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16. Abstract

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This report summarizes the findings from this study. The main results summarized in this report include impacts of pavement marking patterns on a driver's behavior, minimum reflectivity requirements, a general evaluation of traffic marking materials, reflectivity performance, subjective survey evaluation, and final conclusions. The traffic marking types evaluated in this study included traffic paint, thermoplastics, preformed tapes, and Methyl Methacrylate. These traffic marking materials have all been applied in Alaska.

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PERFORMANCE OF TRAFFIC MARKINGS IN COLD REGIONS

By

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A Report on Research Sponsored by
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ABSTRACT

This study evaluated the performance of traffic marking materials used in Alaska and other northwestern states, including Washington, Idaho, and Oregon. Primarily, this study included reviews of existing reports, past studies, and information databases; a field survey that subjectively rated existing traffic markings in Alaska's central region; field measurements of the retro-reflectivity of traffic markings made by using a reflectometer in Alaska's central region; and a subjective opinion survey about the performance of traffic markings.

This report summarizes the findings resulting from this study. The main results summarized in this report include impacts of pavement marking patterns on a driver's behavior, minimum reflectivity requirements, a general evaluation of traffic marking materials, reflectivity performance, subjective survey evaluation, and final conclusions. The traffic marking types evaluated in this study included traffic paint, thermoplastics, preformed tapes, and Methyl Methacrylate. These traffic marking materials have all been applied in Alaska.

SUMMARY

Various traffic markings are used as traffic control devices in the northwestern states of the United States. The most popular materials include preformed tapes, thermoplastics, and traffic paints. In recent years, a new traffic marking material called Methyl Methacrylate has been applied in the northwestern states. Transportation engineers have found that this new type of material provides a better reflectivity and a longer service life, compared to other materials. Another important advantage of this new material is that it can be installed in the field at temperatures as low at 0 ^{o}F, as long as frost is not present.

In July, 1994, Alaska Department of Transportation and Public Facilities requested that the Transportation Research Center of the University of Alaska Fairbanks conduct a research study to evaluate traffic markings used in Alaska, including the new product, Methyl Methacrylate. The main purpose of this project was to collect information from past studies and field data to search for traffic marking materials that are suitable to Alaska climates, cost effective, and durable. The study objectives in the study were:

1. To collect and review existing information on the performance of various traffic marking types from other states and Alaska,
2. To specifically collect performance data on the new product - Methyl Methacrylate,
3. To measure the reflectivity of traffic markings in three regions in Alaska, and
4. To conduct a subjective survey of engineers and employees in the traffic marking industrial sectors.

In this study, researchers searched and reviewed existing data and information resources to evaluate the impacts of traffic marking patterns on drivers' behavior, the minimum reflectivity requirements of traffic markings, and general performances of various traffic marking materials. Researchers conducted a subjective field evaluation to rate the performances of traffic markings. In addition, reflectivity measurements were taken in the field to objectively evaluate the reflectivity of traffic marking materials. Finally, an opinion survey was conducted to collect subjective ratings of traffic marking materials in several aspects. All results are presented in the following report.

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ACKNOWLEDGMENT

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CHAPTER 1. INTRODUCTION

Background

Traffic markings are used to regulate and guide traffic movement and promote safety on the highway. Traffic markings include all lines, longitudinal or transverse, and symbols and words applied to the pavement. Traffic marking performance is judged by factors such as general daylight appearance, color, film condition, bead retention, and reflectance. In cold climates like Alaska's, required performance qualities for traffic markings have been difficult to maintain through the winter months because of high traffic density, studded tires, snow plows, and the use of large quantities of abrasive materials. The reduced life of traffic markings in Alaska has resulted in decreased traffic safety and increased maintenance costs.

Many traffic marking products are available in the markets. Typical products include traffic paint, thermoplastics, preformed tapes, epoxy, polyester, epoflex, and so on. When using a specific traffic marking type, limitations such as application temperature, durability to snow removal equipment, cost-effectiveness, reflectivity, service life, field installation, and so on should be considered.

According to Dale's estimation [1], the quantities of traffic marking materials used annually in the United States consist of

- 37 million gallons of traffic paint,
- 130,000 tons of glass traffic beads,
- 55,000 tons of thermoplastic marking materials,
- $55 million worth of other materials such as preformed tapes, raised pavement markers, polyesters, epoxies, and adhesives.

These materials represent not only a large monetary effort, but an extensive allocation of manpower and application equipment. Adequate traffic markings are one of the highest return, lowest cost operational improvements that can be made to streets and highways.

Many research studies have been conducted to evaluate various traffic markings. A NCHRP (National Council of Highway Research Program) study, conducted by Dale [1] in 1988, summarized the application of traffic marking materials. This study summarized warrants for traffic markings, field installation procedures, traffic marking materials, cost-effectiveness, and future research needs; published research from the study results is a good reference.

A major area studied in the past was the comparative performance evaluation of various traffic marking types [2 - 9]. The main objective of the studies was to evaluate performance qualities of various traffic marking types by conducting comparative field experiments or surveys. Field experiments and information surveys have been considered effective ways to determine performance qualities such as reflectivity, durability, cost-effectiveness, service life, and so on.

Some studies have evaluated some specific qualities of traffic markings, including reflectivity and minimum acceptable reflectivity [10 - 13], durability [12], cost-effectiveness [1, 11, 14], impacts of traffic markings to a driver's behavior [15], and bead application [16]. These studies have provided guidelines for selection of traffic marking types and materials. The leading states in evaluating traffic markings include Arizona, California, Colorado, Florida, Georgia, Mississippi, Kentucky, Ohio, New York, Pennsylvania, Texas, Virginia, and Washington.

