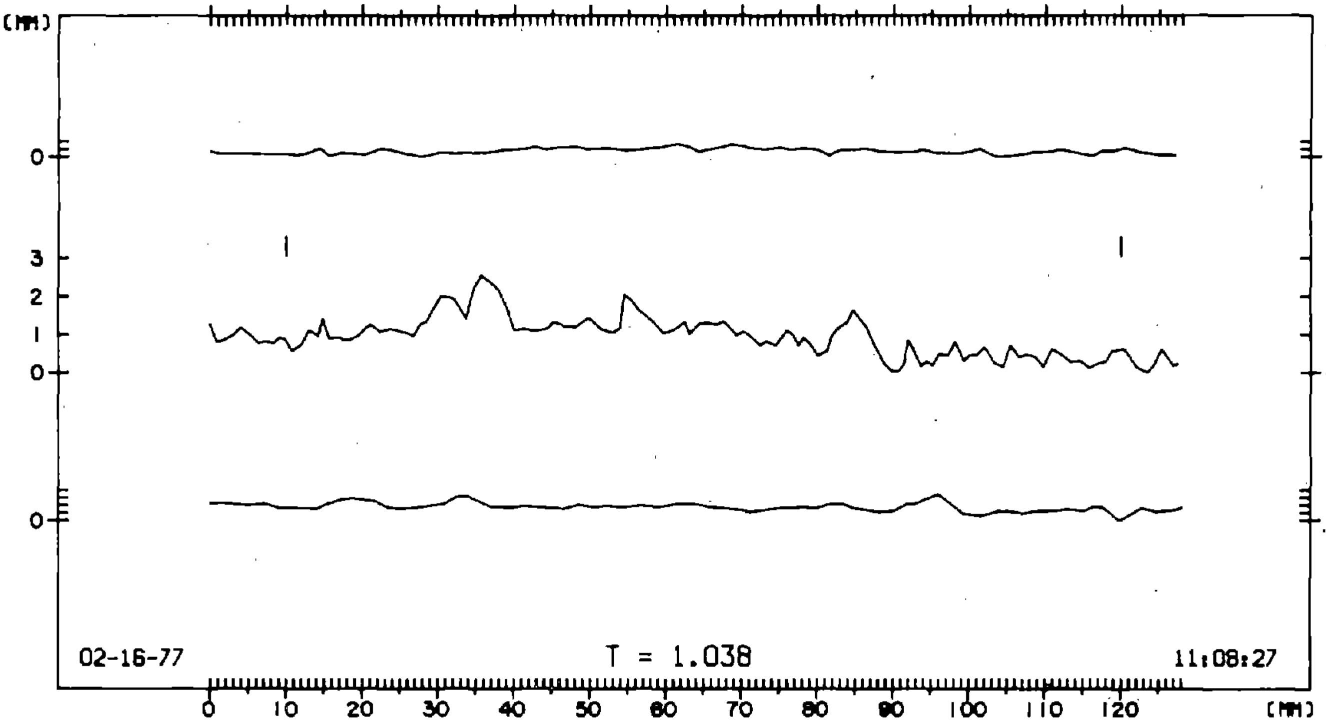

Fig. 24 - 11-Imp-115 PM 23.50 SB 1 of 1 Lane

CHIP SEAL

Date Placed - November 1971

Average Daily Traffic (1975) - 4,700

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 618,000

Cost Per Sq. Yd. (m^2) - \$19.90 (\$23.80)

Aggregate - Aluminum Oxide Grit in a Permapol Rubber Coating

Binder - Permapol 445R Nonskid Coating on 0.69 gallon (3.1 litre) Permapol 440F Primer
Spread Rate Per Sq. Yd. (m^2) - 0.21 gallon (0.95 litre)

Hot summers, cold winters, no chain or studded tire traffic; some polish in the wheel tracks, looks good.
No wet pavement accidents from 11/71 to 1/77.

$SN_{40} = 55$
$SN_{50} = 50$
$SN_{40S} = 39$
$G = 0.50$

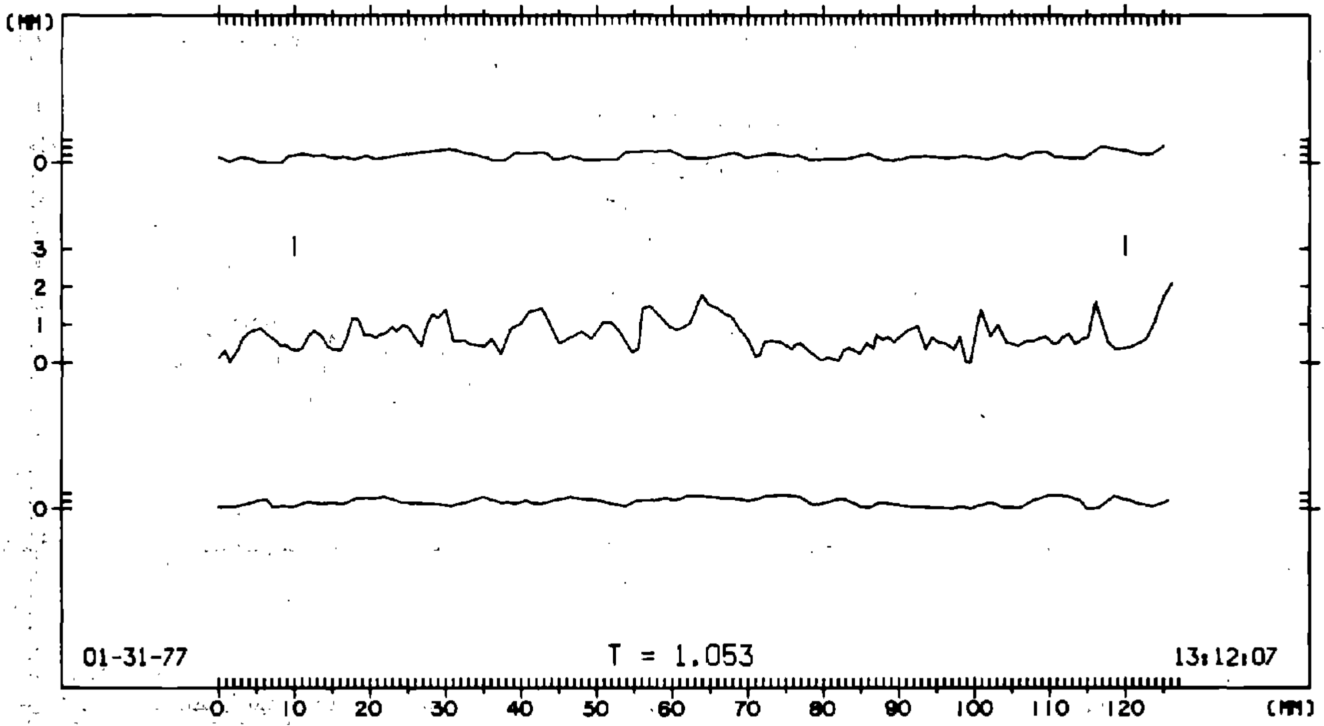

Fig. 25 - 10-SJ-5 PM 6.47 NB 2 of 2 Lanes

OVERLAY
OPEN GRADED ASPHALT CONCRETE

Date Placed - November 1969
Average Daily Traffic (1974) - 170,000
Vehicle Passes to 1/77 - 44,000,000
Truck Passes - Negligible
Cost Per Sq. Yd. (m^2) - \$8.06 (\$9.64)
Aggregate - Blast Furnace Slag 3/8" (9.5 mm) Max.
Binder - 7.5% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate; looks good.
Four wet pavement accidents from 1/71 to 1/77.

$SN_{40} = 48$
$SN_{50} = 43$
$SN_{40S} = 39$
$G = 0.50$

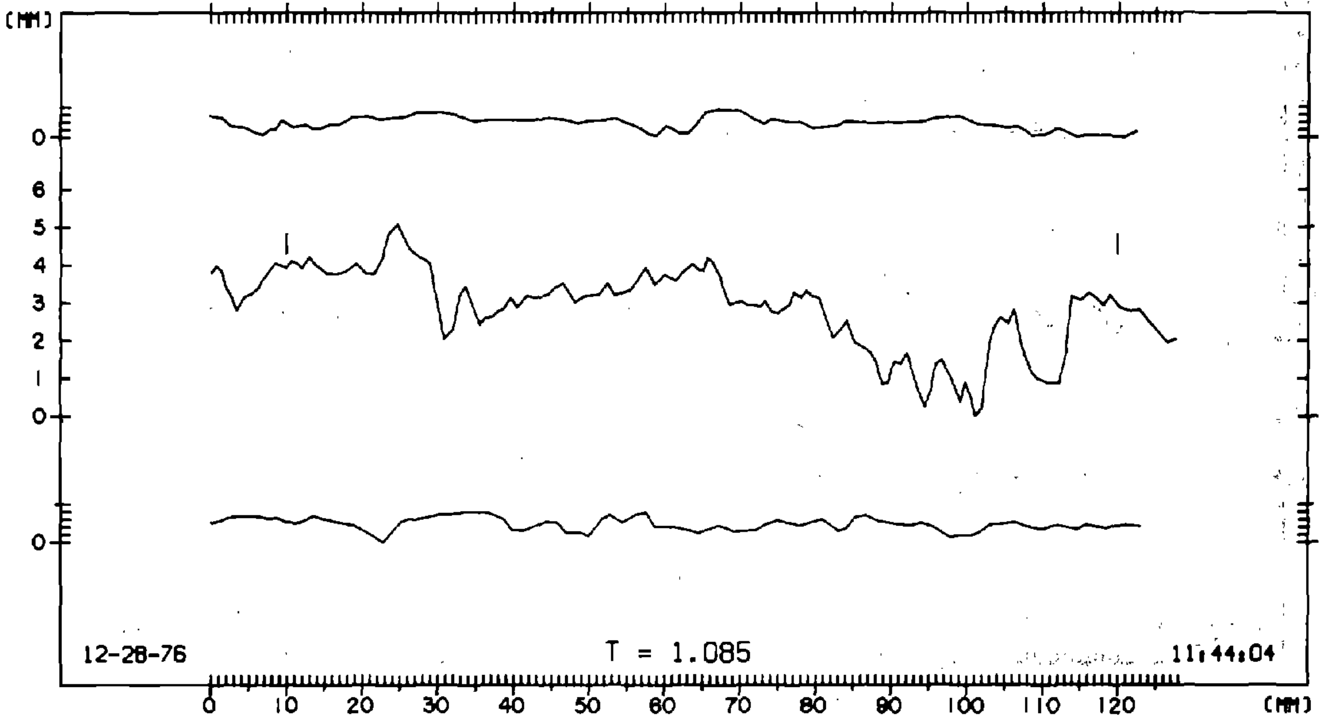

Fig. 26 - 04-SF-80 PM 8.00 EB 1 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - \$2.90 (\$3.47)

Aggregate - Watsonville Granite No. 4 (4.75 mm) Max.
Spread Rate Per Sq. Yd. (m^2) - 10.4 pounds (5.6 kg)

Binder - Coal Tar Modified Epoxy
(California Spec. 701-80-35)
Spread Rate Per Sq. Yd. (m^2) - 0.37 gal. (1.7 litre)

Mild coastal climate.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 45$
$SN_{55} = 42$
$SN_{40S} = 41$
$G = 0.20$

