PERFORMANCE OF THERMOPLASTIC STRIPING IN ALASKA

FINAL REPORT

by

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DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
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16. Abstract

Painted traffic markings have, in the past, been the major form of pavement marking in Alaska. Demand for improved delineation has resulted in the use of raised pavement markers and preformed thermoplastic striping. This report reviews the performance of thermoplastics as an alternative to conventional painting.

This study found that while thermoplastic striping may last considerably longer, they may not be cost effective depending upon traffic, pavement life, etc. Each project should be evaluated on an individual basis.

The study suggests that construction techniques be changed to enhance the life of thermoplastics. These include offsets from joints and application temperatures.

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1.0
INTRODUCTION

1.1 PURPOSE OF STUDY

Until recent years, painted traffic markings were the major form of pavement marker used in Alaska. Demands for better and more cost-effective delineators, however, have resulted in the use of alternative markings such as raised pavement markers and pre-formed thermoplastic striping. State traffic and highway engineers are well aware of the importance of highly-visible lane lines in improving roadway safety; consequently the Department has an intensive restriping program. Painted markings are frequently repainted two or more times each year and even so sometimes are hardly visible during the later winter months. Over the life of the road, the cost of these many paint applications become a sizeable portion of the maintenance budget. This report reviews the performance of thermoplastics as an alternative to conventional painting.

1.2 PAST USE OF THERMOPLASTICS

According to discussions with State Traffic engineers, one of the first Alaskan applications of thermoplastic markers was the placement of hot-extruded markers on Minnesota Drive, in Anchorage, about 1970. None of these extruded markers were located during our study. They are likely obscured by a seal coat.

Since about 1976, pre-formed thermoplastic markers are the only type of thermoplastic product which has been used in a permanent application. Some of these materials which were applied as early as 1977 are still quite visible. Pre-formed ribbon can be installed in one of two ways. First, it can be applied directly to existing pavement by the use of an adhesive. Second, it can be pressed into a newly-applied pavement prior to cooling, making it nearly an integral part thereof. State Standard Specifications (Section 670-3.06) specifies this latter application technique for new construction.

Alaskan experience with pre-formed ribbon is largely limited to materials made by two manufacturers, Prismo-Universal and 3M Company. Prismo-Universal offers both 60-mil and 90-mil products, but until recently specialized in a 90-mil product. 3M Company, under their brand name Sta-mark, has supplied nearly all of the thermoplastic used in Alaska since about 1980. We understand that all of the 3M markers are 60 mils thick.

This report emphasizes 60-mil and 90-mil pre-formed ribbon thermoplastic markers.

1.3 STUDY APPROACH

In order to obtain information on current Alaskan practice, interviews were conducted with several DOTPF engineers. These interviews provided necessary background data, opinions about uses, cost data, and other useful information.

Personal contact was also established with two firms supplying pre-formed thermoplastic ribbon to the Alaska market. This contact provided detailed information about the products as well as allowed us an opportunity to obtain guide specifications for their installation.

In addition, an inspection of selected sections of roads in the vicinity of Fairbanks, Juneau, and Anchorage was made for the purpose of evaluating performance. The results of this field evaluation, and the results of a similar study conducted by Anchorage DOTPF personnel, were used to reach a preliminary conclusion on the performance of these markers.

Subsequent to the field inspection, those sections of the State's 1981 Standard Specifications concerning thermoplastics were reviewed and an evaluation was made of life expectancy and installation costs.

2.0

DATA ACQUISITION

2.1 INTERVIEW OF DEPARTMENTAL PERSONNEL

In order to collect background information on the use of thermoplastic markers and to assess department policy, several knowledgeable State highway and traffic engineers were interviewed. During the interviews, these individuals were asked to complete a written questionnaire, a sample of which is included in Appendix A of this report. The questionnaire was intended to tabulate individual opinions about the suitability and performance of pavement markings. A list of individuals participating in this study follows the sample questionnaire.

A consensus was reached on a few questions such as the primary importance of snowplow activity in the deterioration of thermoplastic markers and the secondary importance of skid resistance for a pavement marker. On other points, such as long-term reflectivity and life-expectancy of the roadway markers, we received a wide range of viewpoints. While response varied extensively, certain generalized statements can be made and are summarized as follows:

- Anchorage and Juneau highway engineers are more apt to specify thermoplastic markings than are engineers in Fairbanks.

- Highway engineers in Fairbanks expect a longer useful life for painted markers than their counterparts in either Juneau or Anchorage.

- Anchorage engineers expect a longer useful life for thermoplastics than their counterparts in either Juneau or Fairbanks.

- The majority of engineers interviewed reported that snowplow damage was the primary cause of deterioration of longitudinally-placed thermoplastic markers. Normal tire wear and chain damage are primary factors in the deterioration of transversely-placed thermoplastic markers.

- Almost all engineers stated that a well-inlaid stripe made by rolling the pre-formed ribbon into a hot asphalt mat provided superior resistance to snowplow damage than any other method of installation.

- Skid resistance, while of some importance to all of the engineers, was not as important as providing a highly-visible marker under a variety of driving conditions.

- Providing highly reflective and visible markers was reported as a primary concern. The long-term reflectivity of thermoplastics was not considered superior to paint by all respondents.

Snowplow activity was reported as being particularly troublesome since snowplow blades snag the leading edge of the stripe, ripping the material from the surface. Chains used on the plows also contribute heavily to marker damage. Other failure mechanisms cited by those interviewed included:

1) normal traffic wear, including wear from studded tires and chains,

2) failure to bond to pavement,

3) failure to bond over remnants or accumulations of paint,

4) abrasion of the beaded surface by snowplows leaving an intact but unreflective surface,

5) deterioration from de-icing chemicals, pavement constituents, or oil drippings,

6) failure to conform to pavement movements during freeze-thaw cycles,

7) rapid starting and stopping movements by vehicles.

Photographs Numbers 1 through 11 contained in Appendix B show typical examples of many of these failures.

Divergent responses were obtained concerning the anticipated life of the two major types of pavement markers in use on Alaskan highways. These responses are tabulated in Table 1 and apply primarily to average roadway conditions of a well-placed longitudinal marker. Some of the responses were qualified by assumptions about usage and site-specific characteristics.

During our interviews, maintenance personnel reported that, while thermoplastic lines can be repaired by installing thermoplastic material over damaged areas, this is rarely done. Damaged areas are more likely to be repainted. The Maintenance and Operations group in Anchorage has repaired some urban streets striping with thermoplastics but reported that this was extremely time consuming and they experienced high loss afterwards. A similar repair result was reported by engineers in Juneau on the Glacier Highway. The replaced markers are generally bonding well to the pavement but show considerable edge-chipping.

Several State employees involved in the design and construction of airfields were also contacted to ascertain the potential use of thermoplastics as an airfield marking material. Generally, these individuals reported limited experience with thermoplastic products. Historically, thermoplastics have not been used on airports regardless of State or Federal ownership. Personnel reported that, while airfield and roadway markings perform similar functions, they are subject to fundamentally different operating conditions. Roadway markings are typically subject to high volumes of traffic and abrasion, and this may be a key factor in their deterioration, especially in non-snow areas. On the other hand, airfield markers are generally subject to low volumes of traffic but can be completely obscured by the deposition of rubber, especially in touch-down areas. Highly abrasion-resistant materials like thermoplastics are thus of less value and paints are expected to be more cost effective. For these reasons little application to airports is presently envisioned.

2.2 OBSERVATION OF A TYPICAL INSTALLATION

During our study, we observed the installation of thermoplastic markers on a portion of Northern Lights Boulevard between Maplewood Street and Lake Otis Parkway in Anchorage. Six-inch-wide ribbon was installed at turn pockets and four-inch-wide ribbon was used for skip striping. During this installation, the material was quickly positioned on the fresh asphalt mat at a temperature of about 150°F and was rolled into place by several passes of a smooth-drum roller. Small manually-operated equipment was used to install the stripes while symbols were manually applied. Photographs 12 through 15 show various phases of the installation process.

Longitudinal markings on this project were applied directly over the construction joint between pulls of the asphalt spreader (see photograph 14). In our opinion, it would have been better to offset the marker from the joint, since positioning of the thermoplastic ribbon can not be placed until the adjacent pull is complete. Meanwhile, the pavement temperature of the first pull could have dropped significantly resulting in a poorly inlaid stripe. Several highly-damaged areas where markers were installed over construction joints were noted on University Avenue in Fairbanks, and on the Douglas-Cordova Street project in Juneau.

2.3 FIELD EVALUATION

As a part of our study, several roads utilizing thermoplastic markers in Anchorage, Fairbanks and Juneau were inspected and the percentage of thermoplastic remaining in service was visually estimated. This inspection was conducted by a single evaluator driving the entire length of a section of roadway and noting where damage occurred, followed by subsequent on-foot inspections and photo documentation of both damaged and undamaged areas.

Subsequent to our field evaluation, the age of each striping project was obtained either from departmental records or by questioning knowledgeable traffic engineers. The results of our evaluation are tabulated in Table 2 and plotted in Figure 1.

A similar evaluation of thermoplastic striping was made in 1980 by two DOTPF Anchorage personnel, Jim Childers and Pat Wittrock. Their unpublished data are tabulated in Table 3 and are plotted together with data collected in this study in Figure 1. The Childers/Wittrock data seem to correlate reasonably well with our data.

Linear regression analysis was used to estimate the average loss per year of these projects. Separate regression curves are shown for Anchorage, Juneau, and Fairbanks. These curves should be used with caution, especially in the Fairbanks area where experience with thermoplastic striping is limited.

Data obtained in this part of our study are rather subjective and may not be duplicated by other evaluators. We suggest that a more quantifiable technique be used in future evaluations. One method of quantifying loss is reported in the FHWA Manual, Roadway Delineation Practices Handbook. This method requires measuring the length and width of damaged sections and calculating the loss based on the areas of simple geometric shapes. As a practical matter, this evaluation technique would probably need to be limited to relatively short roadway sections. Semi-annual inspections would likely result in improved estimates of loss and could be made on a district-by-district basis.

During our field evaluation, certain areas were identified where thermoplastic markers have a high probability of becoming damaged. For example, damage was common wherever markers were installed over a construction joint. This was especially true at the crown of the road where double centerline striping was installed. Frequently, a close examination of these lines revealed that at least one line was poorly inlaid. Another area where damage was noticeably greater was wherever bumps or abrupt changes in grade occurred providing a target for the snowplow blades to strike. High points of very short vertical curves and frost heave bumps are examples. Even with a well-inlaid stripe, the roadway crown presents a high point in the road where abrasion will be high.

Areas such as traffic islands and exit ramps where large amounts of thermoplastic ribbon must be positioned before rolling were noted as potential high-damage areas due to cooling and poor bonding.

Transversely-applied markers such as stop bars showed rapid wear, frequently exposing bare pavement. Stopping and starting movements are key factors in their deterioration. Damage to the transverse stop bars was observed on the Northern Lights Blvd. project, in Anchorage, less than a month after their installation.

Thermoplastic installations on almost all roadways we inspected were made by rolling the ribbon into the hot-asphalt mat during new construction. Cold-applications (overlays) were done on the Peters Creek Interchange (Anchorage), on portions of the Peger Road-Airport Way Intersection project (Fairbanks), and on the Glacier Expressway (Juneau).

Late-season construction and associated poor bonding were frequently cited as a factor in the premature loss of thermoplastics on individual projects. The Douglas-Cordova Street project in Juneau is one such example. During cold weather, it is essential to position and roll-in the thermoplastic ribbon quickly while the fresh asphalt is still hot.

2.4 REVIEW OF STATE STANDARD SPECIFICATIONS

The 1981 Standard Specifications for Highway Construction generally control the installation of thermoplastic markers on Alaska road projects. To analyze how premature losses can best be minimized, these specifications were compared to pertinent sections of a model performance specification prepared by the Institute of Traffic Engineers (ITE) and guide specifications for installation of pre-formed ribbon obtained from 3M Company and Northern Ventures, Inc. Suggested changes are discussed as part of our conclusions.

3.0

DATA ANALYSIS

3.1 GENERAL COMPARISONS

Alaskan experience with thermoplastic markers is essentially limited to the use of pre-formed thermoplastic ribbon in-laid into fresh asphalt. Less frequently, a cold-application of these same products is made over pre-existing pavements with an adhesive backing. Applications of hot spray-on or extruded thermoplastic materials were not evaluated in this study as they have not been used on Alaskan roads within the last five years. Thus, thermoplastic ribbon is compared to painted markings only.

Useful comparisons can be made between the use of thermoplastic markers and paint by comparing the sum of initial costs and discounted future costs for the various alternative treatments over the same analysis period. To accomplish this, it is necessary to have sufficient information on the following variables:

- Expected life of thermoplastic markers;

- The expected life of painted stripes on the same roadway;

- Contractor bid prices for installing the thermoplastic markers;

- Contractors bid prices for applying the initial painted striping if thermoplastics are not used;

- The actual cost of subsequent paint applications by State maintenance crews for the section of roadway being considered.

Whether or not paint or thermoplastic materials make the most effective markers depends upon combinations of these variables which vary from project to project and region to region. In extreme situations, some unanticipated results such as the use of thermoplastics on roads in remote areas could be justified if painting costs are extremely high.

3.2 LIFE EXPECTANCY OF THERMOPLASTIC MARKERS

Utilizing the results of our field investigation, an estimate of the average life of thermoplastic markers can be made. Data obtained from our field evaluation and presented in Table 2 are plotted on Figure 1. Also shown are the data from the Childers-Wittrock study. Linear regression techniques were applied to data obtained from each district to estimate the average amount of thermoplastic material remaining based on its age.