In Alaska, the main traffic markings used in the field include traffic paint, thermoplastics, and preformed tapes. No major study has been performed and documented to compare the field performance qualities of these traffic marking types. Two minor studies were conducted and documented in 1983 [16, 17]. The objectives of the first study were to conduct interviews with Alaska Department of Transportation and Public Facilities (AKDOT&PF) engineers in order to collect background data, opinions about uses, and cost data; and to inspect selected sections of roads in the vicinity of Fairbanks, Juneau, and Anchorage. A single evaluator inspected an entire length of a section of road and noted where damage occurred. Subsequent on-foot inspections and photo documentation of both damaged and undamaged areas followed the initial inspection. This study found that while thermoplastic striping may last considerably longer, it may not be cost effective, depending on traffic, pavement life, and so on. The study also suggested that construction techniques, including offsets from joints and application temperatures, be changed to enhance the life of thermoplastics.

The main purpose of the second study was to develop traffic paint specifications that would allow the State of Alaska to purchase durable paint capable of tolerating cold climates. Interview results obtained in the first study were also used in this study. In addition, field tests evaluated traffic paint that was applied at heavily-trafficked test sites located in Fairbanks, Anchorage, and Juneau. After two to four months of wear, the traffic paint lines were examined for daytime appearance, durability, and night-time appearance. Field test results were based on subjective field survey ratings.

Problem Statement and Research Objectives

Alaska has a long history of using traffic markings on all kinds of highways. Before the 1980's, paint markings were the major form used in Alaska. Demand for better and more cost-effective supplies has resulted in the use of alternative traffic marking materials such as thermoplastics, preformed tapes, raised markers, and so on. However, during the winter season, studded tires and road sand have proven very hostile to traffic markings, and these conditions make performance information from most other states difficult to interpret for the Alaska environment.

In recent years, a new traffic marking product, called Methyl Methacrylate (MMA), has been applied in Alaska, mainly in the Central and Northern Regions. MMA is designed for the extreme conditions of heavy ADT (average daily traffic) areas. Traffic engineers with experience using the new product have estimated that the MMA has a life-expectancy of up to 10 years when applied properly at a thickness of 30 to 120 mils. This new product can be applied at ambient temperatures. Some field engineers have indicated that it can be applied at temperatures as low as -18 ^{o}C (0 ^{o}F), as long as frost is not present, and this new product provides superior night visibility. According to conversations with engineers from AKDOT&PF and comments regarding existing projects in the Central and Northern Regions, it appears that Methyl Methacrylate traffic markings have been well recognized by field engineers in terms of their reflectivity, cost-effectiveness, durability, and ease of installation, and so on. Based on these qualities, this new product may have great potential as a traffic marking material in Alaska.

In July, 1994, AKDOT&PF requested that the Transportation Research Center of the University of Alaska Fairbanks (TRC/UAF) conduct a research study to evaluate traffic markings used in Alaska, including the new product - Methyl Methacrylate. The main purpose of this project was to collect information from past studies and field data to search for traffic marking materials that are suitable to Alaska climates and are cost effective and durable.

The project's main objectives were:

1. To collect and review existing information on the performance of various traffic marking types from other states and Alaska,

2. To specifically collect performance data on the new productt, Methyl Methacrylate,

3. To measure the reflectivity of traffic markings in the three regions in Alaska, and

4. To conduct a subjective survey of engineers and employees in the traffic marking industrial sectors.

This report summarizes the findings resulting from this study. The main results summarized here include impacts of pavement marking patterns on a driver's behavior, minimum reflectivity requirements, a general evaluation of traffic marking materials, reflectivity performance, subjective survey evaluation, and final conclusions. The traffic marking types evaluated in this study included traffic paint, thermoplastics, preformed tapes, and Methyl Methacrylate. These traffic marking materials have all been applied in Alaska.

CHAPTER 2. IMPACTS OF TRAFFIC MARKINGS ON DRIVER'S BEHAVIOR

Traffic markings, according to the Manual on Uniform Traffic Control Devices (MUTCD) [18], are major control devices for traffic movement and safety. Some research has shown that the configuration of traffic markings can affect drivers' behavior. A study conducted by the Scientex Corporation in 1993 evaluated the effect of traffic markings on drivers' behavior [15]. Three kinds of marking patterns were used as edge line for field testing. These patterns were 0.61-m (2-ft) stripes with 11.59-m (38-ft) gaps, 1.22-m (4-ft) stripes with 10.98-m (36-ft) gaps, and 3.05-m (10-ft) stripes with 9.15-m (30-ft) gaps.

A video camera recorded vehicle movements. Data from the recorded pictures was reduced to obtain average running speeds, mean distances from the lane line to the center of the vehicle, average lateral placement, and number of encroachments per run. An encroachment occurred when the outside edge of the rear tire of the observed vehicle crossed the outside edge of the lane line or edge line. Major factors considered in the field included day/night and dry/wet. If all factors are combined, the average impacts of the traffic marking patterns on the driver's behavior can be obtained; there are shown in Figures 1 - 4. For each operational measure examined, the 3.05-m (10-ft) marking pattern generally resulted in better driver behavior performance than either the 0.61-m (2-ft) or 1.22-m (4-ft). This result was reasonable and expected, since the 3.05-m (10-ft) pattern consisted not only of longer strips but also edge lines. The following conclusions were obtained from this study:

- The speed at which drivers traveled decreased as the length of the lane line decreased.
- Drivers positioned their vehicles closer to the center of the lane as the length of the lane line increased.
- The variability of vehicle placement within the lane increased as the length of the lane line decreased.
- The number of encroachments increased as the length of the lane line decreased.