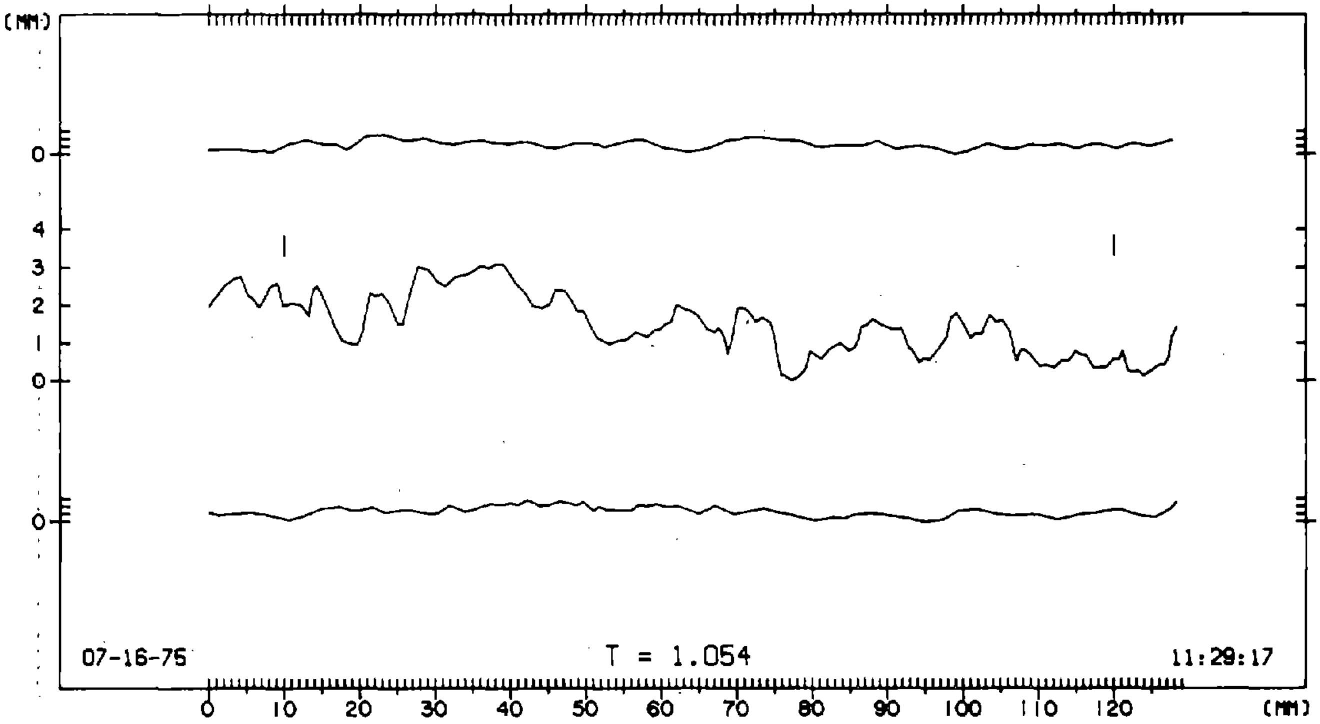

Fig. 27 - 04-SF-80-8.24/8.28 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 5/76 - 29,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - $21.70 ($25.96)

Permapol Rubber Coating incorporating Aluminum Oxide Grit (Permapol 445R) over a primer (Permapol 440)

Products Research and Chemical Corporation - 0.24 gal/sq.yd. (1.1 litre/m^2)

Mild coastal climate.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 41$
$SN_{55} = 40$
$SN_{40S} = 38$
$G = 0.06$

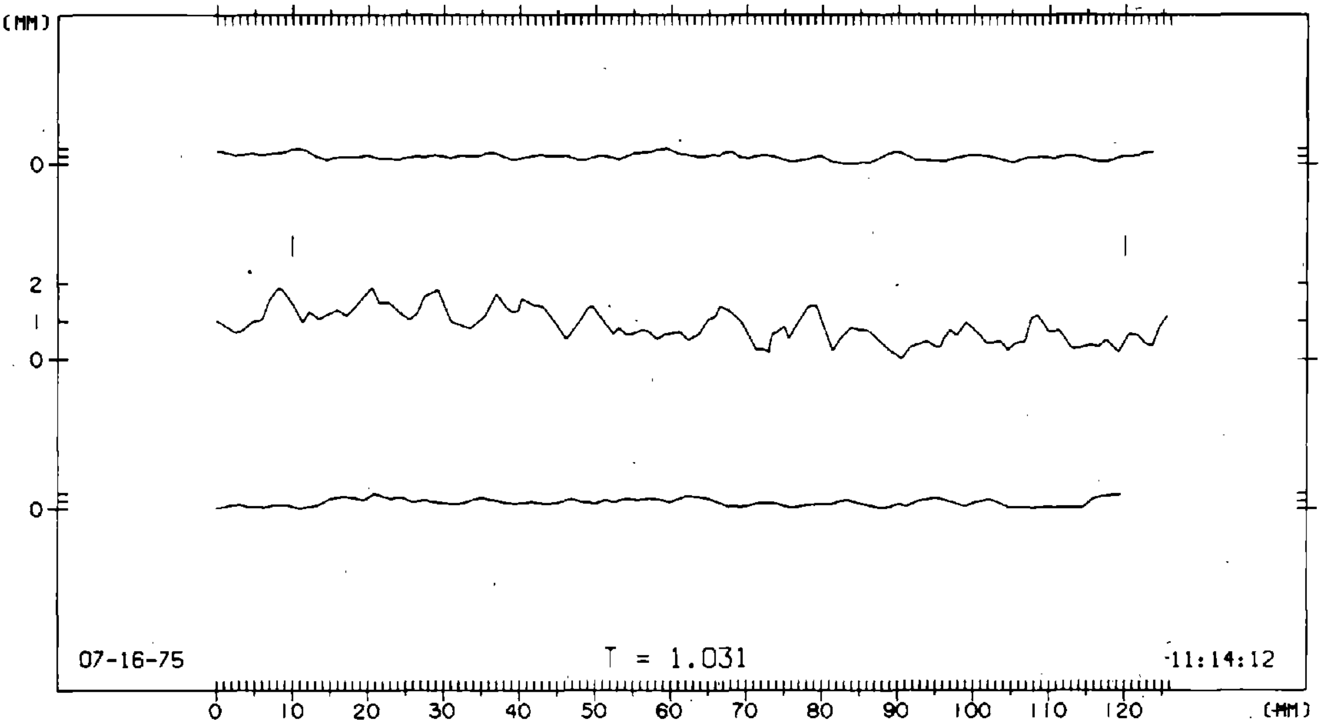

Fig. 28 - 04-SF-80-8.50/8.53 WB 5 of 5 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1/2 inch thickness \$14.60
(12.7 mm -- \$17.46)

Aggregate - Blast Furnace Slag No. 4 (4.75 mm) Max.

Binder - 6.8% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
One wet pavement accident from 9/71 to 1/77.

$SN_{40} = 47$
$SN_{55} = 45$
$SN_{40S} = 27$
$G = 0.13$

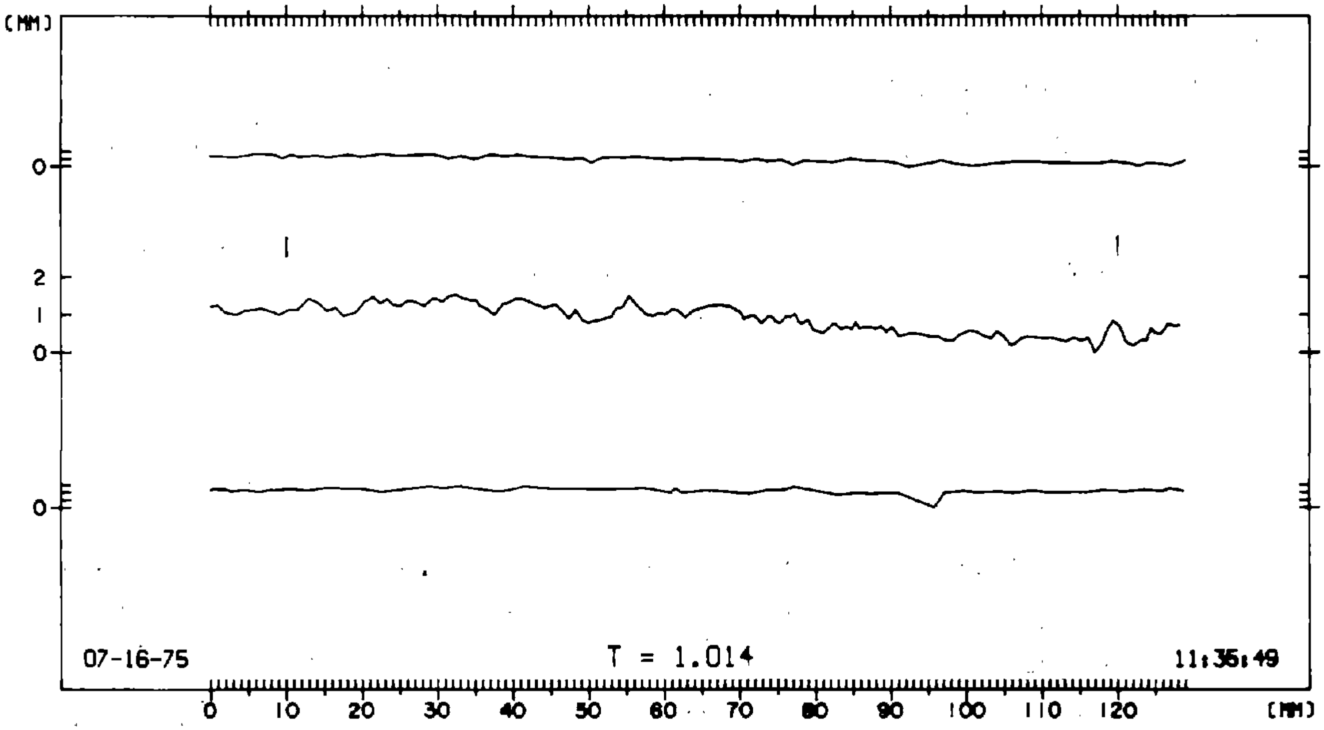

Fig. 29 - 04-SF-80-8.09/8.13 WB 5 of 5 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1 inch thickness $15.40
(25.4 mm - $18.42)

Aggregate - Blast Furnace Slag #4 (4.75 mm) Max.

Binder - 6.8% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
Three wet pavement accidents from 9/71 to 1/77.

$$SN_{40} = 45$$
$$SN_{55} = 42$$
$$SN_{40S} = 41$$
$$G = 0.20$$

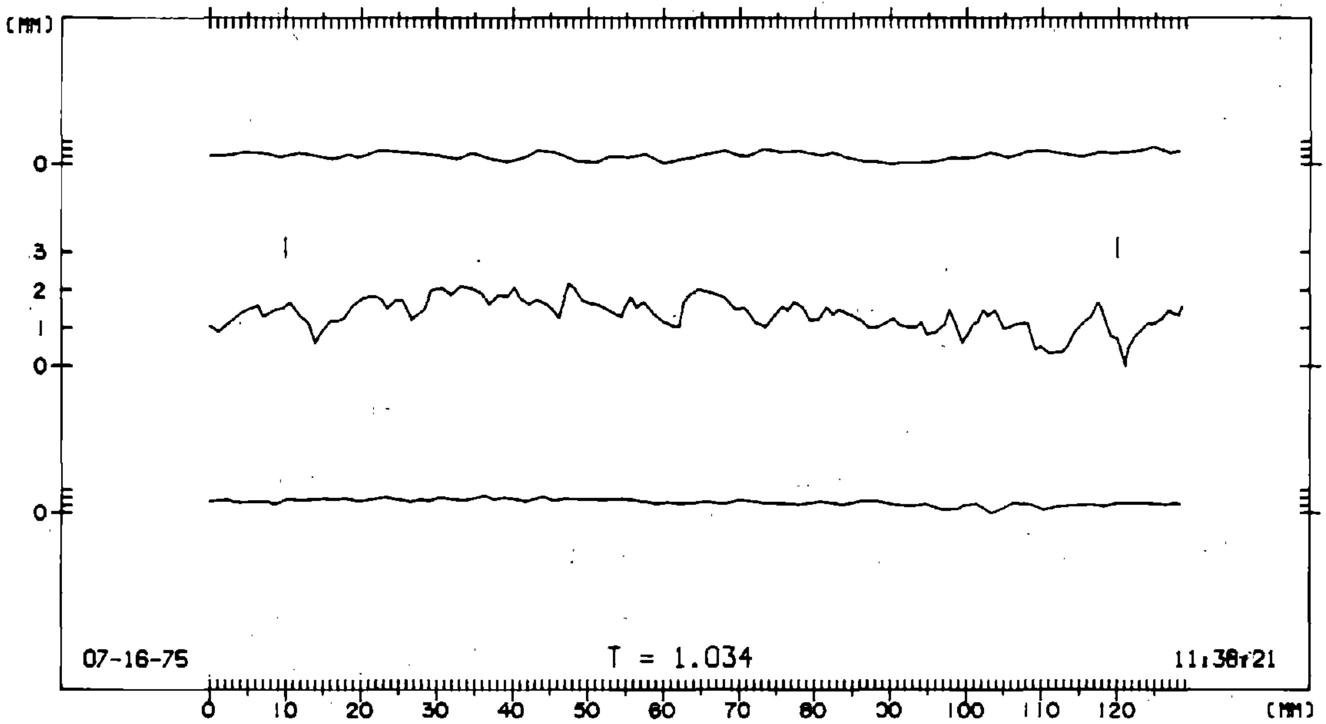

Fig. 30 - 04-SF-80-8.05/8.09 WB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BURLAP DRAG TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 76,000
Vehicle Passes to 1/77 - 5,000,000
Truck Passes - 1,500,000