Eventually, enough of the marker will be missing to justify restriping and, while this amount is not well defined, maintenance personnel routinely make this decision on a project-by-project basis. Paint had been applied over the thermoplastic markers on three of the projects we evaluated. The data points of these three projects are shown as solid symbols in Figure 1, and the average of our estimate for these three projects is 75% of the thermoplastic remaining. This average, supplemented by our judgment, was used to define the minimum acceptable service level shown on Figure 1. Other researchers report that some agencies use lower standards for defining this terminal life (Chaiken-1969). Our definition predicts about 52 months of service life in Anchorage, about 47 months in Juneau, and about 43 months in Fairbanks. Comparison of these predicted life spans shows reasonable correlation with the average expected life, as reported in Table 1.

During this study little attempt was made to evaluate the effect of traffic volumes on the average life of thermoplastic markers. It appears that for longitudinally-placed lines, the majority of loss is due to snowplow activity. Future studies could eliminate some of the subjectivity of the field survey by incorporating traffic volumes and other secondary factors in their predictions.

A factor limiting the economic life of thermoplastic stripes is the life of the roadway before such maintenance activities as repaving or applying a seal coat is necessary.

3.3 BOND

The most extensive study of adhesion of thermoplastic strips encountered in the literature review was conducted by the Texas Transportation Institute. An article entitled "Improving Thermoplastic Stripe Adhesion on Concrete Pavements," (Hofener - 1978) indicates that performance of thermoplastic striping on bituminous pavements is superior to that of concrete pavement. Because this article addresses application of hot-applied thermoplastic materials on concrete pavements, it is not directly applicable to Alaskan conditions. Nevertheless, the article recommends a testing procedure which may be of aid to future studies on adhesion. Using this procedure, bond strengths of several samples were measured after subjection to freeze-thaw cycles. A significant loss in bond strength was observed on these samples. A conclusion, at least applicable to hot-applied thermoplastic products, is that the freeze-thaw cycling is a critical factor in bond failures. Future studies appear necessary to evaluate bonding of pre-formed thermoplastic ribbon installed on bituminous pavements.

During our field inspections, several cold-applied applications of pre-formed ribbon were physically lifted from the pavement by hand. Each of these applications had experienced at least one winter season and generally showed slightly greater snowplow damage than similar projects where the product was in-laid. As with the in-laid applications, failures most frequently occurred at high spots which presented a target to plows. Failure was not necessarily attributed to poorer bond.

3.4 REFLECTANCE AND COLOR PROPERTIES

According to the FHWA Summary Report, "Durable Pavement Marking Material Workshop," the initial reflectivity of pre-formed tape is 5 to 6 times greater than paint. The report further states that there is a marked decrease in reflectivity over time. As far as we know, no definitive studies have been conducted in Alaska on retro-reflective properties of pavement markers. In recent years, meters capable of measuring these properties have become commercially available; in a later section of this report we recommend that the state consider purchasing one to aid in future studies.

Until a retro-reflectometer is obtained, the best means of evaluating reflectivity is by periodically examining the roadway at night with a tungsten light source. Conducted in mid-summer with darkness no greater than twilight, our study only evaluated daytime conditions.

Providing daytime delineation is directly related to the color of the markings. Pre-formed thermoplastic stripes are typically warranted by the manufacturer as meeting all color requirements cited in the FHWA "Manual on Uniform Traffic Control Devices" (MUTDC). During our study, we generally noted good daytime appearance for intact sections. A few areas where markers appeared to have been "shaved" by snowplows were rough and had a "dirty" appearance. Typically, these areas were insignificant in comparison with the total area of striping since this condition was rarely noted. Failures, when they occurred, generally completely removed the stripe.

The literature generally cites better reflectivity for thermoplastic markers than for painted markers, especially during wet night conditions.

3.5 WEATHER CONDITIONS DURING INSTALLATION

Maintaining a high enough pavement temperature during the installation of thermoplastic markers is essential to achieve the well-in-laid application necessary for long life. Any weather condition which allows a rapid drop in pavement temperature can result in poorly-bonded markers. Present standard specifications require minimum ambient air temperatures for normal paving operations of 40°F (Section 401-3.01) and require that the marker be rolled into place before the pavement temperature falls below 120°F. Paving generally is not allowed in rainy weather.

We understand from DOTPF traffic engineers that thermoplastics installed on several projects late in the construction season experienced a high rate of subsequent loss. Installation under marginal weather conditions must be performed by highly experienced and well-staffed crews to ensure rapid positioning before the pavement mat can cool. As a result of these circumstances, tighter pavement temperature control is recommended. The Roadway Delineation Practices Handbook suggests that pre-formed tape be positioned and rolled into place before the pavement mat cools to 130°F.

3.6 SKID RESISTANCE

Although skid resistance was not ranked by State Traffic Engineers as important as providing good color and reflectivity, it was still considered to be a significant factor by all respondents. In particular, it was reported that providing skid resistance is extremely important to the safety of motorcyclists and pedestrians. Differential skid resistance between marked and unmarked pavement surfaces was cited as a possible contributory factor in some accidents.

Under Federal Highway Administration funding, wet-frictional properties of numerous pavement marking materials were studied by Anderson and Henny. Their results are reported by the Transportation Research Record in an article entitled "Wet-Pavement Friction of Pavement Marking Materials." The report states that emphasis was placed on hot-sprayed, hot-extruded and pre-formed thermoplastic ribbon because of their greater thickness and potential for having low-friction characteristics. The report concluded that, while different marking materials have different frictional properties, the characteristics of a beaded surface is primarily determined by the beads. Under several of the tests, paint products had lower British Pendulum Numbers (BPN), a measure of skid resistance, than pre-formed thermoplastic ribbon.

Both of the manufacturers whose products are found on Alaska roadways sell products especially formulated and advertised as having high-traction characteristics. For example, Prismo-Universal manufactures a product called "Plastix-HT" while 3M Company manufactures "Sta-mark", grades 5730 and 5750. These products represent the majority of pre-formed thermoplastic markers used on Alaskan roads in recent years.

When thermoplastic markers are placed as a continuous longitudinal line, a thin layer of water can become entrapped on the uphill side of the marker. When freezing occurs, this condition reduces the skid resistance of a portion of the road surface. Such adverse effects are usually negligible on pavements which have sufficient centerline and cross gradients to prevent ponding. New York State reportedly provides drainage channels in their edge stripes at regular intervals to reduce the possibility of this occurring (Chaiken-1969).

4.0
CONCLUSIONS AND RECOMMENDATIONS

4.1 ADVANTAGES AND DISADVANTAGES OF THERMOPLASTIC MARKERS

Alaskan experience is limited to the use of pre-formed ribbon which preclude some choices available to states using hot-extruded or hot-sprayed products. Product quality control and equipment problems are, however, virtually eliminated by this practice. Pre-formed thermoplastic ribbon is increasingly being specified on newly-paved roadways. Some commonly-cited reasons for this increased use are:

- Thermoplastics are extremely durable, frequently lasting over ten years where snowplow activity is absent (Fullerton-1981);

- Thermoplastics are generally considered to provide higher visibility, especially under wet night conditions (McGrath-1981);

- Thermoplastics, by providing multiple-year life have a distinct advantage over paint in a climate where year-around painting is not possible;

- Installation is simple, requiring less-sophisticated and readily-available equipment which is easily mobilized to the construction site;

- Interruptions to traffic flow are reduced since periodic repainting or other maintenance is not needed until its terminal life is reached;

- Installation costs on qualifying projects are reduced by federal participation.

Thermoplastic markers are not always the most cost-effective pavement marker and their use should consider site-specific characteristics including traffic volumes. Some commonly cited disadvantages are:

- Initial installation costs are several times higher than that required for painted pavement markers;

- On new pavements, the ribbon has to be pressed in while the asphalt is still hot. This requires very tight work scheduling, especially in the fall season when cold weather is setting in;

- High losses are experienced in snow areas since thermoplastics are highly susceptible to damage from snowplows, chains and studded tires;

- Manufacturer warranties are either voided or "watered down" in the snow belt;

- Skid resistance is less than for the unmarked pavement;

- Cold applications made by overlaying the ribbon over existing pavement are especially susceptible to snowplow damage;

4.2 COST CONSIDERATIONS

Thermoplastic markers are a relatively durable and low-maintenance product. Once installed, typically no maintenance such as replacing missing strips is required. On the other hand, paint tends to have a lower installation cost but its life is relatively short. For example, reported costs for paint and thermoplastics on the Cordova-Douglas Street project in Juneau were $0.35 and $1.30, per lineal foot, respectively.

The relative economics between thermoplastic markers and paint striping depend on the expected service life and installation costs for each material. In order to be comparable, the installation costs of the initial painting, usually applied by a contractor, must be added to the cost of subsequent applications, usually applied by Department maintenance crews. Discounting future costs to their present value is necessary to account for the time-value of money. Further discussion on cost tradeoffs and a series of four charts which graphically perform this are presented in Appendix C of this report.

On newly-constructed roadways where paint life is expected to be less than 6 months, we would generally recommend that thermoplastic markers be specified. This recommendation is based on the assumption that paint stripes with less than 6 months of life will not be visible on the roadway for at least part of the winter season.

4.3 REVIEW OF STANDARD SPECIFICATIONS

Moderate gains in increasing the service life of thermoplastic markers can result in significant cost savings. For this reason, we recommend that a thorough review of the Standard Specifications and an aggressive program of field implementation be undertaken. The present State specifications require different performance based on mil thickness and we feel that this could be simplified. There is currently a significant trend toward the use of a 60-mil thickness, which is competitively bid by the two major manufacturers in the industry.

We suggest that Department personnel who will be inspecting the installation of the thermoplastic markers meet with local manufacturer's representatives to view training films and discuss correct application techniques. If possible, these inspectors should visit job sites where the manufacturer's representatives are currently giving technical advice.

Over the past few years, thermoplastic pavement markers have evolved from a manufactured specialty item whose successful application required the presence of a knowledgeable manufacturers representative, to a product routinely installed by major highway contractors throughout the State. Based on our review of the State Standard Specifications, it is our opinion that the State would benefit by simpler generic specifications. A newly-formed committee is currently reviewing the ITE model thermoplastic specification and should provide useful information as to possible changes (especially material testing procedures) not considered in this report. The following paragraphs indicate comments on specific sections of the current specifications which we feel should be considered by State specification writers.

Section 106-1.03 of the 1981 Alaska Standard Specification is relevant in that it requires the State to test all materials used in the construction whenever test methods are cited. The current specification relies heavily on established test methods. Some of these, such as tests for retro-reflectivity, cannot be performed in State material labs. Subject to further review by the Department, we recommend that the responsibility for conducting necessary tests be shifted to the contractor.

Section 670-3.06b which deals with the application of thermoplastics on new roadways is extremely brief and could be expanded to summarize techniques recommended by the major manufacturers. Some possible additions which should be considered are:

- Require that longitudinal markers be offset from the construction joint by at least 3 inches.

- To prevent unwanted movement, we recommend that the initial rolling of the thermoplastic ribbon be in the same direction as the ribbon was applied.

- Require double centerline stripes to be installed on the same pull of the asphalt spreader.

- Since a well-inlaid marker is expected to better resist damage from snowplows, we suggest that a minimum pavement temperature of 140°F be specified for positioning the ribbon, and that the ribbon be rolled into place before the pavement cools to 120°F.

The last recommendation, stated above, deserves further discussion. Section 670-3.06(b) of the Standard Specifications requires that the pre-formed ribbon be rolled into place before the pavement cools below 120°F, but does not specify any temperature above which the ribbon must be positioned. Adding this requirement should enable the Project Inspector to better control the work when the placement crew either falls behind or is too small to position complicated patterns. Rolling the ribbon into place is quickly performed and is usually not a bottleneck to completing the work.

Guide specifications obtained from 3M Company indicate that the ribbon should not be installed when the asphalt is above 160°F. The reason for this provision is to minimize the formation of blisters.

These guide specifications also recommend that the mat be allowed to cool to 150°F before starting and are consistent with current paving specifications (Section 406-3.12) which require pneumatic rolling to be complete at this temperature. Installation before the final rolling would result in displacement and unwanted waviness. For the same reason, the mat must first be sufficiently compacted, so that a rolling wave does not appear ahead of the steel roller.

The present Standard Specifications have different material requirements and test standards for the 60-mil material and 90-mil material. These requirements are set forth in Sections 712-2.14.2 and 712-2.14.3, respectively. Additional standardization of requirements between the two thicknesses appears necessary. For example, we could find no equivalent provision to Section 712-2.14.2B(8) which is a waiver of testing when the 60-mil material is certified, that would apply to the 90-mil material. Since, as previously mentioned, Section 106-1.03 makes it the State's responsibility to perform material testing (at its own cost, except when explicitly stated otherwise) it would appear that the State must seek the manufacturer's certification for 60-mil materials but cannot accept such certification for the 90-mil material. We recommend that this discrepancy be corrected and that the cost for testing these materials be shifted to the contractor. However, where quality control procedures are documented, we recommend that the State consider accepting the manufacturer's certification, possibly backed by test data, as proof of compliance.

During our review, we could not find an equivalent provision to Section 712-2.14.2C for the 90-mil material. This section requires that a manufacturer's representative be present during the installation of the marker. We also understand that this provision is not always enforced. Another drawback of the section is that it does not define what authority the representative has on the site; or to whom he reports. Also, the section requires performance from the manufacturer (vendor) to provide equipment even though he may not be a direct party to the contract. Finally, having a manufacturer's representative present may not materially improve the installation when experienced crews are involved. For these reasons we suggest that serious consideration be given to deleting the requirement for his presence.

State Specification composition requirements for both Type A (60-mil) and Type B (90-mil) thermoplastics require significantly higher pigmentation than any other specification we have reviewed. We recommend that DOTPF review this portion of the specification to determine if filler material can be considered a pigment for purposes of meeting the specification. If filler may not be so considered, neither of the two manufacturers are presently in compliance with this portion of the State Specification.

4.4 SUGGESTED METHODS OF IMPLEMENTATION

During the course of this study, several means were identified which could aid in improving the performance of the pre-formed thermoplastic markers. Implementation of two programs in particular, are expected to produce an almost immediate benefit. The first of these includes a rewrite of the present Standard Specifications with an emphasis on improving application techniques. Items recommended in this report, such as requiring stripes to be offset from construction joints and to one side of the roadway crown, should result in a better-placed marker that is less exposed to snowplow blades. Second, an active training program for Project Inspectors should be implemented. This should result in improved inspection and a more-consistent application of these products. This training program would offset deletion of the present requirement for a manufacturer's representative to inspect the installation.