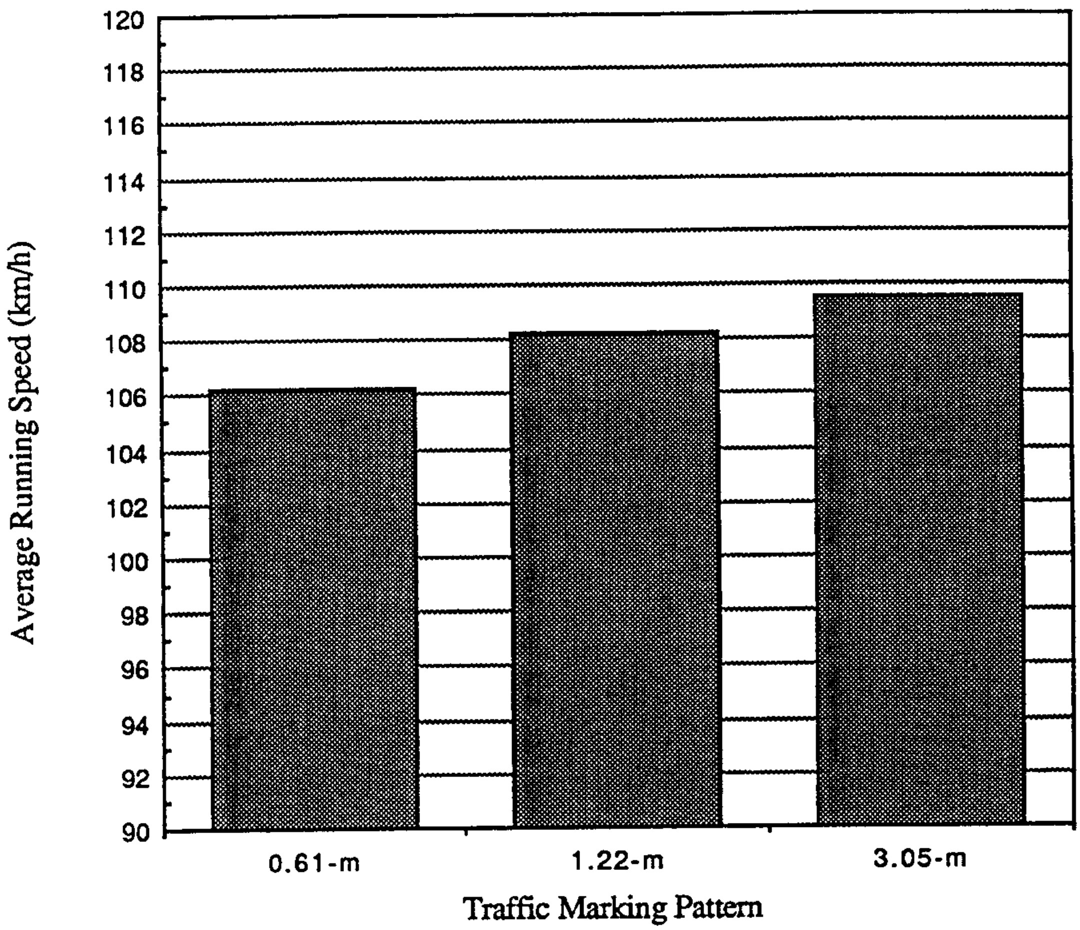

Figure 1. Impact of Traffic Marking Patterns on Average Running Speed.

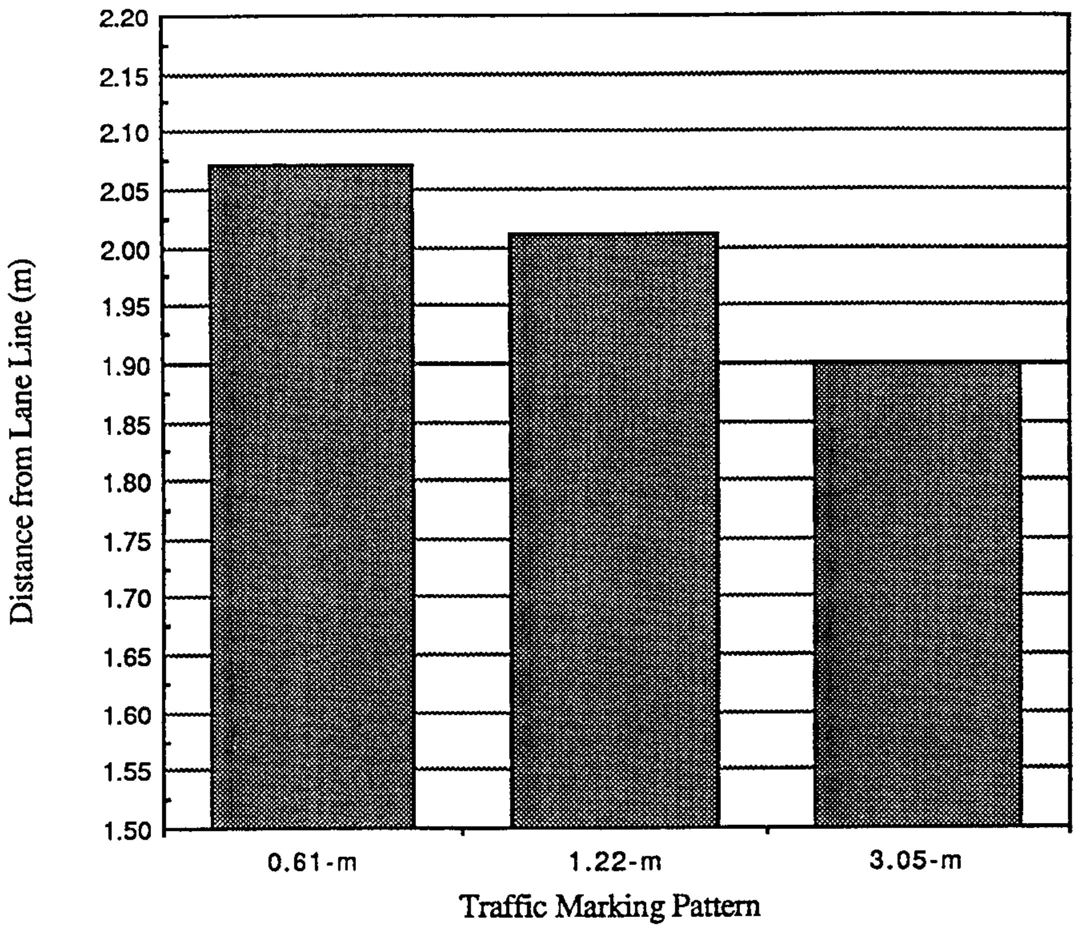

Figure 2. Mean Distance from the Lane Line to the Center of the Vehicle.