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 50$
$SN_{50} = 46$
$SN_{40S} = 37$
$G = 0.40$

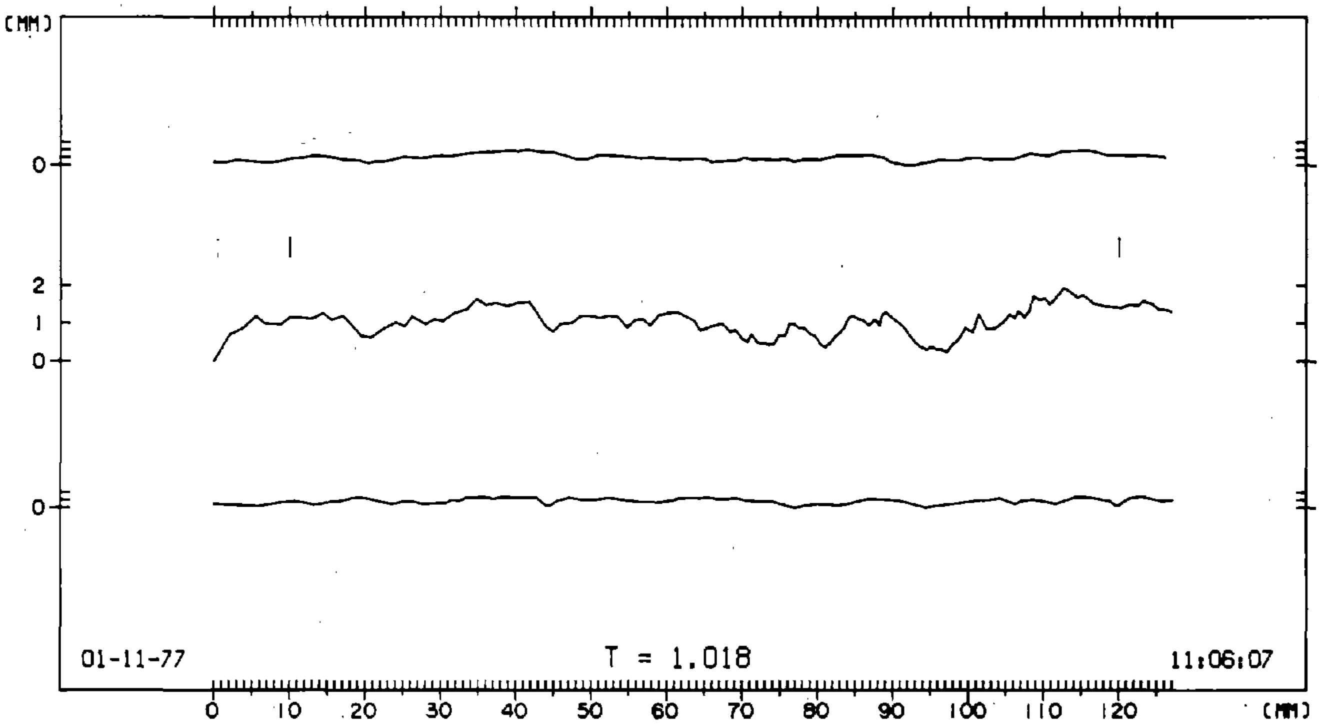

Fig. 31 - 07-LA-10 PM 39.26 EB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BURLAP DRAG TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 76,000
Vehicle Passes to 1/77 - 5,000,000
Truck Passes - 1,500,000

Crushed gravel sprinkled at the rate of 1/6 cu. ft. per sq. yd. (.006 m^3/m^2)

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 46$
$SN_{50} = 43$
$SN_{40S} = 35$
$G = 0.30$

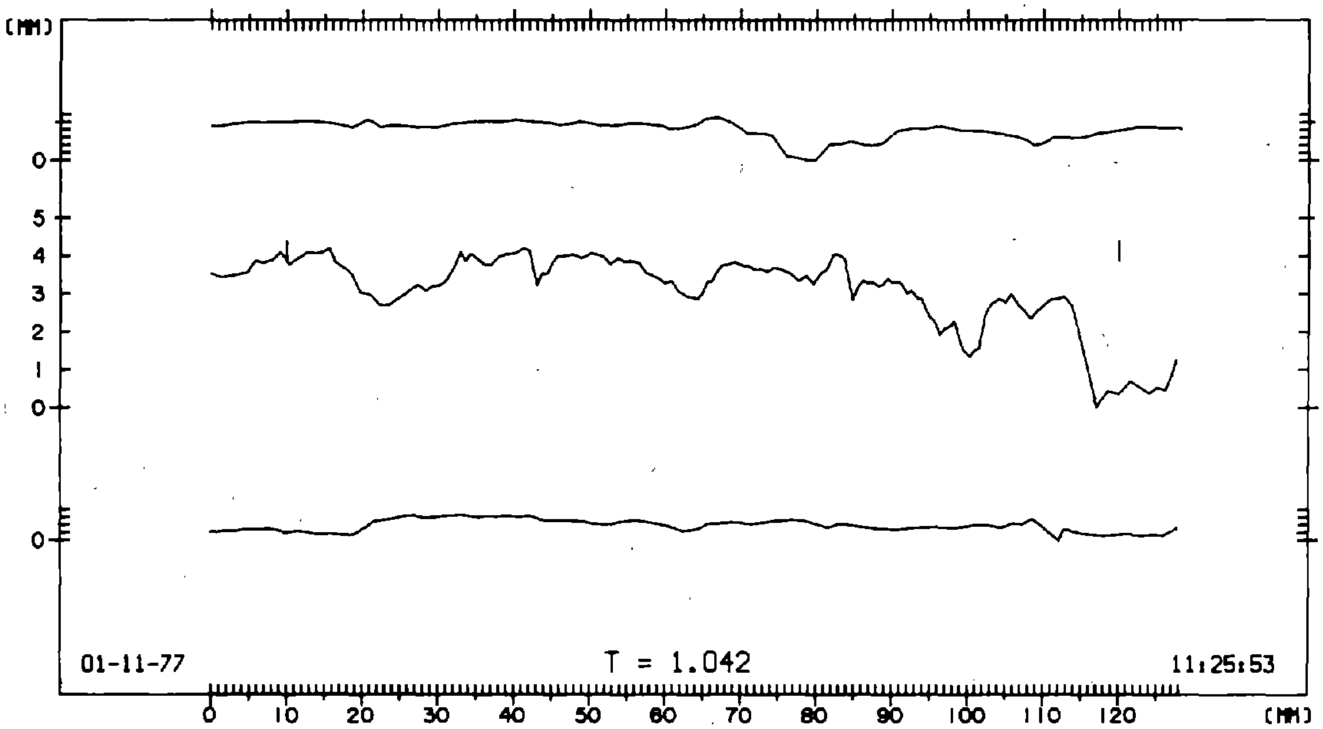

Fig. 32 - 07-LA-10 PM 39.87 EB 5 of 5 Lanes

OVERLAY
DENSE GRADED ASPHALT CONCRETE

Date Placed - June 1969
Average Daily Traffic (1975) - 27,250
Vehicle Passes to 2/77 - 18,600,000
Truck Passes - 4,500,000
Cost Per Sq. Yd. (m^2) - \$0.72 (\$0.86)
Aggregate - American River Streambed 1/2" (12.5 mm) Max.
Binder - 6.0% 85-100 Penetration Paving Grade Asphalt

Hot summers, cold winters, no chain or studded tire traffic; looks good.
No wet pavement accidents from 1/69 to 1/77.

$SN_{40} = 49$
$SN_{50} = 45$
$SN_{40S} = 34$
$G = 0.40$

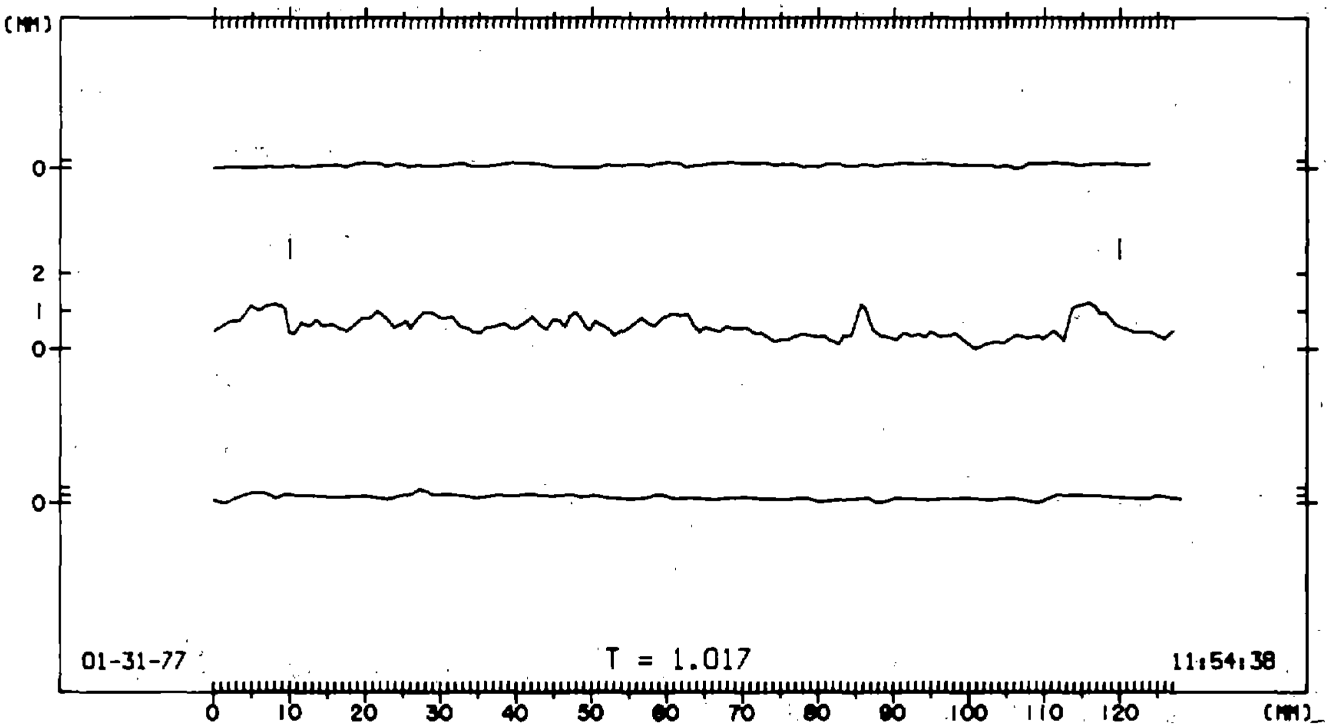

Fig. 33 - 03-Sac-99 PM 11.00 SB 2 of 2 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL TEXTURE, ARTIFICIAL GRASS DRAG

Date Placed - April 1975

Average Daily Traffic (1975) - 25,000

Vehicle Passes to 2/77 - 2,000,000

Truck Passes - 315,000

Measured values and appearance are similiar to those obtained on new longitudinal broomed PCC surfaces. No wet pavement accidents from 5/75 to 1/77.