Presently, there is no means available to department managers to quantify improvements in marker durability or cost-effectiveness. An on-going program to more-fully monitor the wear these markers undergo is a prerequisite to obtaining this information. One method proposed by this study consists of selecting a few short sections of roadway on various projects for a series of intensive evaluations. Successive inspections would be made until the terminal life of the markers is reached. The evaluation would consist of tabulating measured losses, and would require the surveying of damaged areas and calculation of losses based on simple geometric shapes that approximate the missing section. As stated earlier, more information can be obtained from the FHWA Publication "Roadway Delineation Practices Handbook." Periodic repetitions of the survey are expected to give a more realistic estimate of wear than the statistical assumption used in this study. Losses should be tabulated for the various uses to which these markers are exposed. Losses are expected to occur at a different rate, depending on placement variables, such as:

- Centerline markers, including double centerline striping and yellow skip striping;
- Edgeline striping;
- White skip striping dividing "same-direction" lane traffic where "hits" are primarily the result of vehicles changing lanes;
- Skip striping within about 100 ft of an intersection where "hits" are primarily the result of turning movements combined with acceleration from entering vehicles;
- Skip striping within about 75 ft of an intersection where "hits" result primarily from the turning movement and de-acceleration of vehicles exiting the roadway;
- Stop bars and other transversely-applied stripes;

- Markers where the installation deviated from the Alaskan Standards, including markers that were applied cold over existing pavements.

Once specific sites are selected for this intensive survey, accurate traffic volumes can be ascertained by routine monitoring techniques. Traffic data could be gathered on lane distribution and vehicle composition in addition to data on Average Daily Traffic. When such refinements are made, it should be possible to include the effects of traffic volumes in a model for predicting average stripe life.

To aid in better defining minimum acceptable standards for marker visibility as well as to provide a means by which losses in reflectivity can be measured over time, a retro-reflectometer should be purchased. Without such an instrument, evaluating reflectivity will be hampered by its subjective nature.

Finally, before a meaningful model can be developed to determine the cost-effectiveness of lane markers, accurate unit bid data are necessary. These data should be collected for each marker color, width, and symbol type, and should be periodically updated. Data should be referenced to specific project conditions, including geographic location and remoteness from population centers. This is discussed in more detail in Appendix C of this report.

4.5 SUGGESTED FURTHER RESEARCH

Alaskan use of pre-formed thermoplastic markers is presently limited to Standard products made by such firms as Prismo-Universal and 3M Company. These firms have active research and development programs which would be costly for the state to duplicate. Thus future improvements in performance are not likely to be a result of efforts by the State to improve product formulation. It should be noted, however, that product formulation would be an important issue if hot-sprayed or hot-extruded applications are ever used.

There is, however, an on-going need to monitor the cost and performance characteristics of the various alternatives. As described in the foregoing section, comparative tests of life and reflectivity would be useful. Therefore, we recommend that thermoplastic markers be included in any future road service tests conducted by the State.

REFERENCES

1. Comparison of the Performance and Economy of Hot-Extruded Thermoplastic Highway Striping Materials and Conventional Paint Striping, by Bernard Chaiken, Public Roads, Vol. 35, No. 6, February 1969, pp. 135-154.

2. Pavement Traffic Marking. Materials and Application Affecting Serviceability, National Research Board NC HRP Synthesis Report 17, 1973.

3. Traffic Marking Materials - Summary of Research and Development, by Bernard Chaiken, Public Roads, Vol. 35, No. 11, December 1969, pp. 251-256.

4. Improving Thermoplastic Stripe Adhesion on Concrete Pavements, by Steven Hofener, Transportation Research Board Record 692, 1978, pp. 1-7.

5. Wet-Pavement Friction of Pavement Marking Materials, by D.A. Anderson and H.H. Henry, Transportation Research Board Record 777, pp. 58-62.

6. Durable Pavement Marking Materials Workshop, by Marcia McGrath, FHWA - 1P-81-5, Technical Report, September 1981.

7. Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments for Rural Two-Lane Highways, Volume II, by S. Bali, et al., FHWA-RD 78-51, April, 1978.

8. Manual on Uniform Traffic Control Devices for Streets and Highways, USDOT FHWA, 1978.

Table 1

REPORTED EXPECTED LIFE OF PAVEMENT MARKERS

Thermoplastic Markers:

	Low Traffic	Moderate Traffic	High Traffic
2 Fairbanks Engineers	"Not used"	3 yrs.	2 yrs.
Juneau Engineer	---	3 yrs.	2 yrs.
Anchorage Engineer	5 yrs.	5 yrs.	5 yrs.
Anchorage Engineer	---	5 yrs.	5 yrs.
2 Anchorage Engineers	5 yrs.	3-4 yrs.	3 yrs.
Anchorage Engineer	"Not used"	7 yrs.	4 yrs.

Painted Markers:

	Low Traffic	Moderate Traffic	High Traffic
2 Fairbanks Engineers	1-2 yrs.	1 yr.	1 yr.
Juneau Engineer	2 yrs.	1 yrs.	½ yr.
Anchorage Engineer	1 yr.	---	1/3 yr.
Anchorage Engineer	1 yr.	---	1/3 yr.
2 Anchorage Engineers	1 yr.	1 yr.	½ yr.
Anchorage Engineer	1½ yrs.	½ yr.	1/3 yr.

TABLE 2

1982 FIELD SURVEY OF THERMOPLASTICS
(Woodward-Clyde Data)

Location	Estimated Date Installed*	Time Since Installation (Months)	Estimated Percentage of Intact Material (%)
Fairbanks:			
Steese Highway	1978	48	85
University Avenue South	8/78	48	60
Peger Road/Airport Way Intersection	1979	36	80
Thane Road	8/81	12	95
Berners Avenue	1980	24	90
Airport Access	1981	12	90
Juneau:			
Gastineau Channel Bridge	1980	24	75
Cordova Street-Douglas	10/81	10	60
Glacier Highway (near airport)	9/76	71	65
Glacier Highway (Mendenhall Loop Road-Ferry Terminal)	1981	12	100
Glacier Highway (Fritz Cove-Mendenhall Loop Road)	1980	24	85

*Where only the year of application is reported, an August application is assumed.

TABLE NO. 2
(continued)

Location	Estimated Date Installed	Time Since Installation (months)	Estimated Percentage of Intact Material (%)
Anchorage:			
Elmendorf Access Road (5th Avenue-Poast Road)	9/79	35	80
Fireweed Lane (Arctic-Seward Highway)	7/82	1	100
South Birchwood Interchange	10/79	34	75
Minnesota Drive Extension	6/81	14	99
Peters Creek Underpass	1980*	24	90
Benson Boulevard	8/77	60	70
Boniface (Debarr-Glenn Highway)	9/77	59	75
International Airport Road (Minnesota-Old Seward Highway)	7/79	37	90
International Airport Road (Jewel Lake-Minnesota)	9/78	47	80
Debarr Road	8/80	24	65
Lake Otis (Tudor-Northern Lts.)	8/78	48	75

TABLE 3

1980 ANCHORAGE FIELD SURVEY OF THERMOPLASTICS
(Childers-Wittrock Data)

Location	Estimated Date Installed	Time Since Installation (months)	Estimated Percentage of Intact Material (%)
"C" Street (36th Ave-3rd Ave)	9/75	55	75
"I" Street (13th Ave-5th Ave)	9/75	55	80
"L" Street (5th Ave-13th Ave)	9/75	55	75
6th Ave ("L" Street-5th Ave)	10/75	54	80
5th Ave (6th Ave-"L" Street)	10/75	54	80
Glenn Highway (6th Ave-Airport Heights)	10/75	54	40
"A" Street (6th Ave-3rd Ave)	10/75	54	90
Gambell (5th Ave-Northern Lts)	10/75	54	70
Ingra (Northern Lts-5th Ave)	10/75	54	85
Northern Lts (Arctic-Spenard)	6/76	46	80
Minnesota (Tudor-15th Ave)	6/76	46	85

TABLE 3
(continued)

Location	Estimated Date Installed	Time Since Installation (months)	Estimated Percentage of Intact Material (%)
Northern Lights (Spenard west to railroad tracks)	8/77	32	80
Northern Lights (Lake Otis-Seward Highway	8/77	32	95
Benson Boulevard	8/77	32	95
Boniface (Glenn Highway-Debarr)	9/77	31	95
Muldoon (Patteron-Glenn Highway)	10/77	30	99
International Airport South Frontage Road	10/77	30	99
International Airport North Frontage Road	10/77	30	95
Jewel Lake Road (Spenard-South Frontage Road)	6/78	22	99
Debarr (Airport Heights-Muldoon)	7/78	21	95
Lake Otis (Tudor-Northern Lights	8/78	20	95
International (Minnesota-Airport)	9/78	19	99

TABLE 3
(continued)

Location	Estimated Date Installed	Time Since Installation (months)	Estimated Percentage of Intact Material (%)
Eagle River Loop Road	6/78	22	95
Tudor Road (East of Lake Otis)	8/78	20	70
Abbott Road	8/78	20	65
Dimond Blvd. (Arctic-"C" Street)	9/78	19	75
Old Seward Highway (near Dowling Road)	7/79	9	90
Airport Heights	7/79	9	99
Glenn Highway (Turpin-Eagle River)	7/79	9	95
Lake Otis (near Dowling)	10/79	6	99
Boniface (near Northern Lights)	10/79	6	99

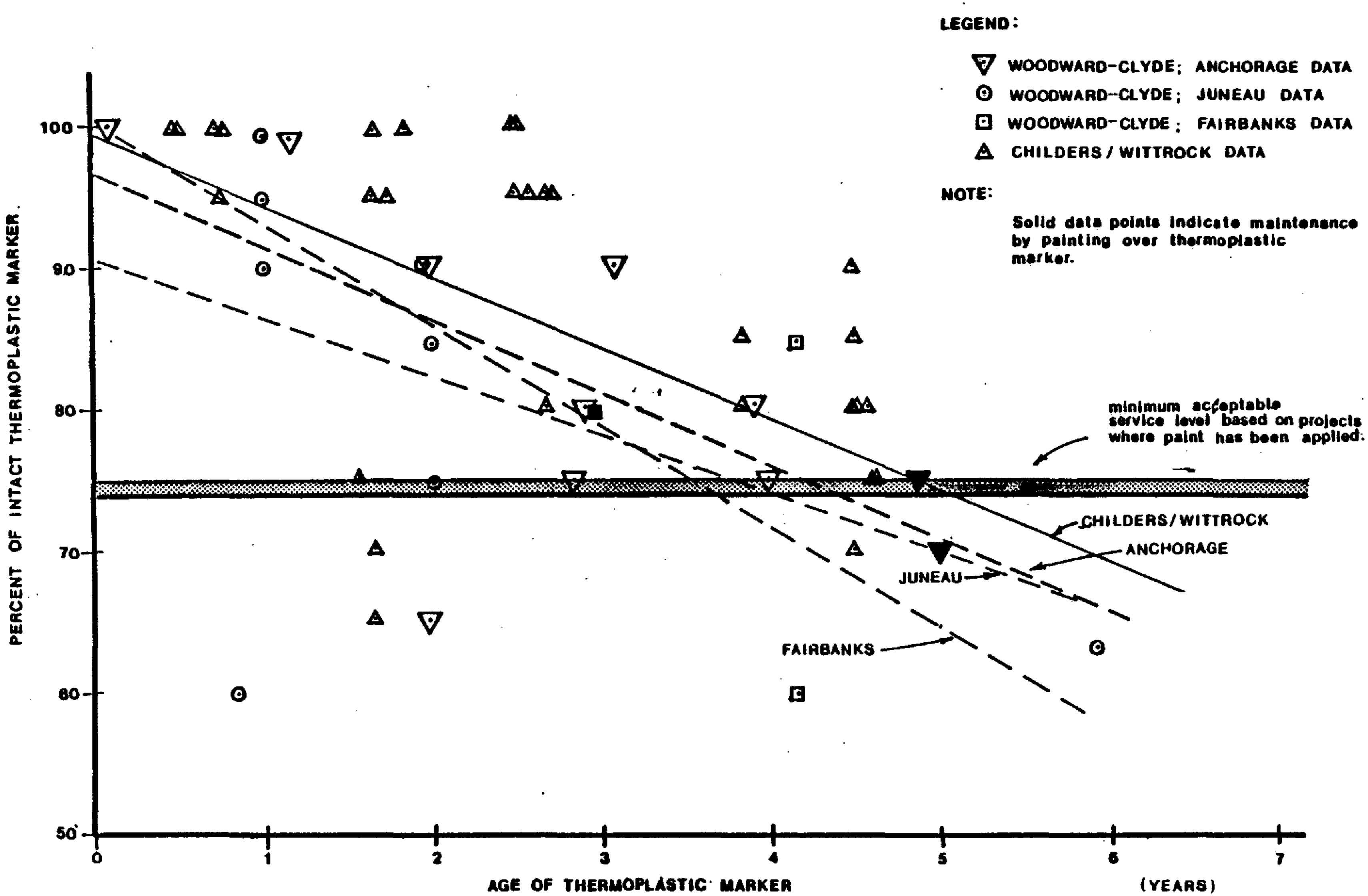


Figure 1 AVERAGE THERMOPLASTIC MARKER LIFE

APPENDIX A

Questionnaire

Contact List

QUESTIONNAIRE

PERFORMANCE OF THERMOPLASTIC STRIPING

Statement of Problem:

Recent failure of thermoplastic roadway striping throughout Alaska indicate a need to review and report on the performance of similar installations in Alaska. Such failures are costly not only in replacement costs, but also in terms of public safety due to the lack of line delineation. While thermoplastic striping has been a topic of discussion nationally, no work has been done to determine their performance in Alaska.