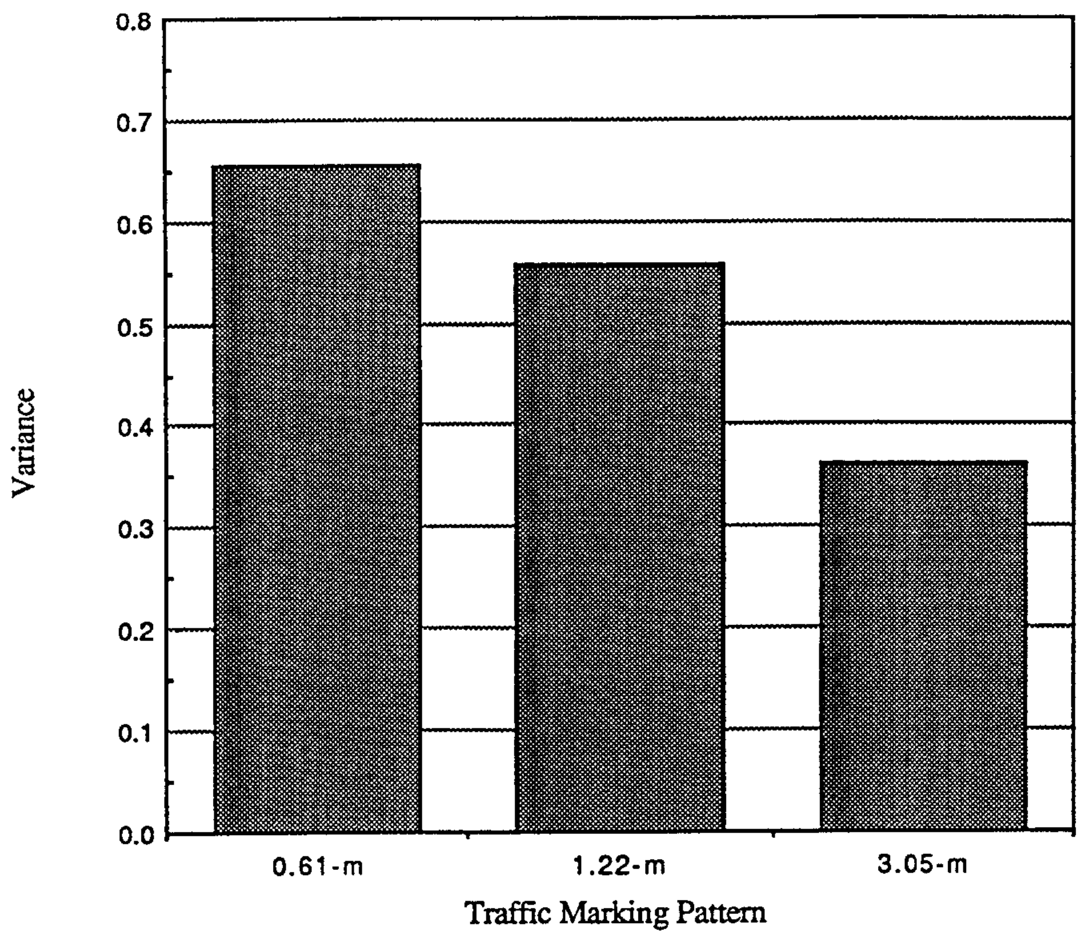

Figure 3. Average Lateral Placement Variance.