$SN_{40} = 52$

$SN_{50} = 47$

$SN_{40S} = 42$

$G = 0.50$

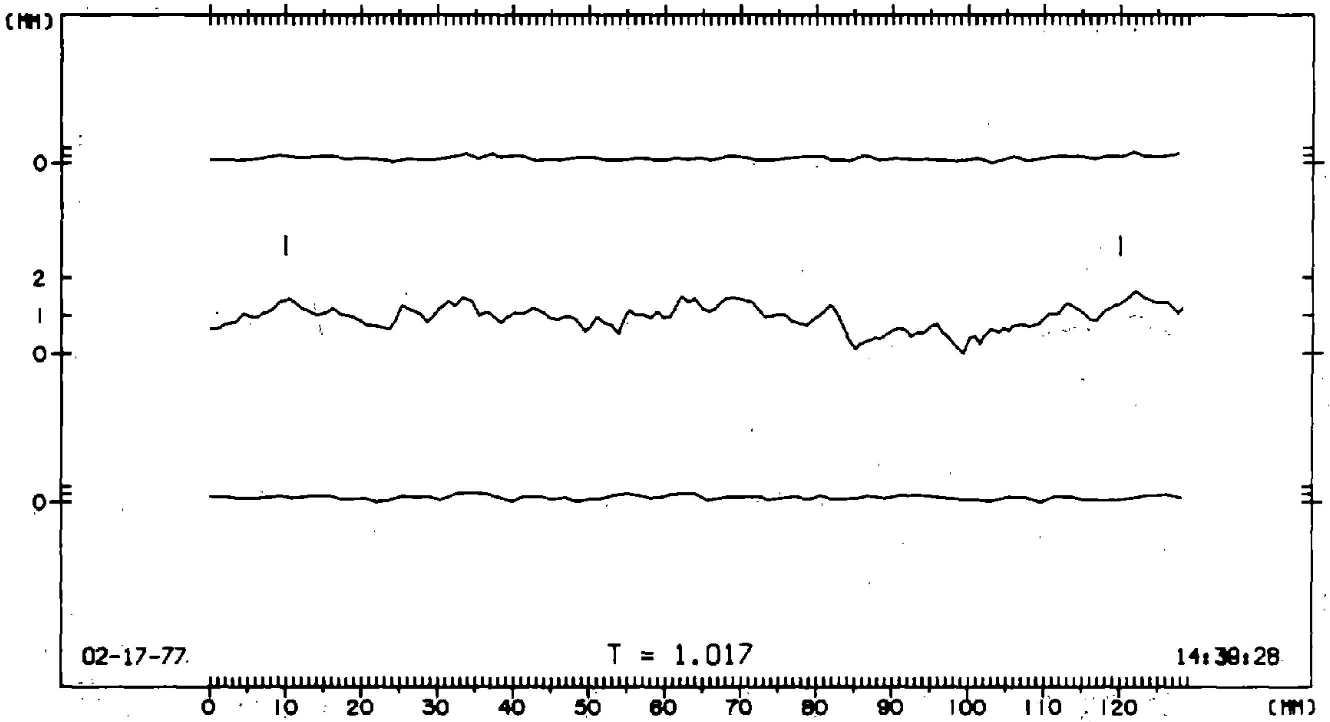

Fig. 34 - 11-SD-805-2.50 NB 4 of 4 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BURLAP DRAG TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 76,000
Vehicle Passes to 1/77 - 5,000,000
Truck Passes - 1,500,000

No water added during finishing

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 47$
$SN_{50} = 43$
SN_{40S} 28
$G = 0.40$

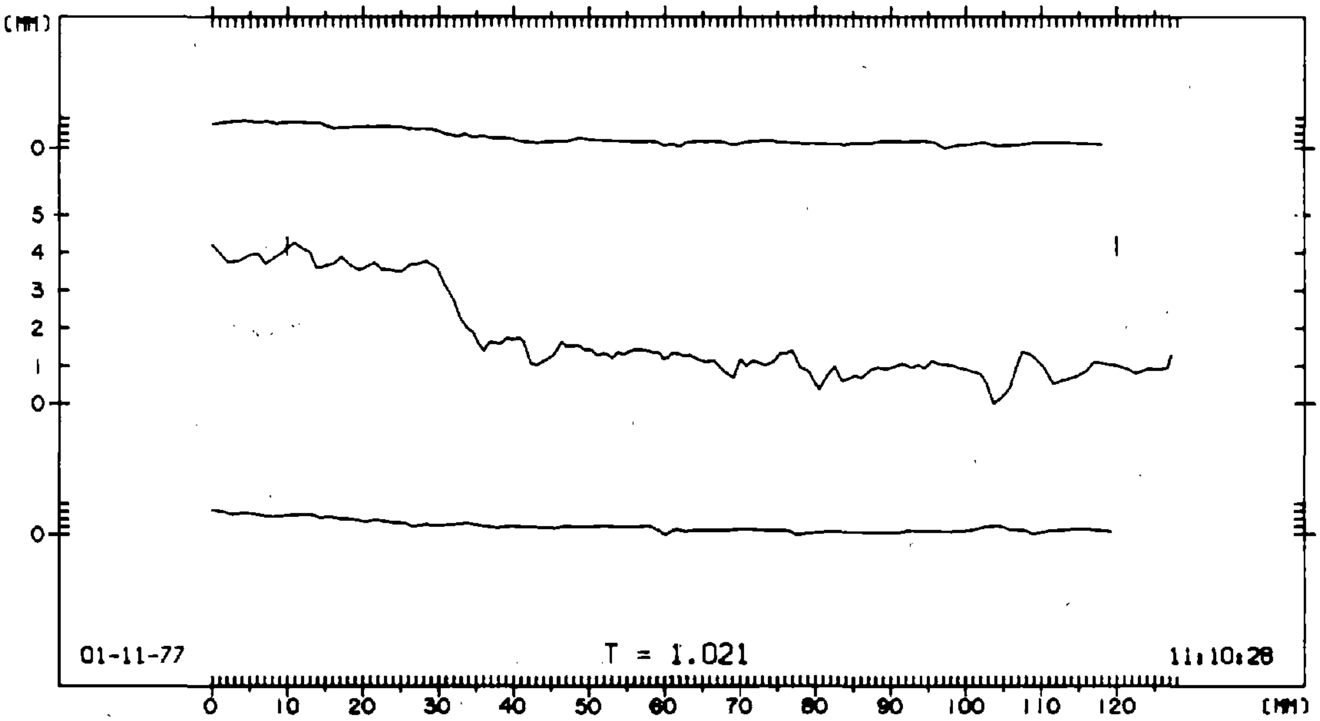

Fig. 35 - 07-LA-10 PM 39.44 EB 5 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BURLAP DRAG TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 76,000
Vehicle Passes to 1/77 - 5,000,000
Truck Passes - 1,500,000

Slag sprinkled at the rate of 1/6 cu. ft. per sq. yd. (0.006 m^3/m^2)

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 49$
$SN_{50} = 43$
$SN_{40S} = 39$
$G = 0.60$

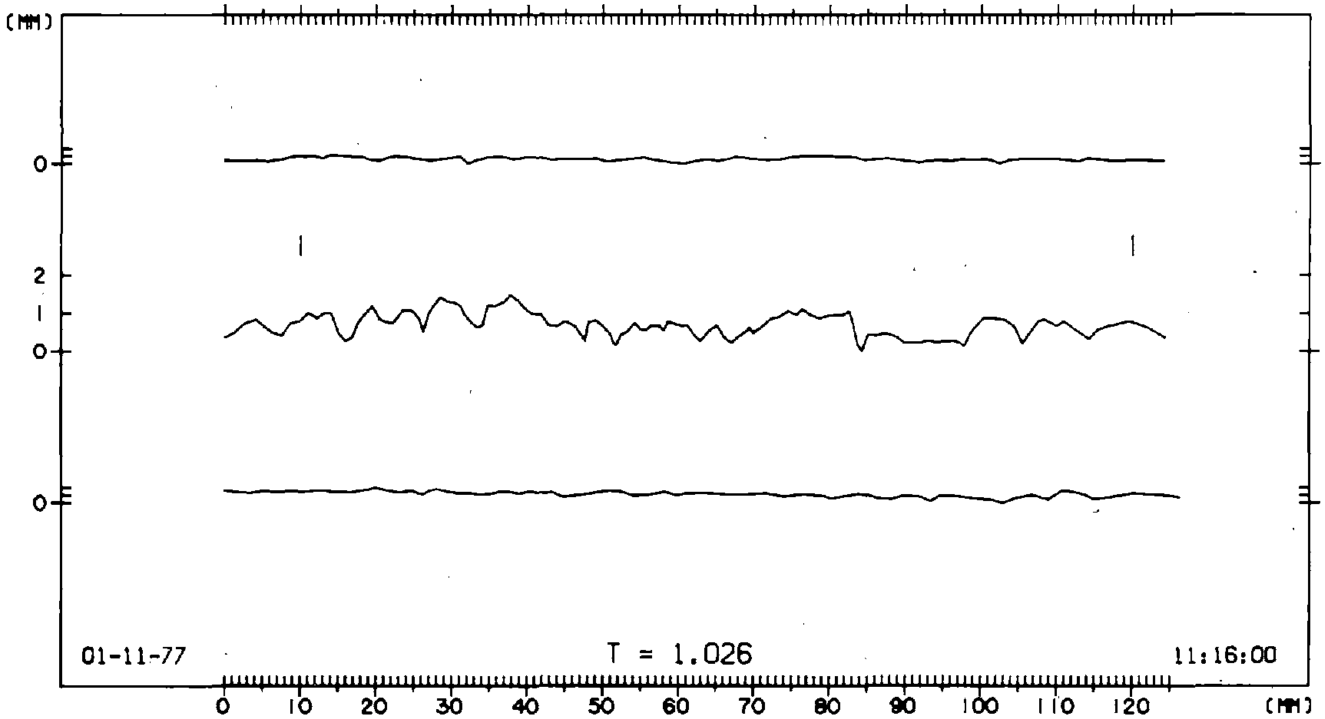

Fig. 36 - 07-LA-10 PM 39.7-39.76 EB 5 of 5 Lanes

CHIP SEAL [illegible]

Date Placed - July 1964

Average Daily Traffic (1975) - 39,500

Vehicle Passes to 2/77 - 45,000,000

Truck Passes - 9,000,000

Cost Per Sq. Yd. (m^2) - \$10.00 (\$11.96)

Aggregate - Silicon Carbide No. 8 (2.36 mm) Max.
  Spread Rate Per Sq. Yd. (m^2) - 11 Pounds (6.0 kg)

Binder - Coal Tar Modified Epoxy Resin
  California Spec. 681-80-35
  Spread Rate Per Sq. Yd. (m^2) - 0.35 gallon (1.6 litre)

Three wet pavement accidents from 1/74 to 1/77.
Shows signs of a bond problem between wheel tracks.
Mild coastal climate.