Questions:

1) In what following areas have you had experience with thermoplastic striping?

   o Materials evaluation and selection
   o Procurement
   o Installation
   o Maintenance

2) Do you have experience with:

   o Hot-extruded thermoplastic materials
   o Preformed plastic ribbon

3) What major recent projects were you involved with which utilized these products; and in what capacity did you act? Where can more detailed information be obtained?

4) Are you equally familiar with the following:

- o Paint with pre-mixed beads
- o Paint with drop-on beads
- o Epoxy or epoxy thermoplastics

5) What experiments or field testing are you aware of within the state concerning paint or thermoplastic striping in the last few years? Are you aware of any planned or presently on-going research activities? Where is this information available?

6) Annually, how may feet of traffic marking is placed in your (department) (section) (crew), etc.?

Paint	____________
Thermoplastic	____________
Other (Specify)	____________

7) How many people work under your direction in striping activities?

8) On the average, how long does thermoplastic striping remain serviceable on a:

- o Low volume roadway
- o Moderate volume roadway
- o High volume roadway

9) On the average, how long does paint remain serviceable in your region on a:

- o Low volume roadway
- o Moderate volume roadway
- o High volume roadway

10) How many feet of striping can a typical crew install in one (1) day?

11) How many miles of roadway lie in your jurisdiction (Maintenance People Only).

12) When installing thermoplastics, do you recommend any pavement pretreatment?

- o No pretreatment necessary
- o Brooming only
- o Sand blast
- o Washing
- o Other

13) During installation, what form of manufacturer support was available?

- o Manufacturers representative was on-site and helped with application

- o Dealer representative was on-site and helped with application

- o Never saw manufacturer or dealer representative

14) In you experience how do thermoplastics fail on specific projects?

- o Failure to bond over remnants or accumulations of paints
- o Failure to bond to pavement
- o Snowplow activity dislodged the material from the pavement
- o Reflective surface was abraded away by snowplow
- o Blistering
- o Normal traffic wear, including wear from studded tire and chains
- o Deterioration from de-icing chemicals, pavement constituents or oil drippings

15) Can you remember what project or specific roadway section failed as indicated above?

16) On the project or projects mentioned above, was the thermoplastic an "inlay" or was it an "overlay" application?

17) How does the reflectivity of thermoplastics compare with paint?

- o Almost always superior to paint
- o Sometimes superior to paint
- o Almost always inferior to paint to terminal life
- o Superior under wet conditions
- o Inferior under wet conditions

18) What specific brand names have been used in Alaska? Name specific projects where these were used.

19) How do the skid resistance of thermoplastics when compared to paint?

- o About the same
- o Superior to paint
- o Inferior to paint

20) How dependent is the application of thermoplastics on temperature and weather? What is the minimum ambient air or pavement temperature you would recommend for a permanent application?

21) What "terminal point" (i.e., percentage of stripe missing) do you recommend before restriping?

22) What materials and installation cost data is available in your department and who do I contact to obtain it?

23) What improvements could be made in the present State specifications?

24) When will present spraying or application equipment be replaced?

25) On what type of job are thermoplastics likely to be specified or used?

- o All new paved construction
- o All new construction with an ADT of more than _____
- o No established policy
- o Other

26) What is your estimate of maintenance-free life of the bituminous pavements presently being constructed?

- o High volume
- o Moderate volume
- o Low volume

27) What is your estimate of percentage of line lost in the first and succeeding years on typical projects? On projects which exceeded this, did the contractor replace the line? At what cost to the State?

28) Do you have any other comments not covered in this questionaire?

29) Attached is a list of individuals who have been recommended as having a high degree of knowledge in traffic delineation. Can you recommend others?

CONTACT LIST

Over the course of the project, information was received from the following individuals. The authors wish to extend their appreciation and thanks for the time and effort these individuals gave to the project team.

<u>Juneau</u>:

Mr. William Cameron* (DOTPF)
Mr. Dick Hamilton* (DOTPF)
Mr. Terry Moore (DOTPF)

<u>Anchorage</u>:

Mr. James Childers* (DOTPF)
Mr. James Eakin (3M Company)
Mr. Thomas Heinreich (DOTPF)
Mr. Steven Horn* (DOTPF)
Mr. Bert Isakson (Northern Ventures, Inc.)
Mr. Kent Isakson (Northern Ventures, Inc.)
Mr. William Knopp* (DOTPF)
Mr. Chuck Landers* (DOTPF)
Mr. Frank Narusch* (DOTPF)
Mr. DeVerl Peterson* (DOTPF)

<u>Fairbanks</u>:

Mr. George Blume (DOTPF)
Mr. Harvey Davis (DOTPF)
Mr. John Mancusco* (DOTPF)
Mr. Tim Miller* (DOTPF)
Mr. Daniel Urbach (DOTPF)

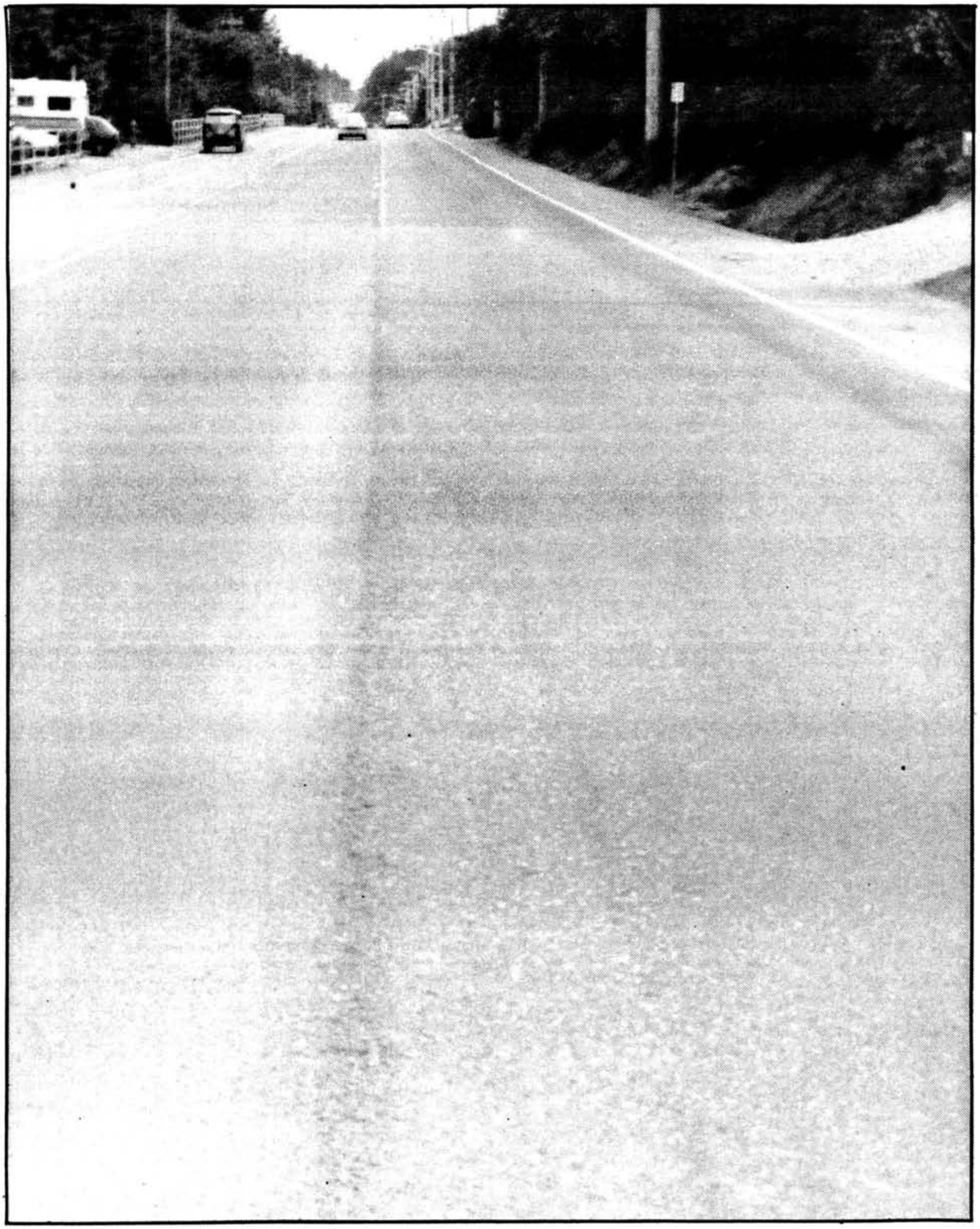
<u>Out of State</u>:

Mr. Dennis Riddiford (Prismo-Universal)

*Denotes an individual who was interviewed on the general performance of thermoplastic products in their district.