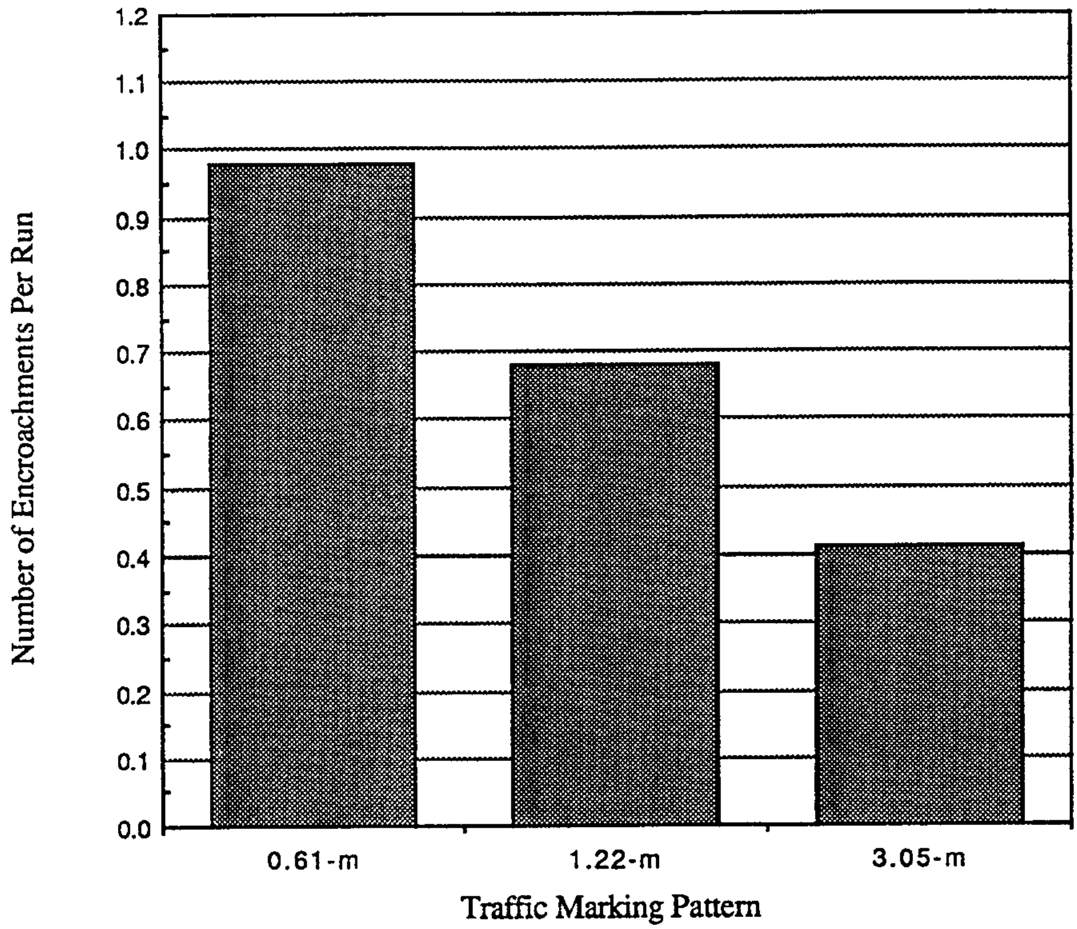

Figure 4. Average Number of Encroachments Per Run.

CHAPTER 3. MINIMUM REFLECTIVITY REQUIREMENT

Reflectivity is the single most important quality of a traffic marking. It has been concluded that the nighttime accident rate is more than three times the daytime rate when computed on a mileage basis [19]. Factors contributing to this statistics may include use of alcohol or other drugs and driver fatigue. The information required by drivers is visual in nature, and the poor visual conditions at night may also be considered a major contributing factor.

Currently, no standard specifications have been made to require minimum reflectivity for traffic markings. However, studies have been conducted to determine minimum field luminance and retroreflectivity levels [10, 12, 13, 20]. Most studies were based on human subjective ratings for given luminance levels. Figure 5 presents a field rating result obtained from a study conducted by Graham and King [10]. Average subjective ratings were used in the study. From this figure, it can be concluded that to reach an adequate rating, the minimum reflectivity would be 100 $mcd/m^2/lx$. The same conclusion was achieved in a study by Ethen and Woltman [13]. Ethen and Woltman used the following subjective rating scale:

7 - Superior,
6 - Excellent,
5 - Very acceptable,
4 - Generally acceptable,
3 - Minimum acceptable,
2 - Unsatisfactory, and
1 - Very poor.

Field subjective rating regression is presented in Figure 6. A minimum reflectance of 100 $mcd/m^2/lx$ is needed to maintain a minimum acceptable luminance level under dark conditions.

In the study by the New York State Department of Transportation [12], although instrument measurements and subjective ratings were not formally conducted, based on several years of experience in subjectively rated traffic marking materials, the following approximate relationships between luminance levels and ratings were established:

	White	Yellow
Excellent	over 300	over 250
Good	225-300	175-250
Fair	140-225	110-175
Poor	below 140	below 110

Determining the reflectivity of traffic markings has traditionally been a difficult task in the United States because of the lack of recognized standards and equipment for making high-speed field evaluations. Reflectivity standards are used in France and Germany. The French have established an acceptable reflectivity value of 150 $mcd/m^2/lx$ as measured with an Ecolux retroreflectometer, and the Germans use a range of values from 150 to 70 SL, based on traffic conditions as measured with a German-made retroreflectometer [21].

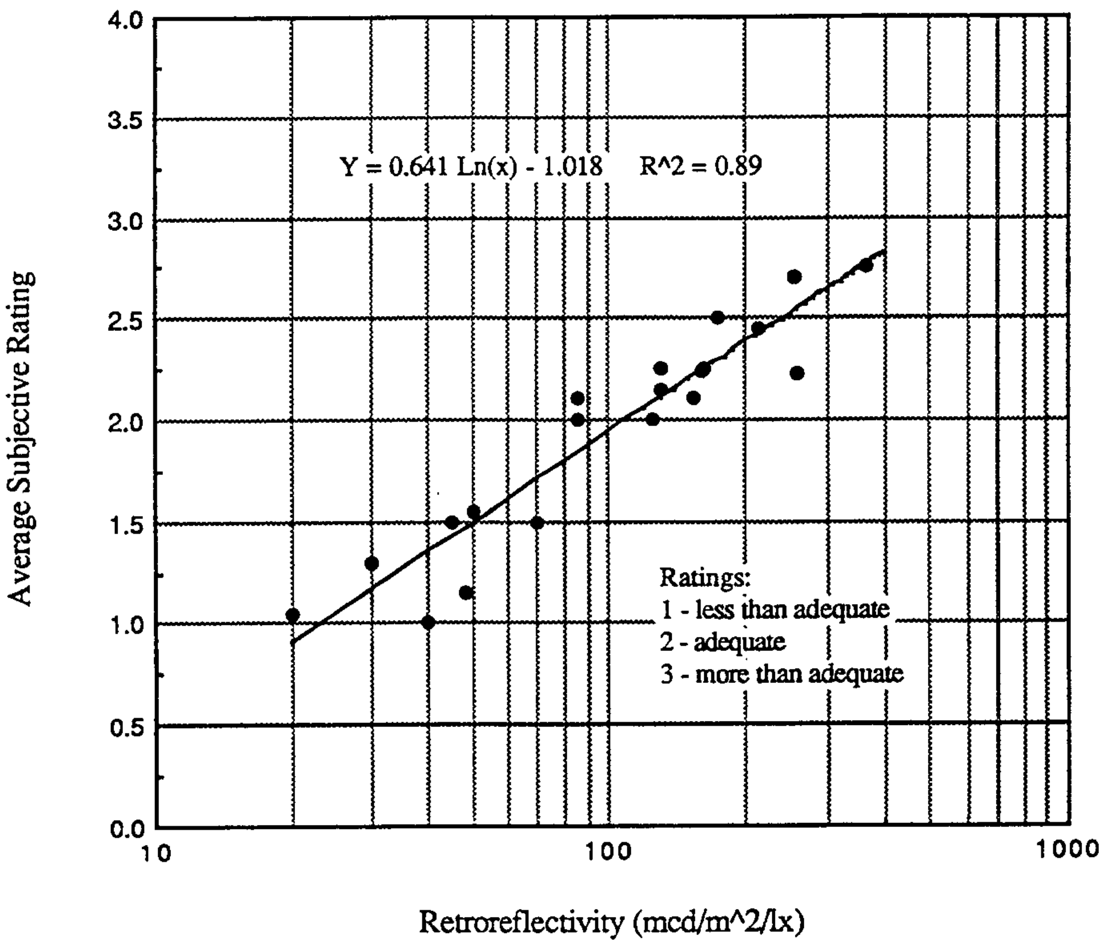

Figure 5. Average Subjective Rating of Field Retroreflectivity [10].