$SN_{40} = 40$
$SN_{50} = 36$
$SN_{40S} = 26$
$G = 0.40$

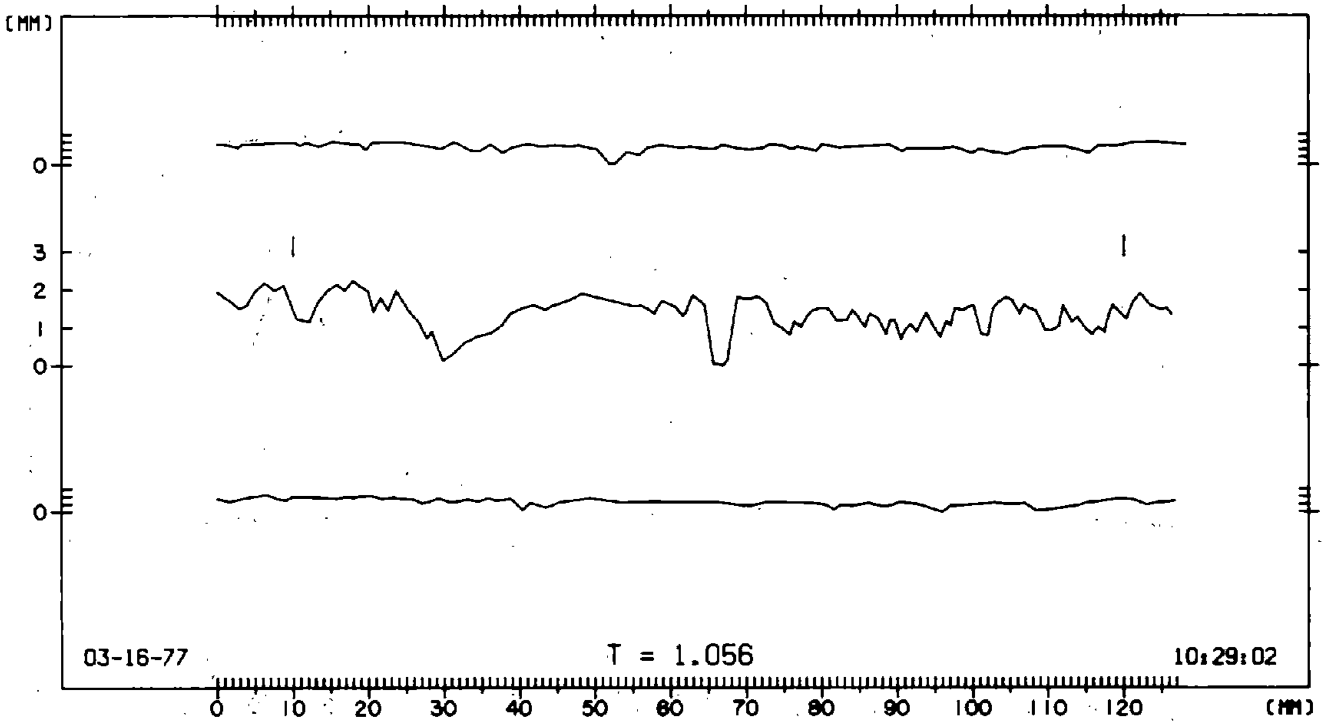

Fig. 37 - 04-Ala-80 PM 7.27-7.33 EB 1 of 5 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BURLAP DRAG TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 76,000
Vehicle Passes to 1/77 - 5,000,000
Truck Passes - 1,500,000

1/2" (12.5 mm) Max. Light Weight Aggregate sprinkled at the rate of 1/6 cu. ft. per sq. yd. (0.006 m3/m2)

No wet pavement accidents from 7/75 to 1/77.

$SN_{40} = 48$
$SN_{50} = 42$
$SN_{40S} = 32$
$G = 0.60$

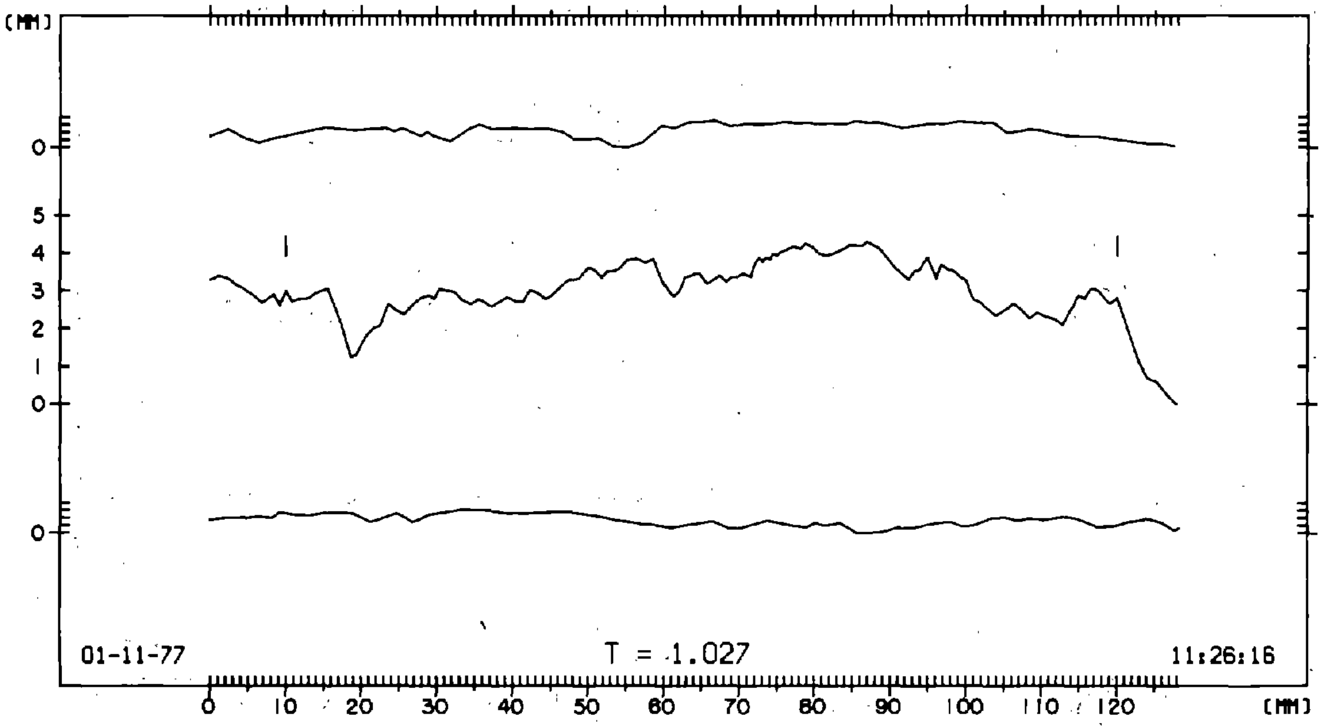

Fig. 38 - 07-LA-10 PM 40.06 EB 5 of 5 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1/2 inch thickness $14.50
(12.7 mm - $17.34)

Aggregate - Expanded Shale -- Basalite No. 4 (4.75 mm) Max.

Binder - 10.0% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
Two wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 50$
$SN_{55} = 39$
$SN_{40S} = 24$
$G = 0.73$

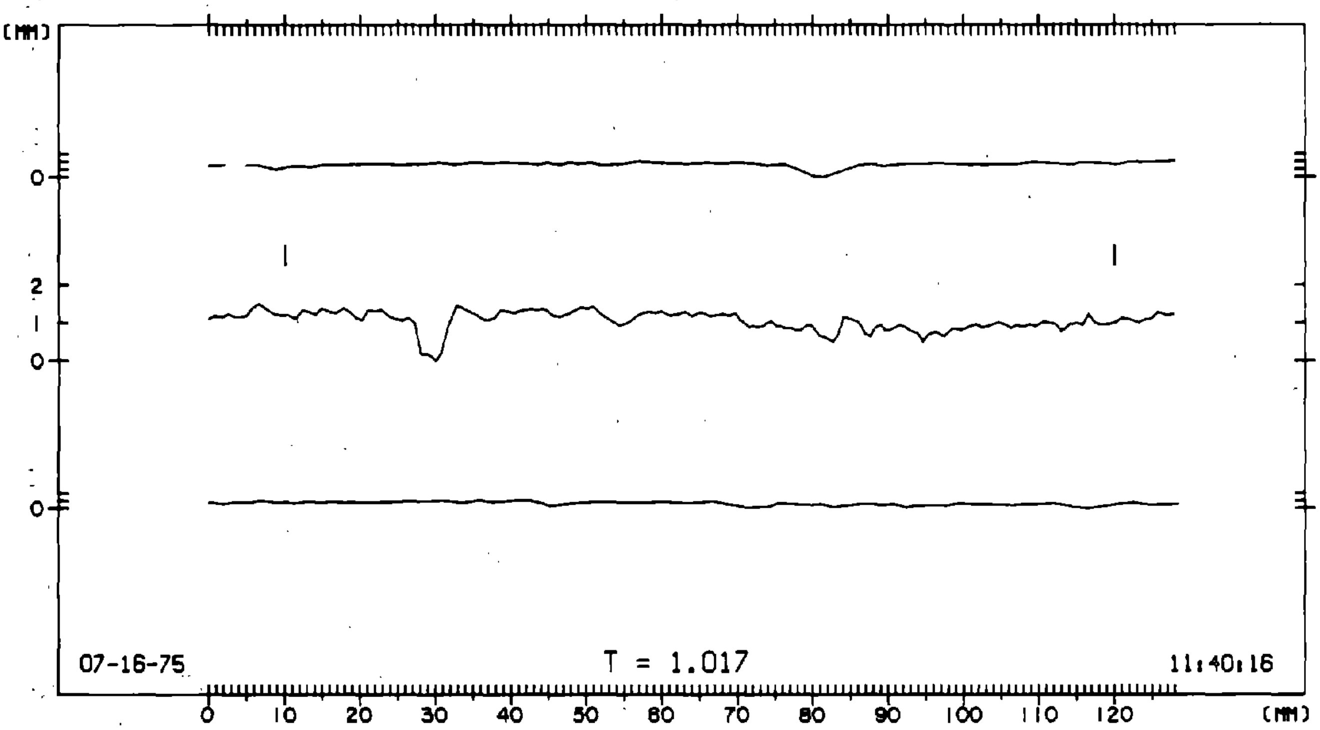

Fig. 39 - 04-SF-80-7.98/8.02 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - \$2.90 (\$3.47)

Aggregate - Monterey Sand
  Spread Rate Per Sq. Yd. (m^2) - 20.4 pounds (11.1 kg)

Binder - Coal Tar Modified Epoxy Resin
  (California Spec. 701-80-35)
  Spread Rate Per Sq. Yd. (m^2) - 0.29 gal. (1.3 litre)

Mild coastal climate.
No wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 45$
$SN_{55} = 37$
$SN_{40S} = 30$
$G = 0.53$

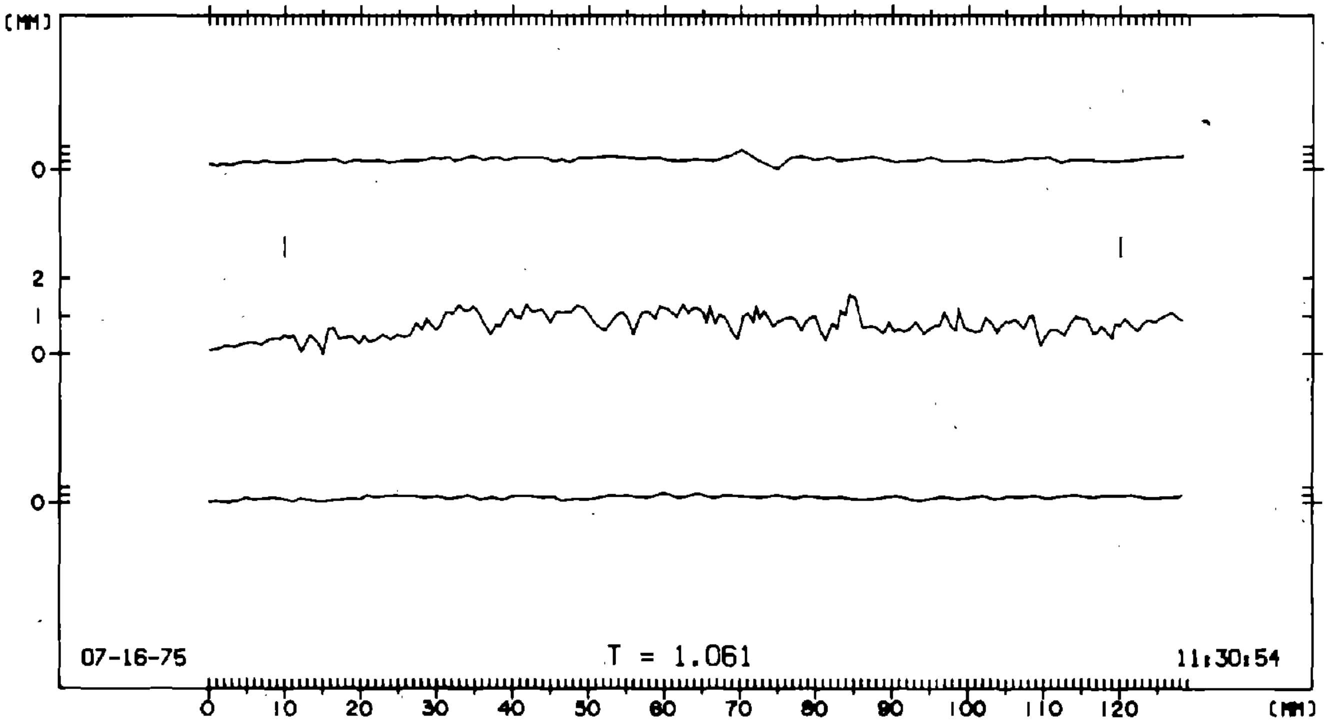

Fig. 40 - 04-SF-80-8.20/8.24 WB 5 of 5 Lanes

CHIP SEAL

Date Placed - June 1965

Average Daily Traffic (1974) - 63,000

Vehicle Passes to 8/76 - 42,000,000

Truck Passes - 6,000,000

Cost Per Sq. Yd. (m^2) - approx. \$5.00 (\$6.00)

Aggregate - Bear River Sand No. 8 x No. 16
Spread Rate Per Sq. Yd. (m^2) - 18 pounds (8.2 kg)

Binder - Shell Guardkote 140
Spread Rate Per Sq. Yd. (m^2) - 0.3 gal. (1.4 litre)

Hot summers, cold winters, no chain or studded tire traffic; some wear in the wheel track.