APPENDIX B

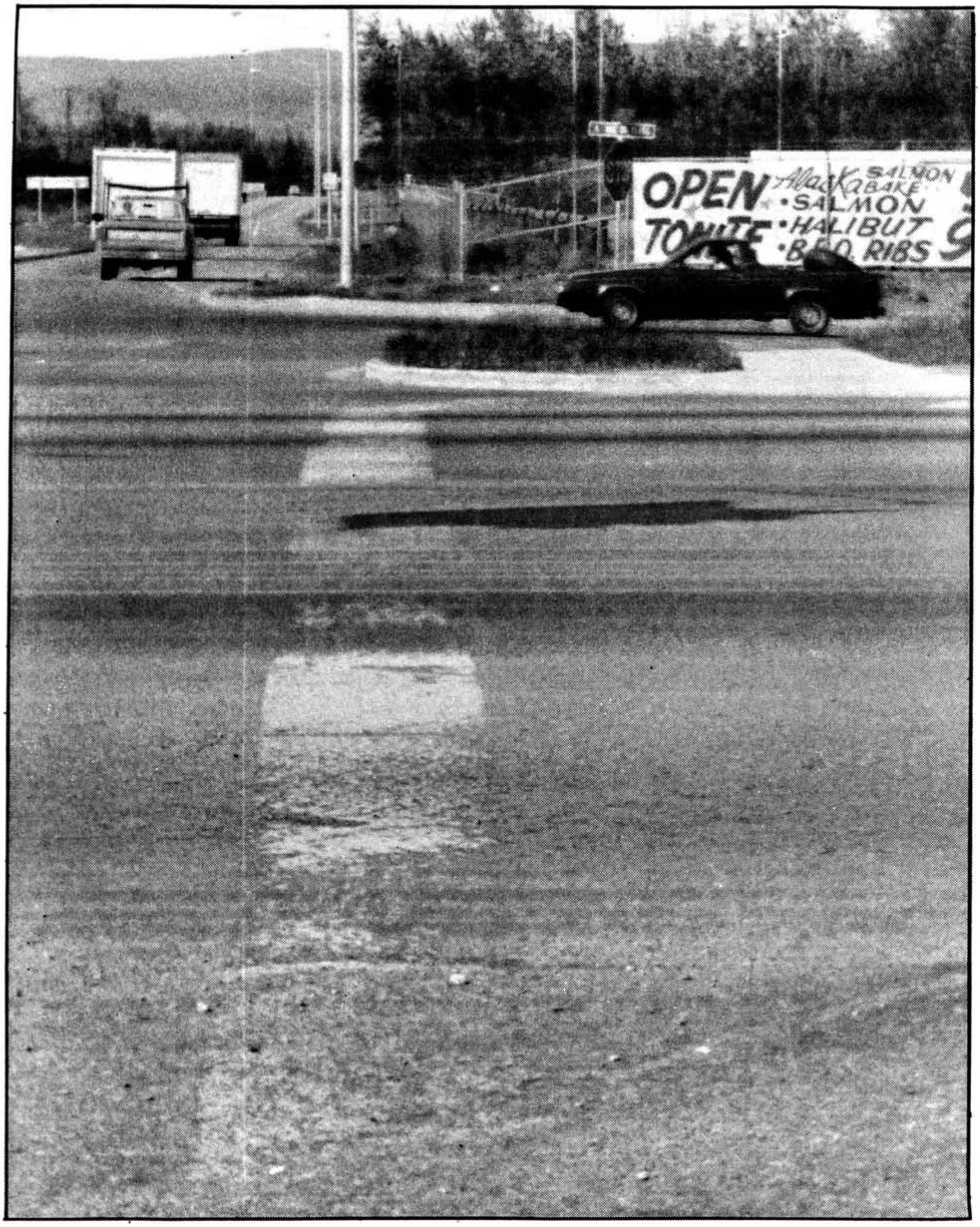
Photos



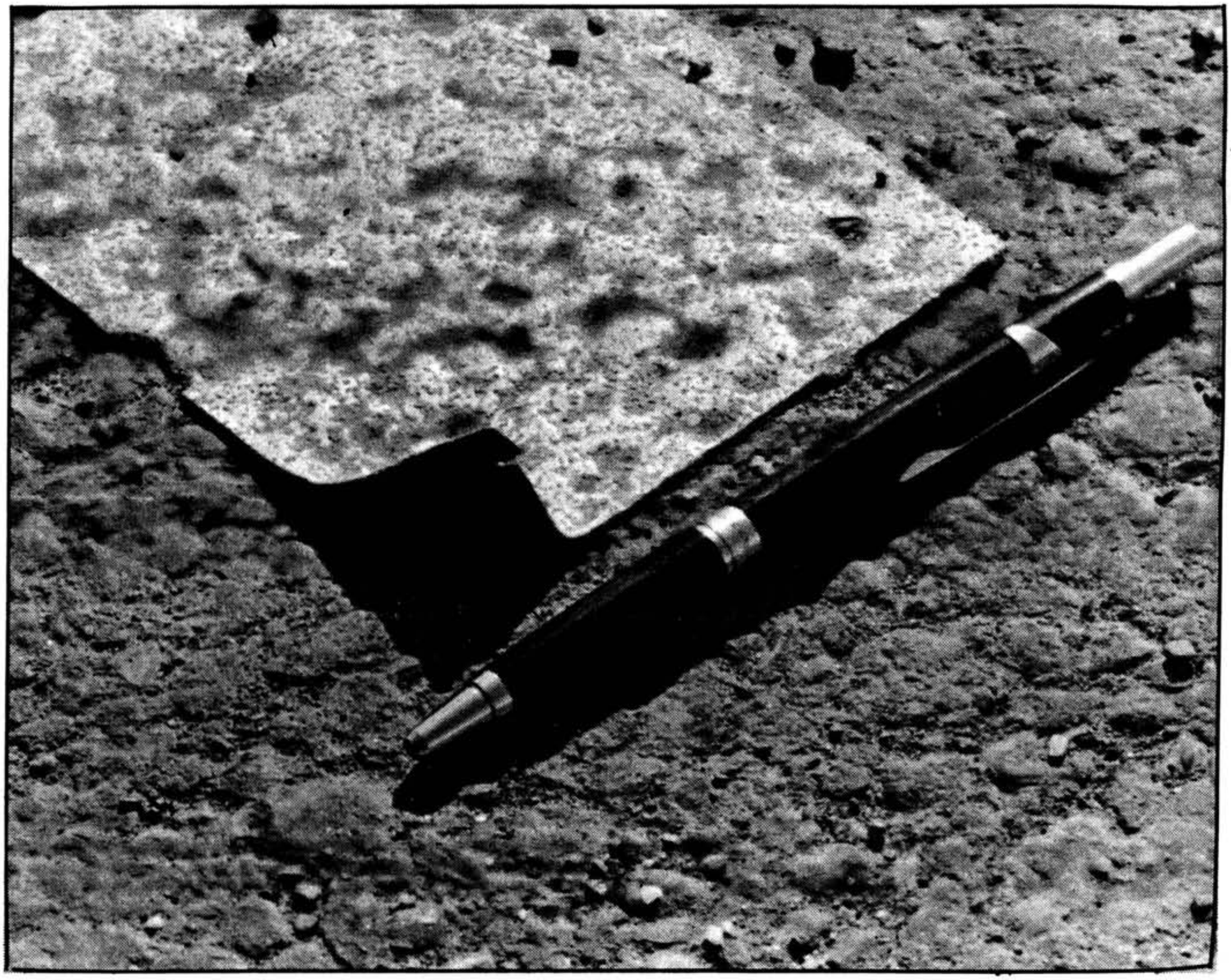
Photograph 1 Missing double centerline striping with visible construction joint at crown of road section (Douglas-Cordova St. Project). Project was constructed late in the season. Poor bonding may have resulted from rapid pavement cooling before final rolling.

Photograph 2 Damage from snow removal equipment (Birchcreek Underpass).

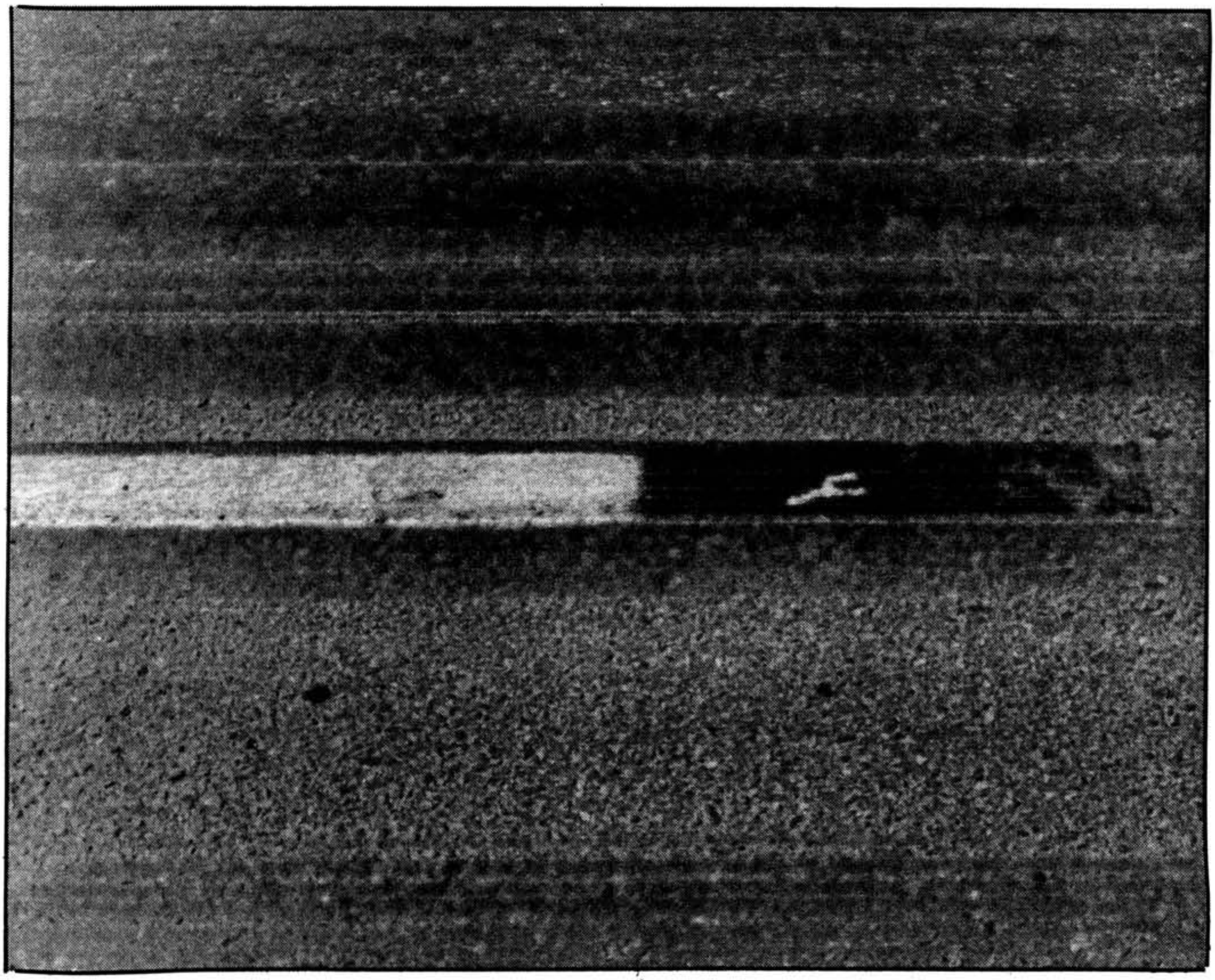
Photograph 3 Closeup of damaged centerline marker (Peger Road). Edge chipping was probably caused by snowplow blades. Damage could also be from chains.



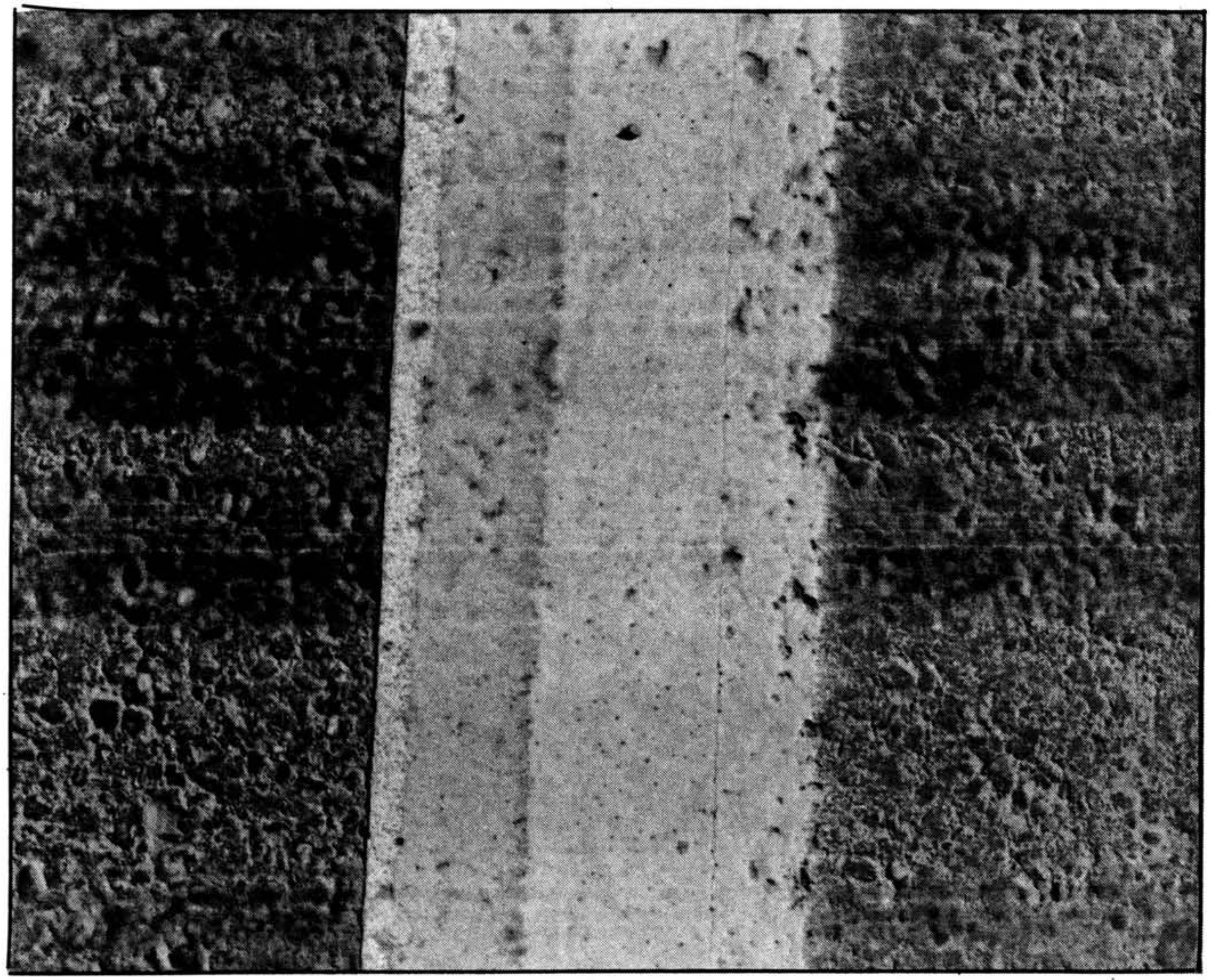
Photograph 4 High wear in wheel paths at stop bar (Peger Road). Stop bars have since been repainted.



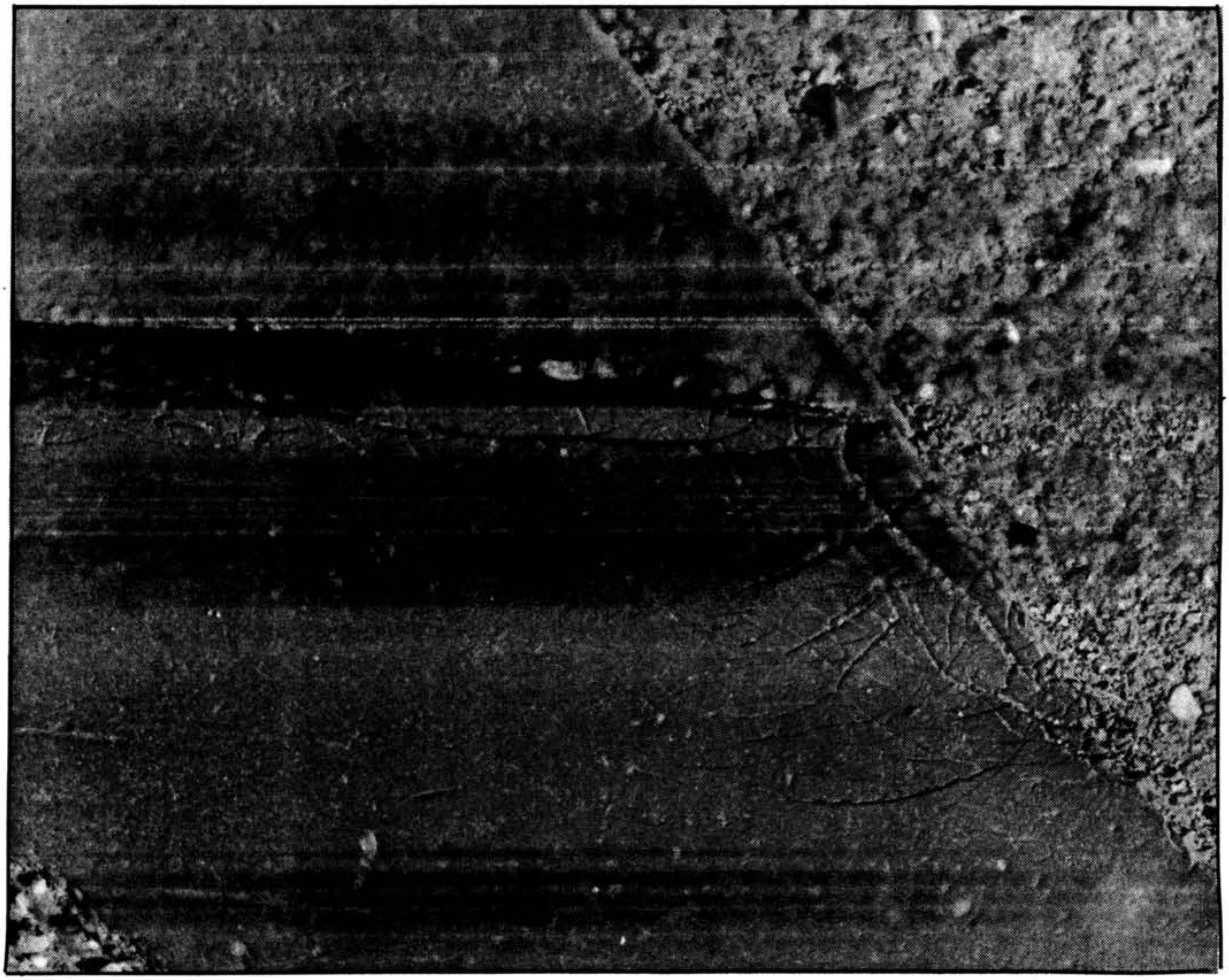
Photograph 5 A cold-application of thermoplastic ribbon which could be lifted with fingers (Peger Road-Airport Way Intersection).