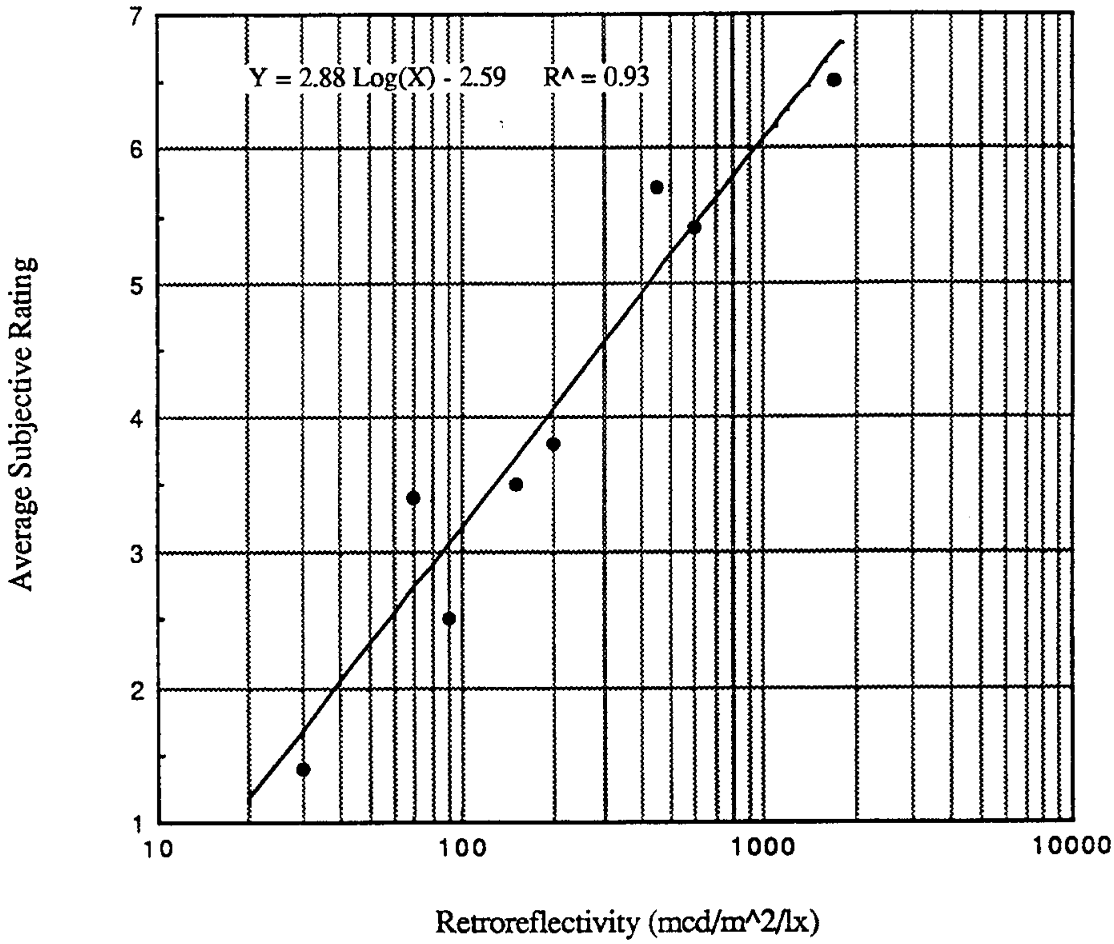

Figure 6. Average Subjective Rating of Field Retroreflectivity [13].

CHAPTER 4. GENERAL EVALUATION OF TRAFFIC MARKINGS

This chapter evaluates the general performance of various traffic markings including traffic paints, thermoplastics, Methyl Methacrylate, and preformed tape. The issues discussed cover traffic marking characteristics, costs, service life, and application temperature. More detailed field evaluation, reflectivity measurements, and other performance qualities obtained through information surveys will be presented in the following chapters.

Traffic Marking Characteristics

Traffic Paint

Traffic paints, the most widely used traffic marking materials in the United States, are comprised of a paint vehicle, a solvent, a pigment, and glass beads. The specific ingredients determine the length of the traffic paint drying time. The durability of traffic paints is affected by material composition, weather conditions, traffic volume, and pavement type and surface conditions. The major problems associated with traffic paints include bonding to surfaces, reapplication over existing materials, and discoloration of paint due to softening of the pavement surface. Traffic paints have the shortest life of all marking materials and offer poor wet-night visibility. The major advantages of traffic paints are relatively low initial cost, ease of installation, and well-established technology. Traffic paints provide good dry-night visibility and a range of drying times, and are relatively safe to handle.

Thermoplastics

Thermoplastics consist of a resin binder, coloring agents, inorganic filler, and glass beads. An important factor contributing to service life is environmental temperature. In southern states, an average service life of 10 years can be achieved. However, in northern states, thermoplastics may not last one year if traffic is heavy. The most common problems in northern climates are (1) abrasion and shaving caused by snow removal equipment, abrasive materials, and studded tires; and (2) bond failure resulting from improper installation due to inadequate heating and dirty or oily pavement surface. Because of the thickness, thermoplastics cannot be used for transverse lines in areas with high traffic volumes and for longitudinal lines where turning traffic is common. Thermoplastics are more effective on asphalt than on concrete. Under the right circumstances, thermoplastics are relatively durable reflectorized traffic markings. Their initial appearance is generally excellent and reflectivity is sustained throughout the service life. Reflectivity under dry conditions is equivalent to traffic paint, but the reflectivity under wet conditions is comparatively better than that of traffic paint.