$SN_{40} = 43$
$SN_{50} = 37$
$SN_{40S} = 33$
$G = 0.60$

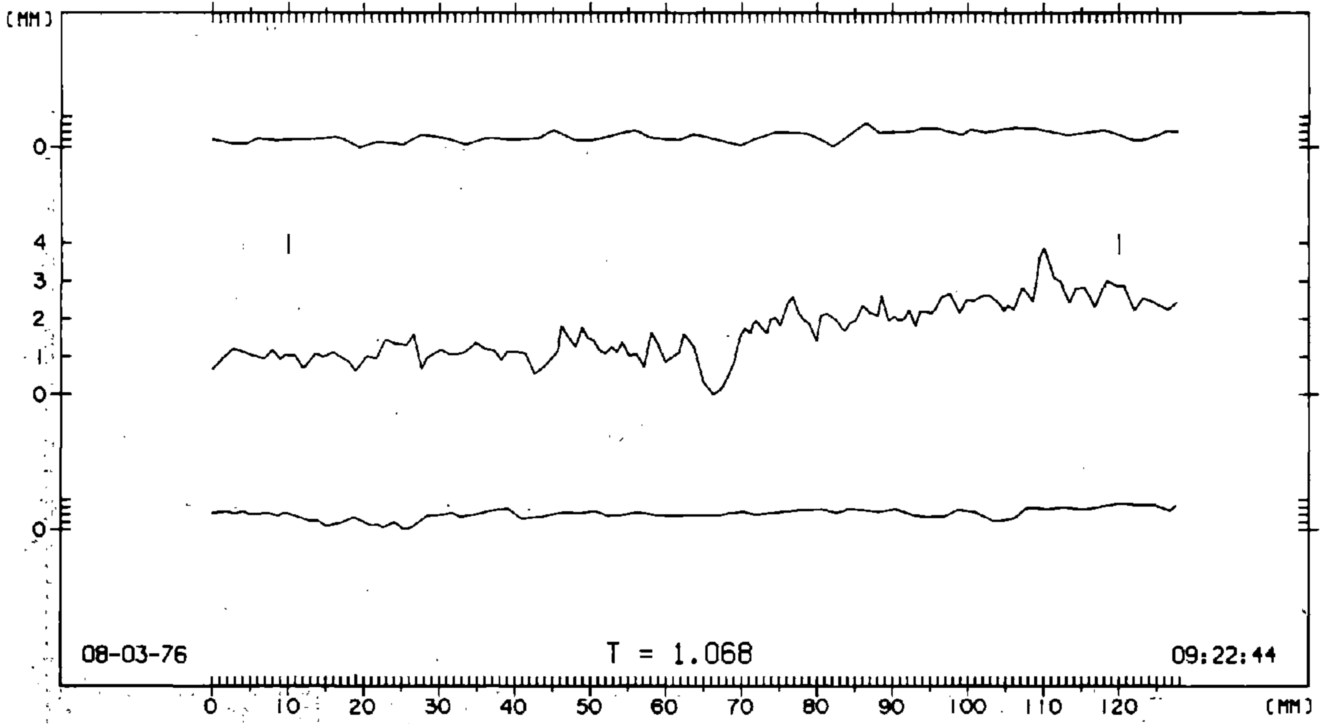

Fig. 41 - 03-Sac-99-20.5 NB 3 of 3 Lanes

PORTLAND CEMENT CONCRETE
LONGITUDINAL BROOMED TEXTURE

Date Placed - June 1975
Average Daily Traffic (1975) - 25,000
Vehicle Passes to 2/77 - 2,000,000
Truck Passes - 315,000

No wet pavement accidents from 5/75 to 1/77.

$SN_{40} = 44$
$SN_{50} = 40$
$SN_{40S} = 35$
$G = 0.40$

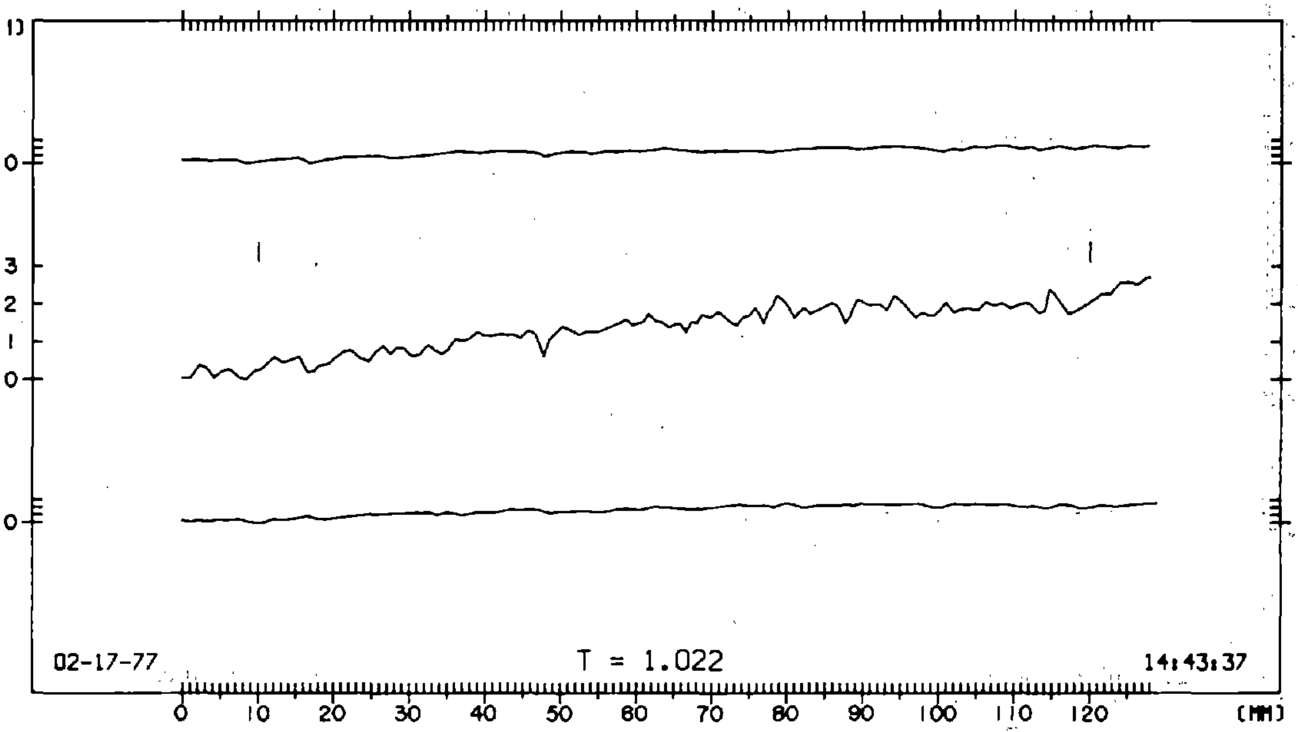

Fig. 42 - 11-SD-805 PM 2.62 NB 4 of 4 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1 inch thickness $15.30
(25.4 mm -- $18.30)

Aggregate - Watsonville Granite No. 4 (4.75 mm) Max.

Binder - 6.7% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
Four wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 46$
$SN_{55} = 39$
$SN_{40S} = 26$
$G = 0.47$

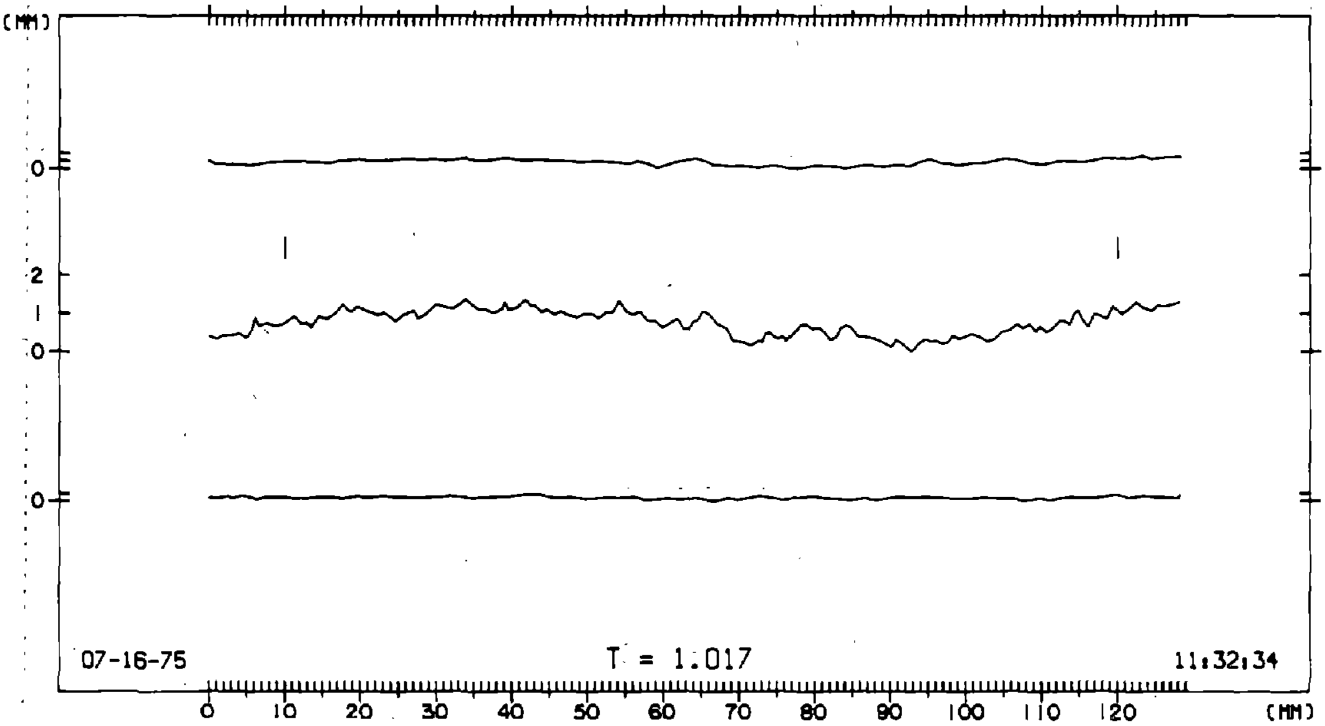

Fig. 43 - 04-SF-80-8.16/8.20 WB 5 of 5 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1 inch thickness $15.20
(25.4 mm -- $18.18)

Aggregate - Expanded Shale-Basalite No. 4 (4.75 mm) Max.