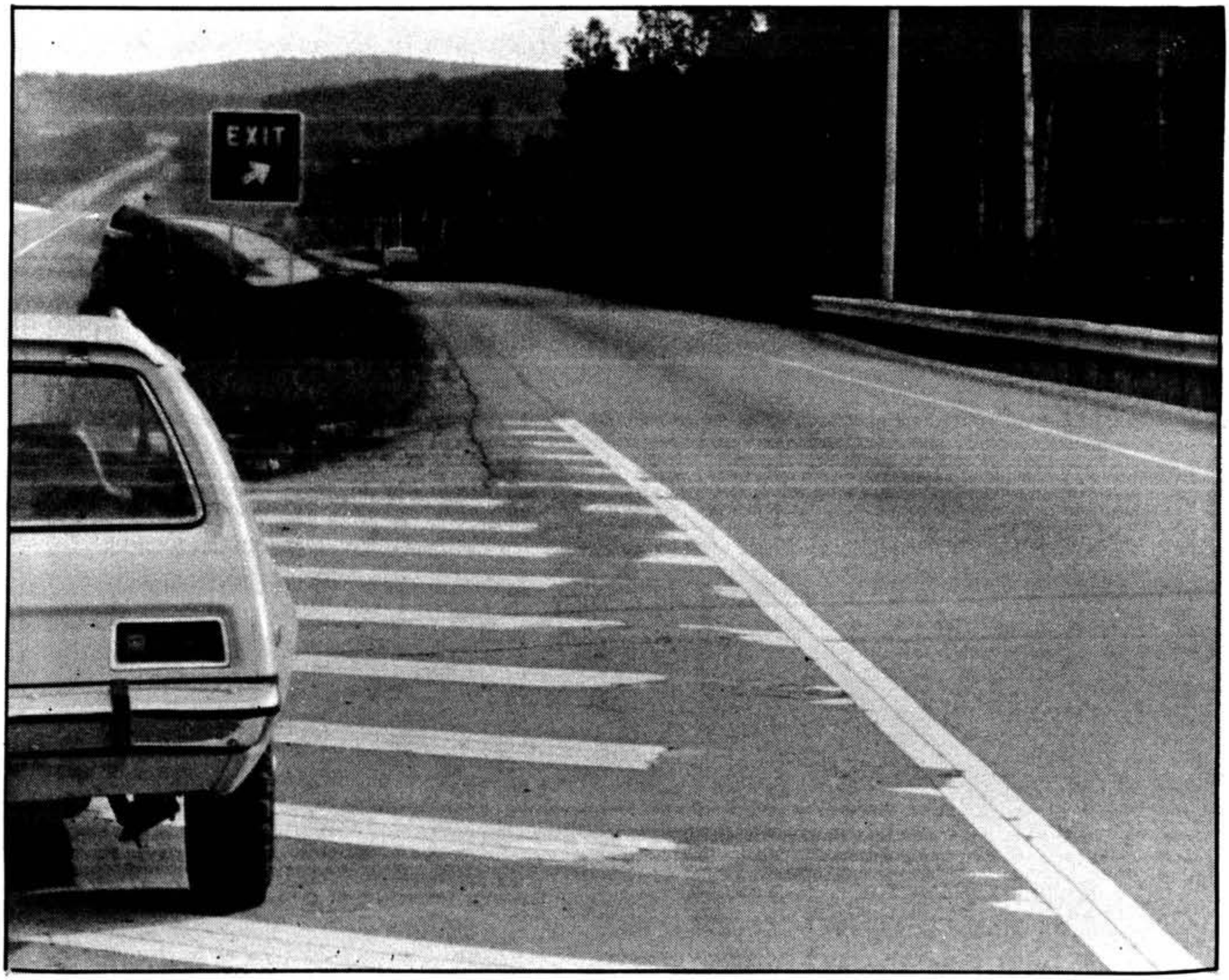
Photograph 6 Paint applied over remaining black adhesive backing of marker where bond was inadequate (Benson Street).



Photograph 7 Paint applied over thermoplastic markers (Peger Road/Airport Way).

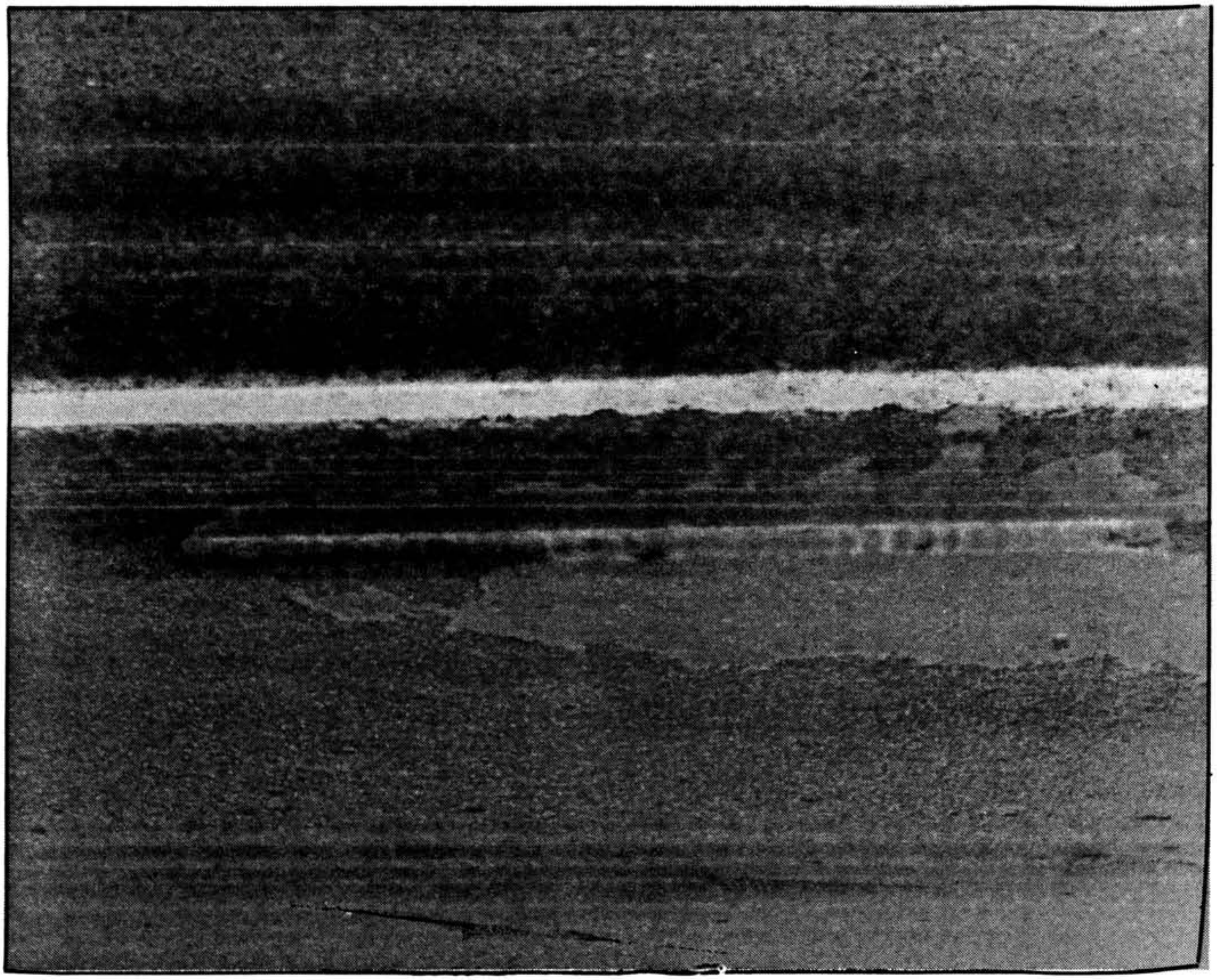


Photograph 8 Typical lapped splice (Chena Hot Springs Exit-Steese Highway). Nearly all of the adjacent lapped splices at this traffic island were extensively damaged.

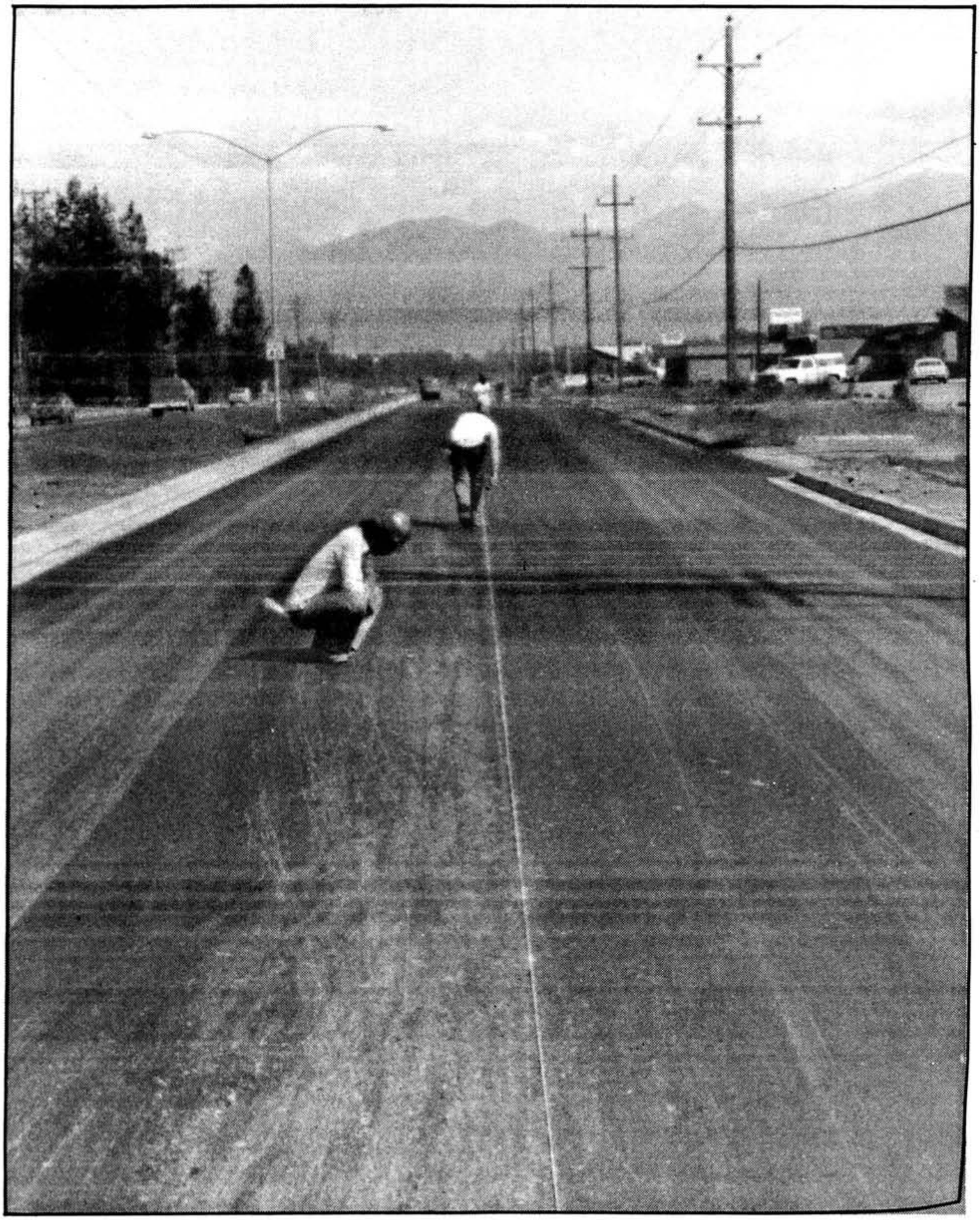


Photograph 9 Highly-damaged area at abrupt change in pavement grade (Exit Ramp-Steese Highway).

Photograph 10 Thermoplastic obscured by asphalt deposit (Glacier Highway).