Methyl Methacrylate (MMA)

Applications of MMA in cold regions with extreme environmental conditions, such as heavy snowplow areas and mountain passes, have been reported. The main users are northern states and provinces in Canada. MMA materials have been used in both extruded and sprayed applications on both asphalt and concrete pavement surfaces. However, no reports that formally document long-term comparative field evaluations have been found. Very limited information and data are available. As discussed in a FHWA Region 10 report [6], extruded MMA can provide a durable long-life marking for 2 to 7 years, depending on the conditions. Sprayed MMA did not appear to have the longevity of the extruded version, but did demonstrate potential as a less expensive, longer lasting material and may be an appropriate cost-effect treatment in some applications. Generally, good visibility of MMA materials for night and wet conditions has been indicated by field engineers with traffic markings experience. Because of its long service life, good reflectivity, low application temperature, and durability, MMA materials may be widely used in cold regions with severe winter conditions such as those funded in Alaska. However, MMA materials may not be as effective in areas with high humidity because a relatively dry environmental condition is necessary during MMA materials installation. Engineers from AKDOT&PF have noted this limitation.

Preformed Tapes

A variety of preformed tapes have been applied on asphalt and concrete pavement surfaces. The 3M Stamark product is the most common. The durability of preformed tapes depends primarily on pavement conditions and the number of pieces used. Durability is poor on old and deteriorating pavements, and especially on concrete surfaces. One problem associated with the use of preformed tapes is the loss of retroreflectivity, typically in less than two years. Some agencies consider preformed tapes most suitable in lighted areas where retroreflectivity is not critical. State officials consider three years to be a conservative estimation of the service life [2]. The installation of preformed tapes is simple, safe, and clean. Preformed tapes present their appearance and initial reflectivity about 5 to 6 times better than traffic paints. Preformed tapes adhere well, especially when applied on new pavements.

Use of Traffic Markings in Northern States

In 1994 FHWA Region 10 Division performed a survey to collect information on use of various traffic markings in the region (Alaska, Idaho, Oregon, and Washington) [6]. Table 1 summarizes the use distribution of traffic paints, thermoplastics, Methyl Methacrylate, and preformed tapes.

Based on a review of the existing reports and information collected from other resources, use of traffic markings is summarized in Table 2.

Traffic Marking Service Lives

The expected service lives of traffic markings have been reported in several research studies. However, the service life of a specific material cannot be accurately predicted because many factors contribute to it. These factors include installation techniques, pavement type and conditions, traffic volume, type of marking, environmental conditions, use of snow removal equipment, abrasive materials, use of studded tires, and so on. Based on these past studies, the service lives of the traffic markings discussed earlier (traffic paints, thermoplastics, MMA, and preformed tapes) are estimated and shown as follows:

Traffic Marking Materials	Expected Service Life
Traffic Paints	4 months - less than 1 year
Thermoplastics	1 - 7 years
Methyl Methacrylate	2 - 7 years
Preformed Tapes	2 - 6 years

Studies have indicated that severe winter conditions significantly decrease the service lives of thermoplastics and preformed tapes due to the use of snow removal equipment, abrasive materials, and studded tires. Thermoplastics and preformed tapes are not recommended for use in areas with severe winter conditions. Generally, the expected service lives of traffic markings applied on asphalt surfaces are longer than those on concrete surfaces.

Initial and Life Cycle Costs

Information on initial and life cycle costs are necessary to any analysis of cost-effectiveness. Several recent studies have provided estimations for such information [1, 2, 4, 5]. Based on cost data from these studies and information, provided by traffic marking materials suppliers, initial costs for traffic markings are listed as follows:

Traffic Marking Materials	Line Width and Thickness	Initial Cost Estimation
Traffic Paints	10.16 cm (4 in.) and 8 mil	$ 0.10 - $ 0.20/m
Thermoplastics	10.16 cm (4 in.) and 120 mil	$ 0.98 - $ 1.31/m
Methyl Methacrylate	10.16 cm (4 in.) and 40 mil	$ 0.82 - $ 4.10/m
Preformed Tapes (3M Stamark)	10.16 cm (4 in.) and 60 mil	$ 4.85 - $ 5.41/m

The study conducted by the FHWA Region 10 office provided another rank of initial cost estimation [6]. The initial costs were classified as follows:

Cost	Cost Rank
less than $ 0.82/m (10.16 cm)	low
$ 0.82 - $ 4.10/m (10.16 cm)	medium
more than $4.10/m (10.16 cm)	high

Thus, based on the material costs, traffic marking materials can be ranked as follows:

Traffic Marking Materials	Cost Rank
Preformed Tapes	high
Extruded Methyl Methacrylate	high
Thermoplastics	medium to high
Sprayed Methyl Methacrylate	medium
Standard Paints	low

Determination of a life cycle cost is based on the initial cost and the expected service life. According to the information summarized previously, life cycle costs for traffic marking materials can be calculated. Table 3 presents life cycle costs assuming a life cycle of 7 years. Results shown in Table 3 basically match the cost ranking resulting from the FHWA Region 10 study. The estimated life cycle costs can be used as references when selecting a traffic marking material type.

Application Temperature of Traffic Markings

The application temperature is an important factor contributing to traffic marking performance qualities such as service life, durability, reflectivity, appearance, and so on. The application temperature should be well controlled when installing traffic markings in the field. Relevant application temperatures include material temperature and pavement temperature for some traffic marking material. The following presents the requirements for application temperature:

Traffic Marking Materials	Application Temperatures (^oC)
Traffic Paints	ambient - 93 (200 ^oF)
Thermoplastics	204 - 218 (400 - 425 ^oF) [pavement temperature must be higher than 12 ^oC (55 ^oF)]
Methyl Methacrylate	-1 (30 ^oF)
Preformed Tapes	21 (70 ^oF)

In cold regions, most field installation work is done during summer or fall to ensure the required application temperature for a traffic marking type. However, MMA has an advantage in that is applicable at temperatures as low as -1 ^oC (30 ^oF), which gives it greater potential for use in cold regions such as Alaska.