Binder - 10.0% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
Three wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 45$
$SN_{55} = 39$
$SN_{40S} = 25$
$G = 0.40$

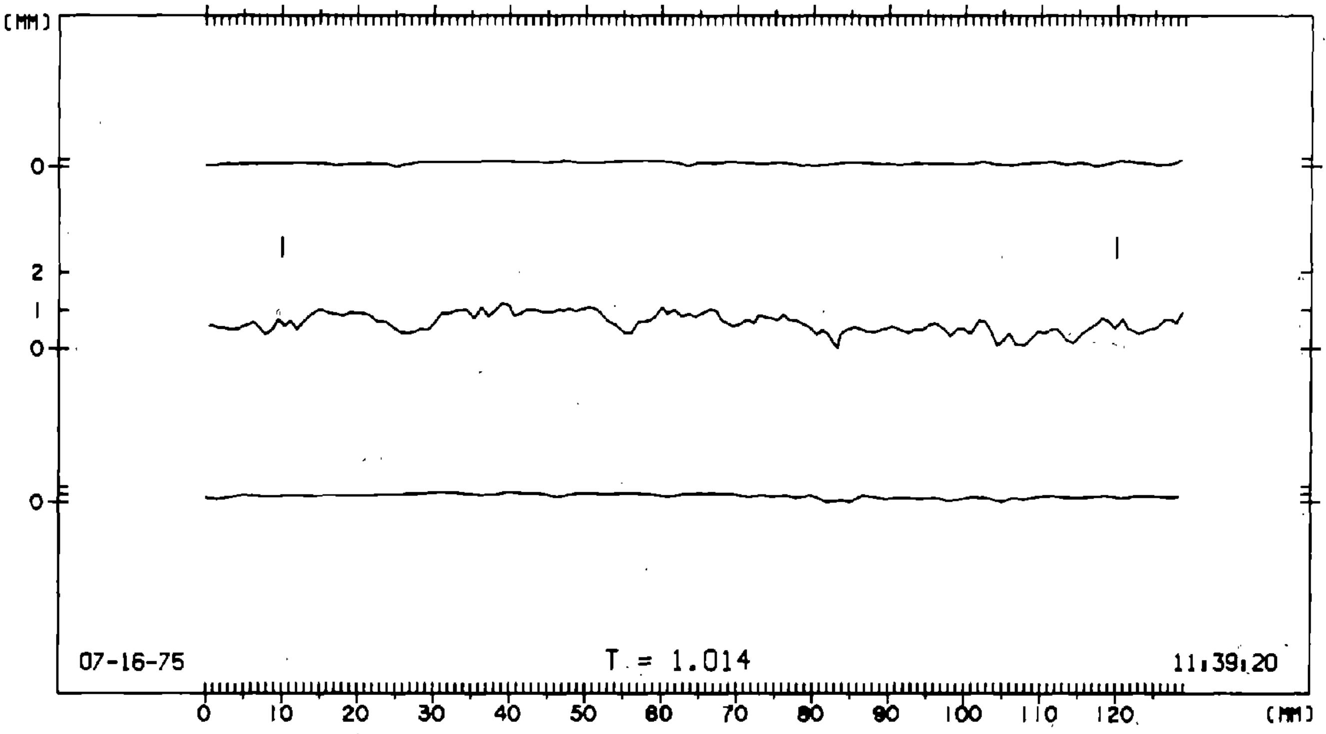

Fig. 44 - 04-SF-80-8.02/8.05 WB 5 of 5 Lanes

EPOXY ASPHALT CONCRETE

Date Placed - September 1971

Average Daily Traffic (1974) - 170,000

Vehicle Passes to 1/77 - 33,000,000

Truck Passes - 6,500,000

Cost Per Sq. Yd. (m^2) - 1/2 inch thickness $14.60
(12.7 mm -- $17.46)

Aggregate - Watsonville Granite No. 4 (4.75 mm) Max.

Binder - 6.7% Epoxy Asphalt-Adhesive Engineering

Mild coastal climate.
Two wet pavement accidents from 9/71 to 1/77.

$SN_{40} = 46$
$SN_{55} = 39$
$SN_{40S} = 24$
$G = 0.47$

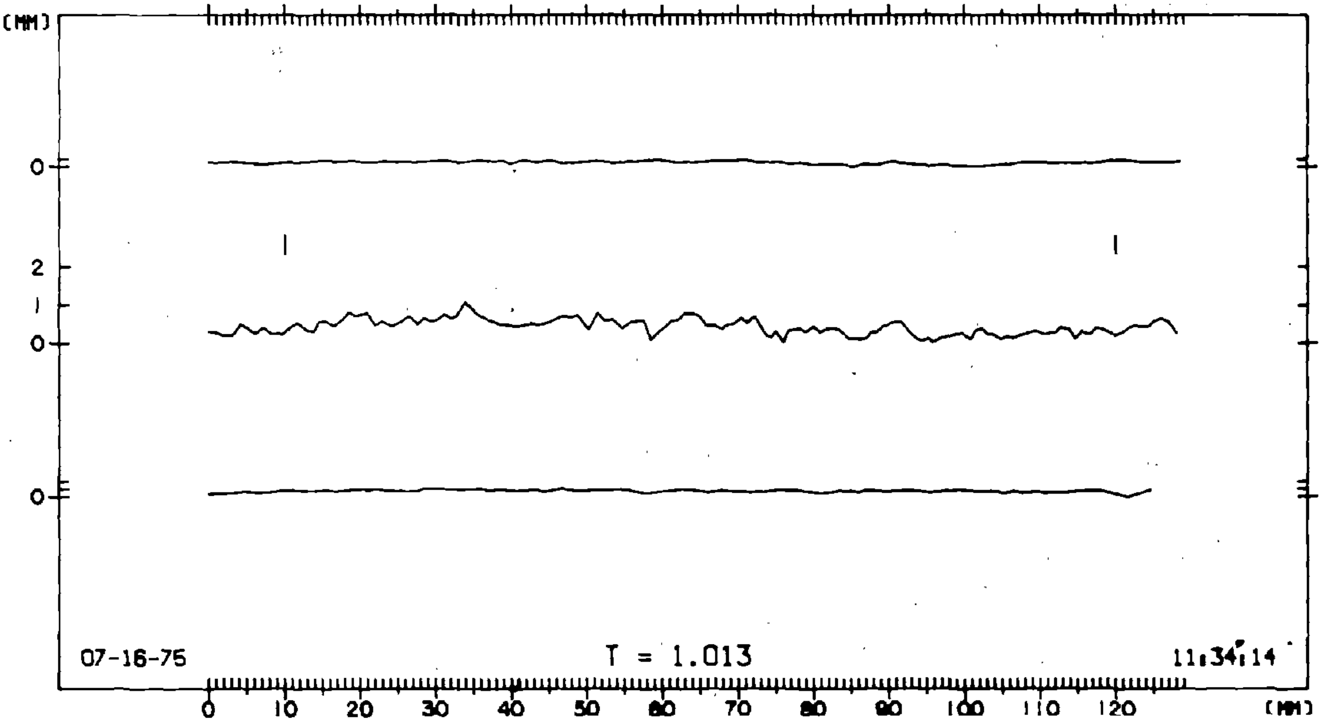

Fig. 45 - 04-SF-80-8.13/8.16 WB 5 of 5 Lanes

APPENDIX C

TABLE 1
CHIP SEAL AGGREGATES

Gradation, % Pass Sieve Size (mm)	Calcined Bauxite	Watsonville Granite	Yuba River Source	Bear River Quartz	Silicon Carbide	Copper Slag	Monterey Sand	Crushed Igneous
3/8" (9.5)		100	100	100				90-100
1/4" (6.3)		--	90-100					45-70
#4 (4.75)	100	79	60-85	80	100			5-30
#6 (3.35	97-100	--	--	--	--			--
#7 (2.80)	85-95	--	--	--	--			--
#8 (2.36	--	9	0-25	14	95-100	100		0-10
#10 (2.00)	--	--	--	--	85-95	97	100	--
#12 (1.70)	--	--	--	--	28-38	--	--	--
#16 (1.18)	5-20	4	0-5	2	0-10	51	42-60	0-5
#20 (0.85	--	--	--		--	12	10-30	--
#30 (0.60	0-2	3	0-3		0-2	3	3	--
#200 (0.075)			0-2					0-2
Aggregate Composition, Percent	Aluminum Oxide 86 Silica 7.5 Titanium Dioxide 4 Iron Oxide 2.5 Mohs hardness ≥8	Quartz 67 Granitic 11 Feldspar 10 Quartzidte 6 Hornfels 2 Volcanic 2 Ultrabasic 1 Sandstone <1 Mica <1	Vein Quartz 32 Granitic 30 Greenstone 16 Quartzite 8 Chert 8 Schist 5 Gneiss 1	Quartz White 53 Gray 13 Quartzite 8 Metavolcanic 5 Andesitic 4 Schist 4 Quartzitic Metasedimentary 4 Silicified Volcanic 2 Serpentine 1 Slate <1 Limonite <1	Norton Co. Worchester, Mass. Mohs hardness ≥7.5	American Grouting Redwood City, CA	Predominantly Quartz, Feldspar, and Mica	Scoria 44 Granitic 17 Gneiss 11 Quartz - Feldspar-Aglomerate 10 Quartz 7 Schist 4 Hornfels 3 Feldspar 2 Amygdaloidal Basalt 1 Sandstone 1

APPENDIX C

TABLE 2 - ASPHALT CONCRETE AND EPOXY ASPHALT CONCRETE AGGREGATES

Gradation, % Pass Sieve Size (mm)	American River Streambed Open Graded AC	American River Streambed Dense Graded AC	Crushed Blast Furnace Slag Open Graded	Crushed Blast Furnace Slag Dense Graded	Expanded Shale	Watsonville Granite Open Graded	Watsonville Granite Dense Graded
3/4 (19.0)		100					
1/2 (12.5)		95-100					
3/8 (9.5)	100	80-95	100	100	100	100	100
No. 3 (6.3)	85-100	--	85-100	--	--	85-100	--
No. 4 (4.75)	--	55-72	--	81	82	--	88
No. 8 (2.36)	15-32	38-55	15-32	59	60	15-32	61
No. 16 (1.18)	0-15	--	0-15	39	35	0-15	40
No. 30 (0.60)	--	18-33	--	30	25	--	33
No. 50 (0.30)	--	--	--	19	17	--	24
No. 100 (0.15)	--	--	--	10	11	--	17
No. 200 (0.075)	0-3	4-8	0-3	4	8	0-3	11
Aggregate Composition, Percent	Basic Metaigneous Quartzitic Metasediments Vein Quartz Andesite Hornfels Amphibolite Granitic Dioritic Gaboric	37-43 26-28 1-13 7-9 6-8 3-5 2-5 2-5	U.S. Steel Co. Geneva, Utah		Basalt Rock Co. Napa, California	Quartz 67 Granitic 11 Feldspar 10 Quartzite 6 Hornfels 2 Volcanic 2 Ultrabasic 1 Sandstone <1 Mica <1	

APPENDIX C

TABLE 2 (cont'd) - ASPHALT CONCRETE AND EPOXY ASPHALT CONCRETE AGGREGATES

Gradation, % Pass Sieve Size (mm)	Metasandstone Open Graded	Metagraywacke	-- Expanded Shale	95% Metagraywacke combined with 5% (7-15% by Volume) Expanded Shale by Volume
3/4 (19.0)	100			
1/2 (12.5)	95-100			
3/8 (9.5)	75-100	100	100	100
No. 3 (6.3)	30-75	80-100	45-65	72-94
No. 4 (4.75)	25-40	65-85	0-6	60-80
No. 8 (2.36)	5-20	44-62		36-54
No. 16 (1.18)	0-10	24-42		20-40
No. 30 (0.60)	--	16-30		14-31
No. 50 (0.30)	--	10-22		10-25
No. 100 (0.15)	--	5-15		9-17
No. 200 (0.075)	0-3	3-10		8-14