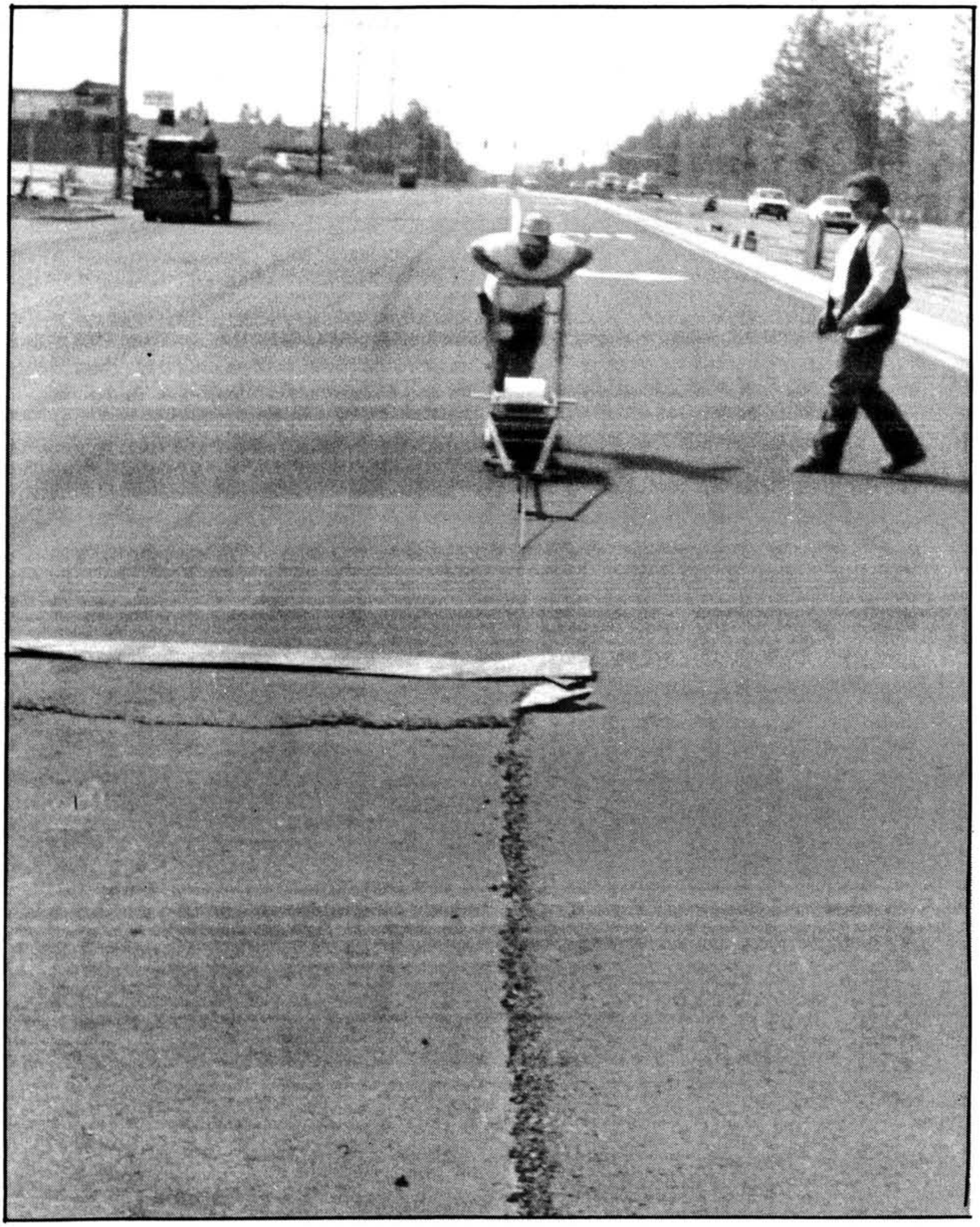


Photograph 11 Old thermoplastic showing through flaw in seal coat (Muldoon Interchange).

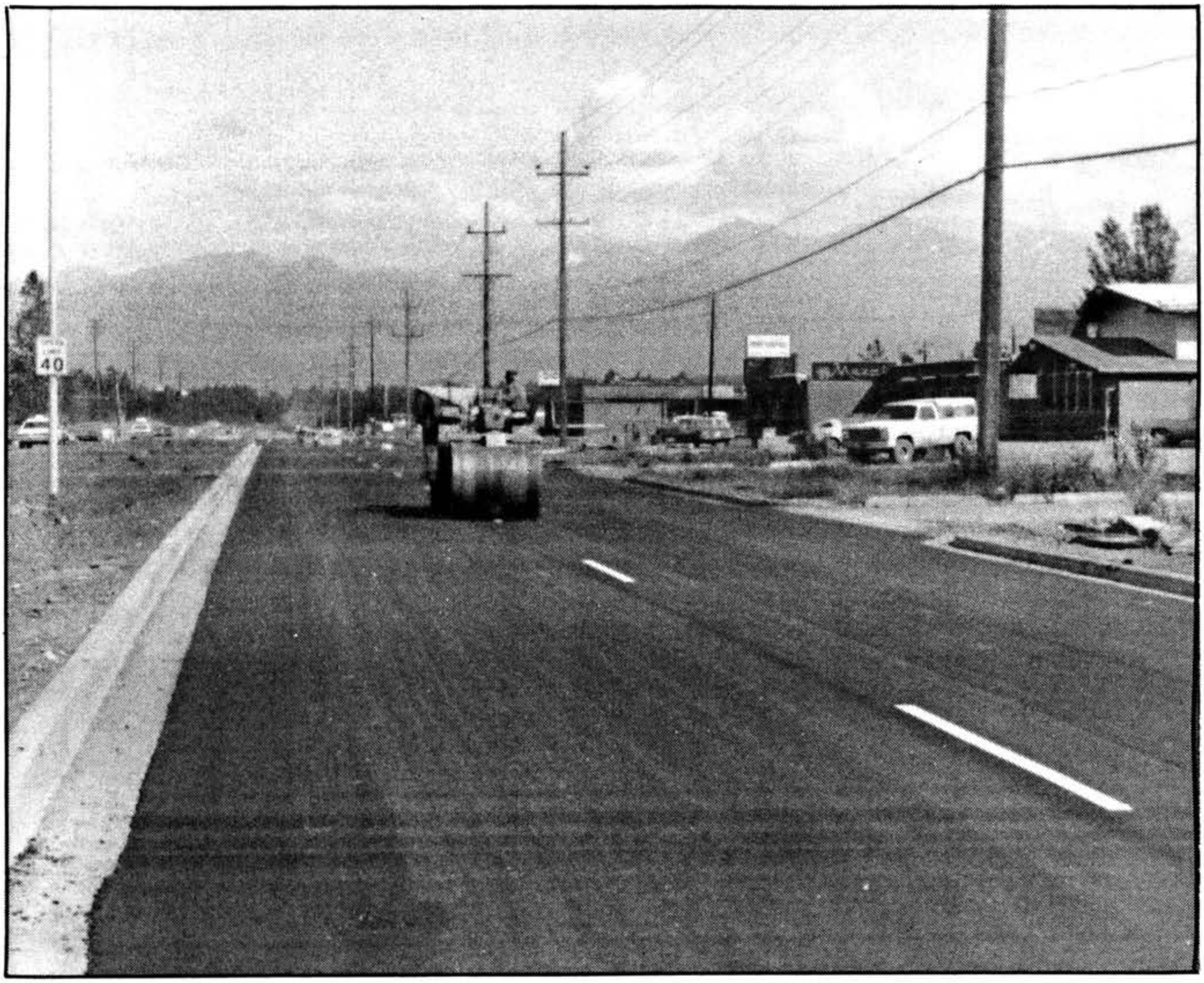


Photograph 12 Marking pavement with use of string-line prior to installation of skip striping (Northern Lights Boulevard).

Photograph 13 Positioning solid stripe at turn lane. Machine applicator is able to apply thermoplastic material as fast as the operator can walk.



Photograph 14 Machine-applied stripe. Note position of construction joint in asphalt.



Photograph 15 Rolling thermoplastic stripe into hot asphalt mat.

APPENDIX C

Cost Tradeoffs

COST TRADEOFFS

An analysis of historic bid tabs can be used to accurately forecast the cost of new construction where variations in project complexity are minimal. To be effective, however, the input data must be current and should be well-documented. Results will also be most useful if the analysis includes subcategories of various widths and symbol types.

Currently it is the policy of the Department to use a lump-sum pay item for new pavement markings regardless of whether paint or thermoplastics is used. Payment on this basis has the advantage of eliminating quantity measurements, but has the disadvantage that unit costs are not directly reported. Consequently, the results of detailed quantity take-offs must be available before unit costs can be computed. In our study, this data was available on only a limited number of projects. Significantly improved results are expected if data from a larger number of current projects could be included for each district.

Figure C-1 tabulates past bids for thermoplastics, based on unit prices obtained from DOTPF personnel for the projects listed. In order to account for the effects of inflation and periodic fluctuations in the construction industry, a cost-adjustment factor was applied to data from projects constructed in previous years. These costs factors were calculated in terms of 1982 value by using roadway costs indices published by the Department of Transportation and Public Facilities. Linear regression techniques can be used to confidently predict cost as a function of project size when current data is available.

During the course of our interviews, it became apparent that the State typically chooses between two alternative schemes when selecting a program for highway delineation. First, they can elect to paint stripes on the newly-installed pavement, followed by continued reapplication of paint, or alternatively they can elect to install thermoplastic markers which have a life expectancy several time that of paint. Once past their initial life, maintenance crews simply paint over the remnants of the thermoplastic markers. It is apparent that if thermoplastic markers are to be cost-effective they must be able to offset their higher initial cost by reducing the need to paint.

The relative economics between the two choices discussed above can be ascertained by assuming that, for paint to be cost-effective, the discounted costs of future paint applications when taken over the estimated life of a thermoplastic markers, plus the initial cost of a contractor-applied stripe, must be less than the cost to install a thermoplastic marker. Since the initial cost of paint is stated in terms of present value it can be subtracted from the cost of thermoplastics without changing the validity of the above expression. In other words, paint will be more cost-effective whenever the discounted value of future paint applications are less than the net of the bid prices for thermoplastic markers less the bid prices of painted markers.

Other things being equal, a decision maker would be neutral when the discounted cost of future painting equals the difference in first costs between installing thermoplastic markers and paint. Figures C-2 through C-5 illustrate this procedure for paint with an expected life of 3 months, 6 months, 12 months and 24 months, respectively. An example of the use of these figures is provided on Figure C-3.

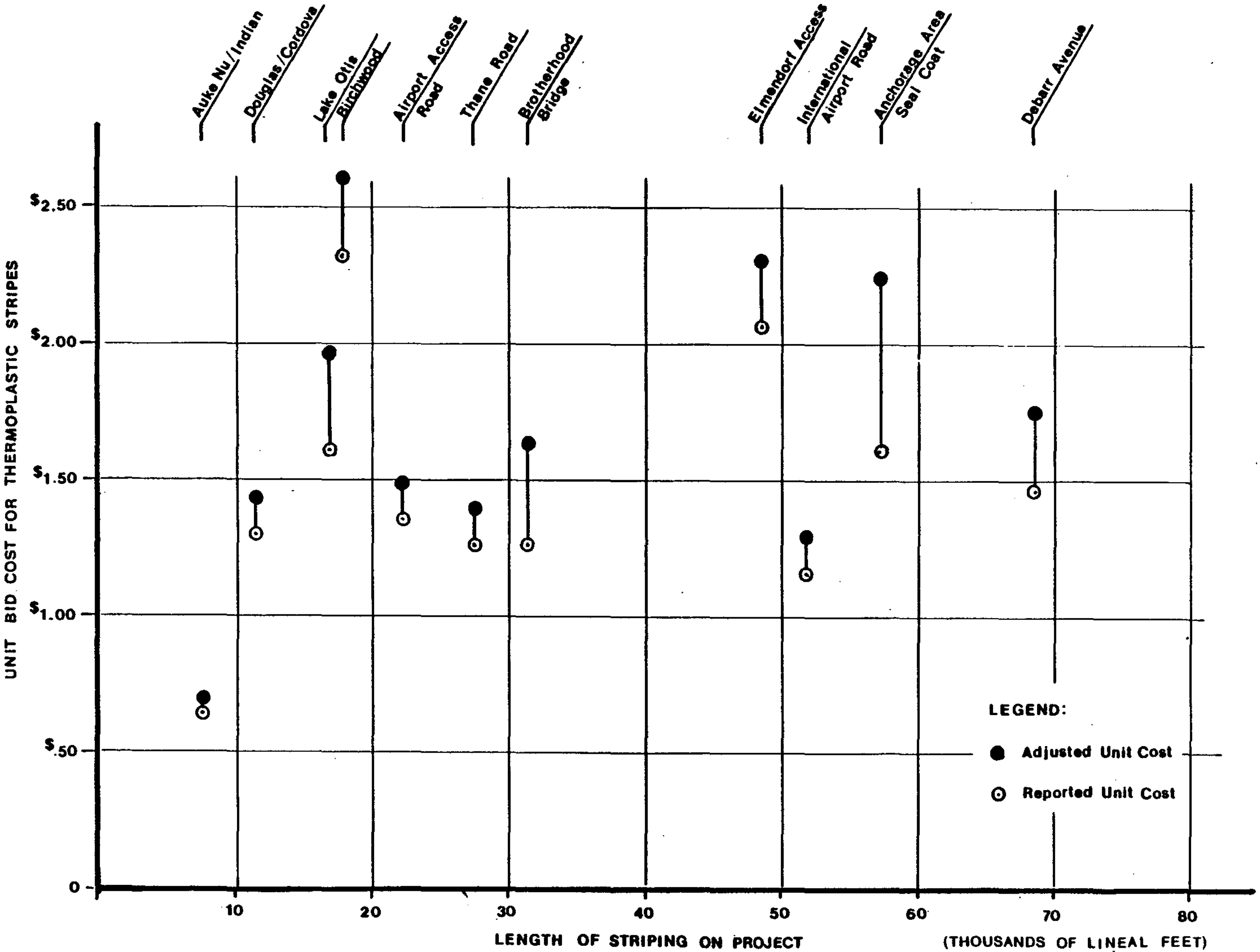


Figure C-1 UNIT COST BY PROJECT SIZE

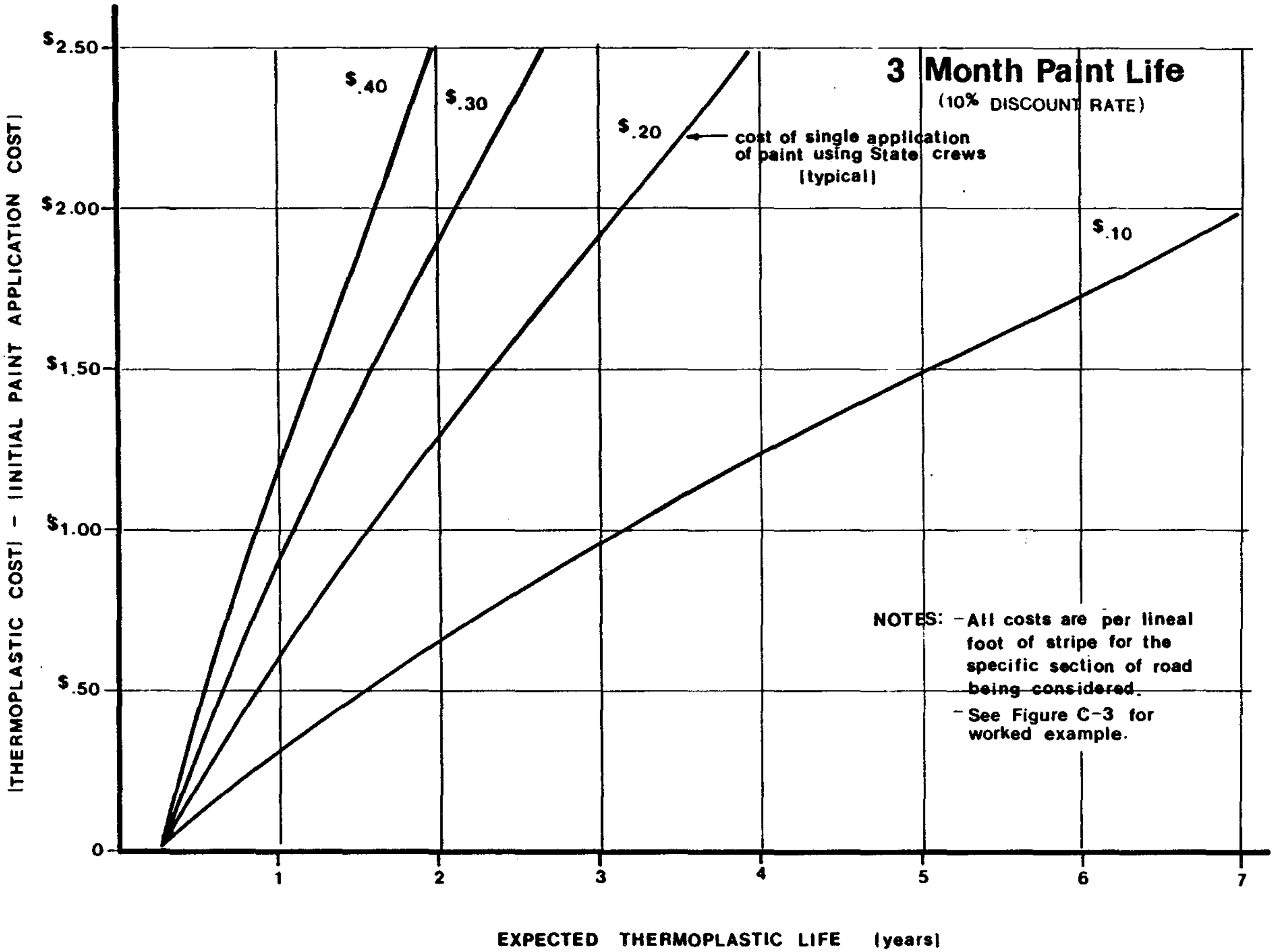


Figure C-2 BREAK-EVEN BETWEEN PAINT & THERMOPLASTICS

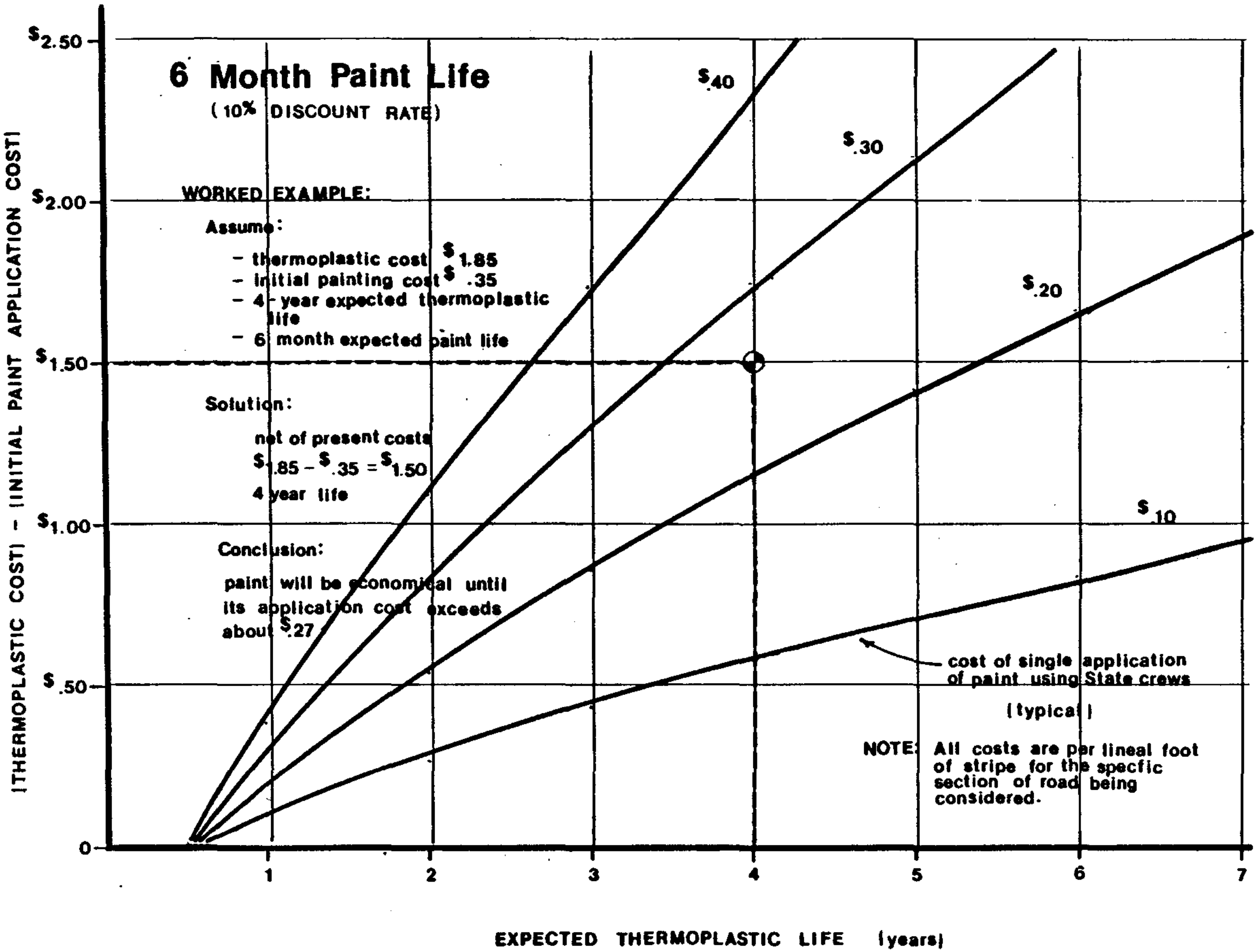


Figure C-3 BREAK-EVEN BETWEEN PAINT & THERMOPLASTICS

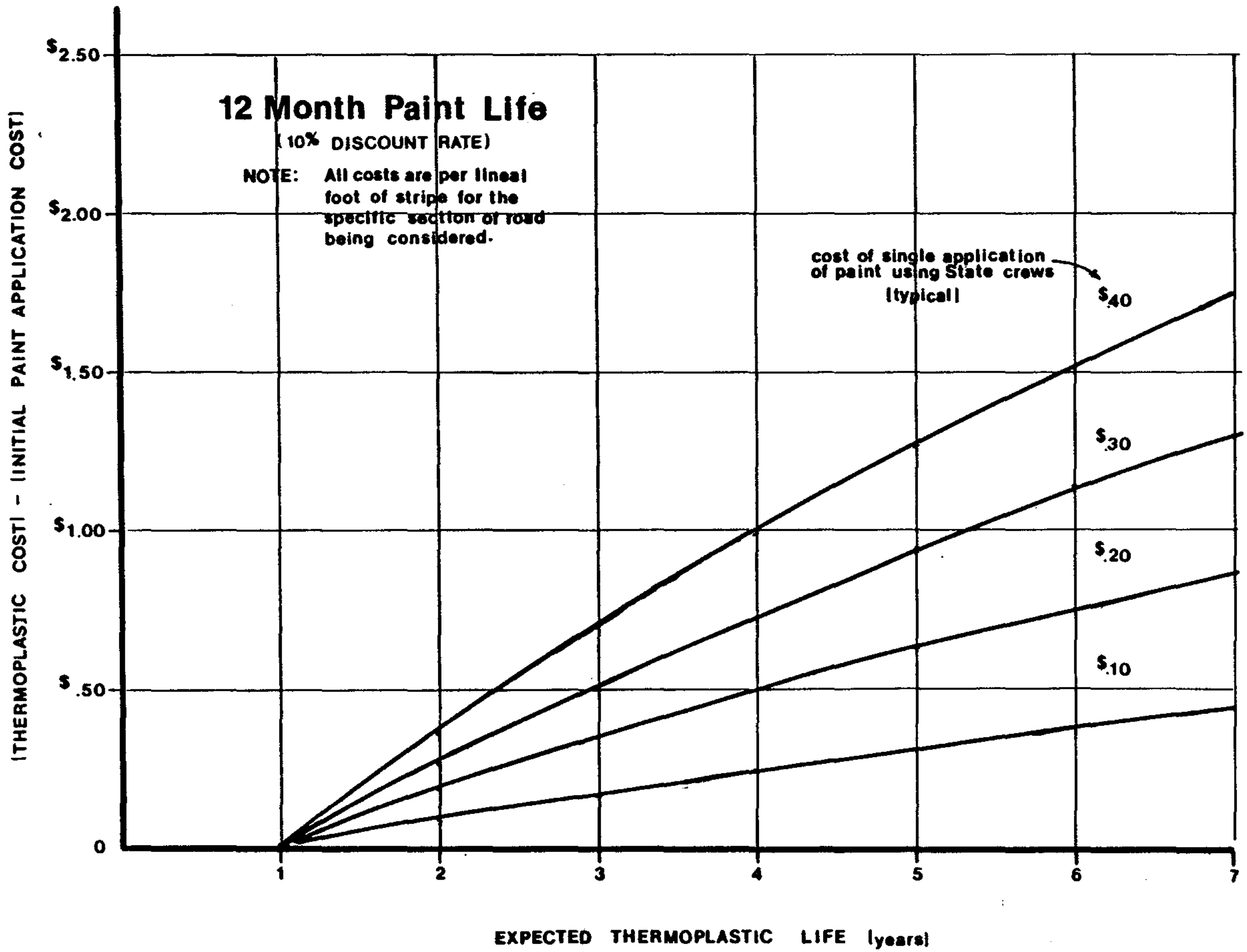


Figure C-4 BREAK - EVEN BETWEEN PAINT & THERMOPLASTICS

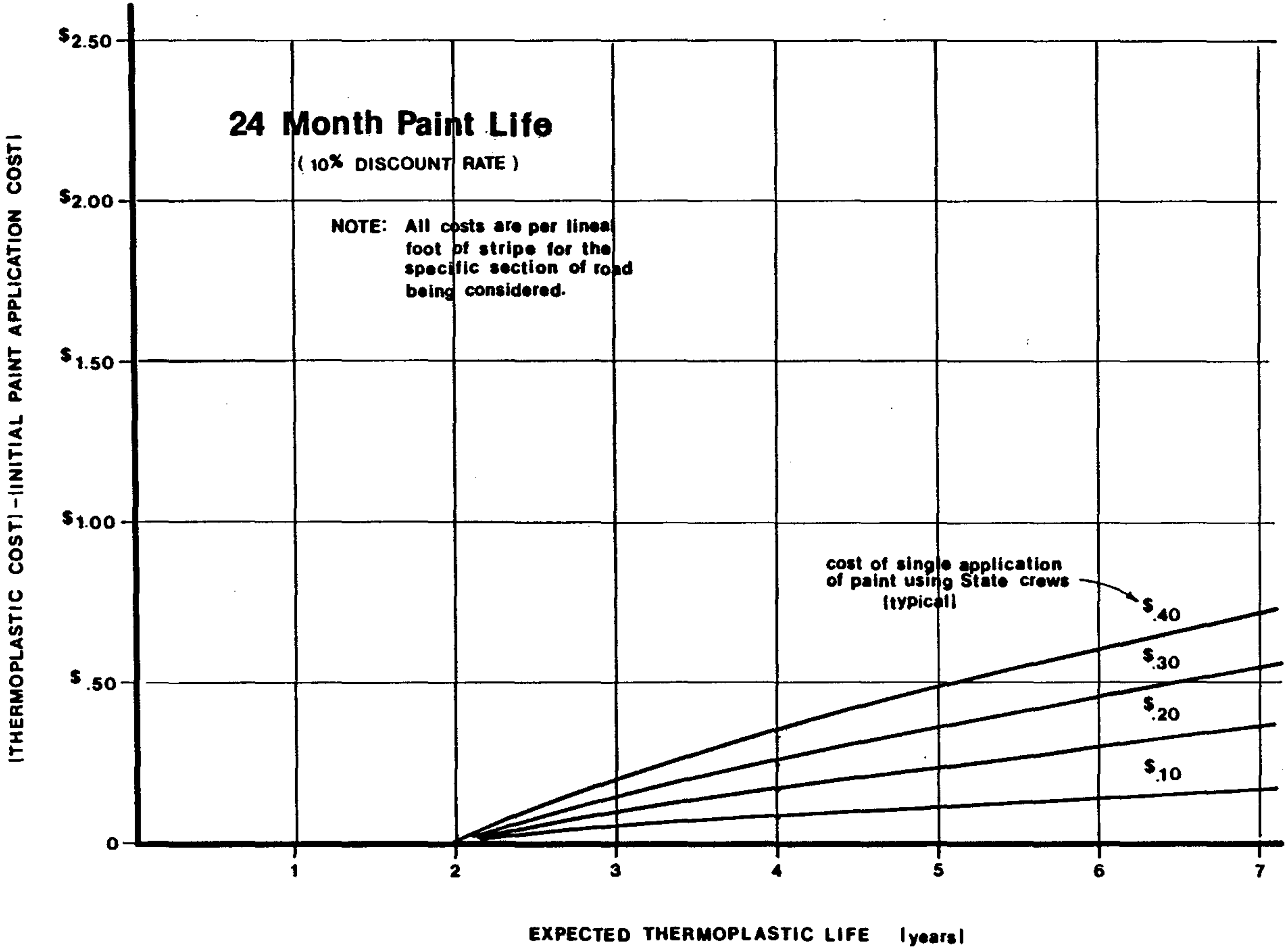


Figure C-5 BREAK-EVEN BETWEEN PAINT & THERMOPLASTICS