Aggregate Composition, Percent	Metasandstone	99.7	Metasandstone	99.7
	Quartz	trace	Calcite	trace
	Feldspar	"	Quartz	"
	Ultrabasic	"	Mica	"
	Mica	"	Ultrabasic	"
			Volcanic	"

APPENDIX C

TABLE 3 - AGGREGATE FOR SEEDING PORTLAND CEMENT CONCRETE TEXTURE

Gradation, % Pass Sieve Size (mm)	Blast Furnace Slag	Crushed Gravel	Lightweight Aggregate
3/4" (19.0)	100	100	100
1/2" (12.5)	96	98	97
3/8" (9.5)	46	45	55
1/4" (6.3)	--	7	5
No. 4 (4.75)	5	4	1
No. 8 (2.36)	0	0	0
	International Mill Service Fontana, CA	Granite -- Quartz Monzonite 34 Granite gneiss 17 Gneissic granite porphyry-dark 13 Biotite schist 12 Gneissic granite porphyrylight 9 Quartz diorite 4 Quartz schist 3 Greenstone 3 Hornblende granodiorite 2 Vein quartz 2 Diabase 1	Ridgelite-Rocklite Lighweight Processing Co. Los Angeles, CA

APPENDIX D

	Rank			
Fig.	SN_{40}	G*	T*	SN_{40}+G+T
1	5	1.5	5	11.5
2	5	12.5	2	19.5
3	17	1.5	10	28.5
4	1	18	11	30
5	13	12.5	7.5	33
6	5	12.5	16	33.5
7	9.5	21.5	4	35
8	30	4	3	37
9	25	12.5	1	38.5
10	25	5.5	9	39.5
11	2	21.5	19	42.5
12	5	29.5	12	46.5
13	17	7.5	22.5	47
14	5	29.5	14.5	49
15	35	5.5	13	53.5
16	30	21.5	6	57.5
17	17	12.5	31.5	61
18	25	12.5	24	61.5
19	21	18	22.5	61.5
20	30	24	7.5	61.5
21	13	29.5	21	63.5
22	9.5	38.5	18	66
23	35	18	17	70
24	11	29.5	30	70.5
25	8	38.5	28	74.5

*G - Speed Gradient
T - Texture

APPENDIX D

	Rank			
Fig.	SN_{40}	G*	T*	SN_{40}+G+T
26	25	38.5	14.5	78
27	39.5	12.5	27	79
28	44	3	33	80
29	30	7.5	43.5	81
30	39.5	12.5	31.5	83.5
31	17	29.5	38	84.5
32	35	21.5	29	85.5
33	21	29.5	40.5	91
34	13	38.5	40.5	92
35	30	29.5	37	96.5
36	21	43	35	99
37	45	29.5	26	100.5
38	25	43	34	102
39	17	45	40.5	102.5
40	39.5	41	25	105.5
41	43	43	20	106
42	42	29.5	36	107.5
43	35	35.5	40.5	111
44	39.5	29.5	43.5	112.5
45	35	35.5	45	115.5

*G - Speed Gradient
T - Texture

APPENDIX E

Fig.	Surface Type	Date Placed	Test Section Length	Study Period	Accidents			% Wet Pave-ment Time	County Average % Wet Accidents
					Wet	Dry	% Wet		
1	ECS	9-71	200 ft.	9-71/9-76	0	5	0	5	20
2	OGAC	12-65	1 mi.	1-74/1-77	0	3	0	4	17
3	CS	7-74	1 mi.	7-73/7-74	0	1	0	4	19
				7-74/7-75	1	0	100		
				7-75/7-76	0	1	0		
4	ECS	9-71	200 ft.	9-71/9-76	0	1	0	5	20
5	OGAC	12-65	1 mi.	1-74/1-77	1	2	33	4	17
6	PCC	4-75	1/2 mi.	5-75/1-77	0	2	0	3	12
7	OGAC	7-75	2 mi.	1-72/6-75	12	67	15	6	24
				7-75/1-77	9	43	17		
8	ECS	9-71	200 ft.	9-71/9-76	1	0	100	5	20
9	PCC	6-75	1 mi.	7-75/1-77	0	2	0	7	20
10	CS	7-74	1 mi.	7-73/7-74	0	4	0	4	19
				7-74/7-75	0	0	0		
				7-75/7-76	1	1	50		
11	RCS	11-74	1/2 mi.	7-72/11-74	0	0	0	1	4
				11-74/1-77	0	0	0		
12	PCC	4-75	500 ft.	5-75/1-77	0	0	0	3	12
13	ECS	9-71	200 ft.	9-71/9-76	0	1	0	5	20
14	PCC	4-75	450 ft.	5-75/1-77	0	0	0	3	12

1 ft. = 0.3 m
1 mi. = 1.6 km

APPENDIX E

Fig.	Surface Type	Date Placed	Test Section Length	Study Period	Accidents			% Wet Pave-ment Time	County Average % Wet Accidents
					Wet	Dry	% Wet		
15	OGEA	11-69	600 ft.	1-71/1-77	15	108	12	5	20
16	PCC	6-75	1 mi.	7-75/1-77	0	0	0	7	20
17	PCC	4-75	465 ft.	5-75/1-77	0	0	0	3	12
18	OGEA	11-69	600 ft.	1-71/1-77	5	13	28	5	20
19	ECS	9-71	200 ft.	9-71/1-77	2	0	100	5	20
20	ECS	9-71	200 ft.	9-71/1-77	2	4	33	5	20
21	EAC	11-76	500 ft.	-	-	-	-	5	20
22	EAC	11-76	500 ft.	-	-	-	-	5	20
23	ECS	9-71	200 ft.	9-71/1-77	0	0	0	5	20
24	RCS	11-74	1/2 mi.	7-72/11-74 11-74/1-77	0 0	1 1	0 0	1	4
25	RCS	11-71	800 ft.	11-71/1-77	0	1	0	3	13
26	OGEA	11-69	600 ft.	1-71/1-77	4	14	22	5	20
27	ECS	9-71	200 ft.	9-71/1-77	0	3	0	5	20
28	RCS	9-71	200 ft.	9-71/1-77	0	0	0	5	20
29	EAC	9-71	200 ft.	9-71/1-77	1	0	100	5	20
30	EAC	9-71	200 ft.	9-71/1-77	3	3	50	5	20
31	PCC	6-75	1293 ft.	7-75/1-77	0	1	0	2	13
32	PCC	6-75	1000 ft.	7-75/1-77	0	0	0	2	13

1 ft. = 0.3 m
1 mi. = 1.6 km

APPENDIX E

Fig.	Surface Type	Date Placed	Test Section Length	Study Period	Accidents Wet	Accidents Dry	Accidents % Wet	% Wet Pavement Time	County Average % Wet Accidents
33	DGAC	6-69	2 mi.	1-68/7-69 7-69/1-77	0 0	4 27	0 0	4	17
34	PCC	4-75	500 ft.	5-75/1-77	0	2	0	3	12
35	PCC	6-75	850 ft.	7-75/1-77	0	0	0	2	13
36	PCC	6-75	650 ft.	7-75/1-77	0	1	0	2	13
37	EAC	7-64	150 ft.	1-74/1-77	3	6	33	4	17
38	PCC	6-75	1100 ft.	7-75/1-77	0	0	0	2	13
39	EAC	9-71	200 ft.	9-71/1-77	2	2	50	5	20
40	ECS	9-71	200 ft.	9-71/1-77	0	2	0	5	20
41	ECS	6-65	25 ft.	-	-	-	-	4	17
42	PCC	4-75	500 ft.	5-75/1-77	0	0	0	3	12
43	EAC	9-71	200 ft.	9-71/1-77	4	3	57	5	20
44	EAC	9-71	200 ft.	9-71/1-77	3	1	75	5	20
45	EAC	9-71	200 ft.	9-71/1-77	2	2	50	5	20

1 ft. = 0.3 m
1 mi. = 1.6 km

PCC - Portland Cement Concrete
EAC - Epoxy Asphalt Concrete
ECS - Epoxy Chip Seal

APPENDIX F

Photogrammetric System Summary

A technique for accurately measuring pavement texture profiles using stereo cameras was utilized to obtain quantitative values for this report. The standard error for the horizontal measurement is ±0.068 mm and the standard error for the vertical measurement is ±0.112 mm. To obtain this accuracy the cameras were calibrated for focal length, principal point location and symmetric radial lens distortion. The system uses two single-lens-reflex Nikon 35 mm cameras that have been calibrated at the 400 mm distance that they will be used.

Profile measurements from the stereo pairs are made on a Zeiss PSK Stereocomparator, a precise XY coordinate measuring device with a least count of 1 micrometre. XY coordinates along a selected profile in the stereoscopic portion of each pair of color transparencies are read and recorded on punch cards. Readings and recordings on the fiducial marks and control points (images of metric scales) are also made.

A mathematical three dimensional model is then created with the aid of a computer. This model is corrected for all known distortions such as lens observations and film distortion. The resulting output is XYZ ground coordinates of the profiles.

From the file of XYZ profile coordinates, a plot tape is made and the final profiles are then plotted automatically on the Xynetics, Model 1200 Flatbed Plotter.

Three cross-sectional profiles of the surface texture are produced from each stereo photo. One highly detailed profile is obtained from 300 readings across the center of the photo - transversely to the direction of traffic - and two others, parallel to the first, are obtained at the quarter points. The latter two cross-sections are not as detailed as the first, but provide the maximum-minimum asperity heights and spaces between them.

The top and bottom profiles of the pavement surface are plotted on a 1 to 1 scale to provide a visual concept of the uniformity of the pavement surface.

From the middle profile, a surface texture value, T, has been obtained by dividing the length of the profile line in millimetres by 110 millimetres (which is the horizontal distance that the profile covers). The vertical measurements of the middle profile have been amplified five times before plotting so that more detail can be observed.

The date is shown in the lower left corner and the time of measurement is shown in the lower right corner along with the plots. The time in seconds provides a check on stereo pairs in addition to a sequence log.

The cost to obtain the profile from the two exposures is approximately $250.00. Both the man-hours required to read the profiles and the computer time are greater than originally estimated.

A picture of the assembled unit is presented as Figure 46.

Standard equipment and settings:

Film: ASA 64 (Color Slide Film)
Camera Shutter Speed: 1/4 second
Camera Aperture: f8
Camera Flash Synchronization: FX
Flash Setting: Automatic

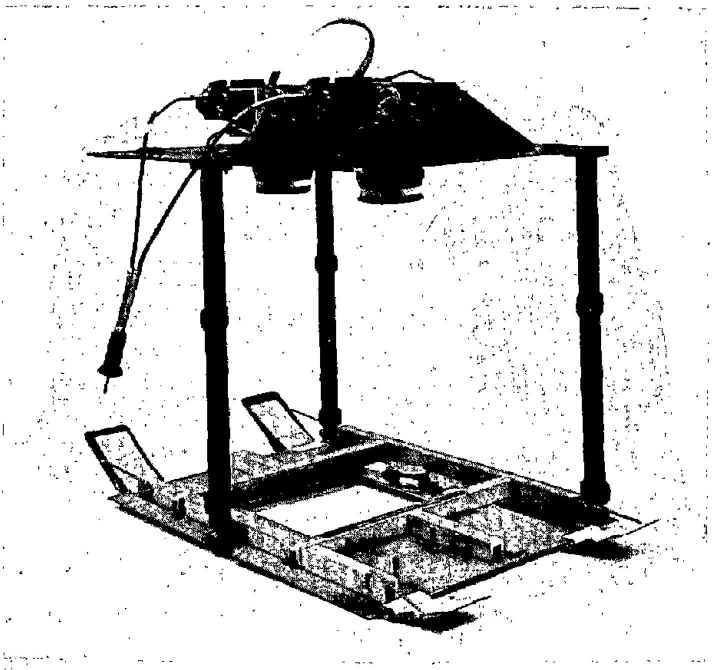

Figure 46 - Assembled Stereo-Photo Unit (Double exposure to show black cloth cover.)

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