Table 1. Traffic Marking Applications in FHWA Region 10 [6].

		States in FHWA Region 10			
Traffic Markings		Alaska	Idaho	Oregon	Washington
Traffic Paints		yes	yes	yes	yes
Thermoplastics	Extruded	yes	yes	no	yes
	Sprayed	no	no	no	yes
Methyl Methacrylate	Extruded	yes	yes	yes	yes
	Sprayed	yes	yes	no	yes
Preformed Tapes		yes	yes	yes	yes

Table 2. Suitable Conditions for Traffic Markings in Cold Regions.

Traffic Markings	Traffic Volumes			Pavement Types		Marking Types		Suitable for Severe Winter Conditions
	Low	Medium	High	Asphalt	Concrete	Longitudinal	Transverse	
Traffic Paints	yes	yes	no	yes	yes	yes	yes	yes
Thermoplastics	yes	yes	yes	yes	no	yes	no	no
Methyl Methacrylate	yes	yes	yes	yes	unknown	yes	yes	yes
Preformed Tapes	yes	yes	yes	yes	yes	yes	yes	yes

Table 3. 7-Year Life Cycle Costs of Traffic Marking Materials.

Traffic Markings	Initial Cost ($/m of 10.16 cm)	Expected Marking Life	Yearly Cost	7-Year Life Cycle Cost
Traffic Paints	$ 0.10 - $ 0.20	min. 4 months	max. $ 0.30 - $ 0.60	max. $ 2.10 - $ 4.20
		max. 1 year	min. $ 0.10 - $ 0.20	min. $ 0.70 - $ 1.40
Thermoplastics	$ 0.98 - $ 1.31	min. 1 year	max. $ 0.98 - $1.31	max. $ 6.86 - $ 9.17
		max. 7 years	min. $ 0.14 - $ 0.19	min. $ 0.98 - $ 1.33
Methyl Methacrylate	$ 0.82 - $ 4.10	min. 2 years	max. $ 0.41 - $ 2.05	max. $ 2.87 - $ 14.35
		max. 7 years	min. $ 0.12 - $ 0.59	min. $ 0.84 - $ 4.13
Preformed Tapes	$ 4.85 - $ 5.41	min. 2 years	max. $ 2.43 - $ 2.71	max. $ 17.01 - $ 18.97
		max. 6 years	min. $ 0.81 - $ 0.90	min. $ 5.67 - $ 6.30

CHAPTER 5. FIELD SUBJECTIVE SURVEY OF TRAFFIC MARKINGS

Since the introduction of Methyl Methacrylate as a traffic marking material about three years ago, its durability and reflectivity have received positive reports from AKDOT&PF engineers. Compared with thermoplastics and preformed tapes, MMA may be more suitable to Alaska climates. In addition, its low application temperature [as low as -1 ^{o}C (30 ^{o}F)] makes it possible to install MMA during fall, spring, and summer seasons.

To evaluate the performance of MMA in Alaska, field surveys were conducted in the state's central region. The first field subjective survey was conducted on May 2 and 3, 1994. Another field survey was conducted on October 12 -14, 1994. The main purpose of these surveys was to assess whether or not the MMA material could be used in Alaska climates, compared to other traffic marking materials.

The only field subjective study that was documented to evaluate the performance of MMA was performed by the Idaho Transportation Department [22 - 25]. The study reports were not formally published. The main objectives in the study were to subjectively evaluate the appearance and reflectivity of Methyl Methacrylate markings, compared with other traffic marking types; and objectively measure retroreflectivity of traffic markings, including Methyl Methacrylate, preformed tapes, thermoplastics, and traffic paints. The subjective survey results will be summarized in this chapter. The objective measurements of reflectivity will be presented in the next chapter.

First Field Subjective Survey in Alaska

All the survey sites were in the central region. MMA traffic markings installed in 1992 and 1993 were subjectively surveyed by traffic engineers and awarded ratings of excellent, good, fair, and poor. They based their ratings on appearance and reflectivity. Survey site locations and results are shown in Table 4. Comments were provided by the survey team and are summarized as follows:

Site 1. This project shows two winter seasons of wear. MMA measurements exhibited 60 to 70 mil thickness on the stripes and 80 mils on the markings. Studded tire rutting at the intersection of Lake Otis and Abbott Road had worn the markings and pavement. The turn arrows and "ONLY"s were holding well in the low traffic volume areas. There was some evidence of snow grader wear along the route. Evidence indicated that corrections to poor applications occurred within relatively short distances. MMA appeared to be in good shape throughout the project.

Site 2. Some poor application was exhibited. One long yellow center turn lane stripe had no beads and had not been corrected soon enough. The material looked much brighter with one winter season's use, as compared to the two winters' use on the project. The mil thickness was 60 to 70. The overall appearance of the striping was excellent.

Site 3. This site was a very heavy traffic volume area with numerous driveways and crossover traffic. The MMA appeared to be resisting wear very well and only one section about 30.5 m (100 feet) long showed noticable wear. Some grader wear was visible. In general, this was a good application.

Site 4. This project originally called for preformed tape, but the majority of this material peeled and was replaced with MMA. MMA had been sprayed directly over the preformed tape. Heavy tire wear indicated where trucks swing for turns. A great deal of wear had occurred within the first year, illustrating how much abuse different types of markings could take. This was an excellent area for observing the minimum life of any type of striping.

Site 5. A combination of preformed tapes and MMA were used on this project. Excessive wear was evident on the cross walks. The MMA still showed completely across the intersection, while the preformed (3M) tape was worn completely through in the ruts. The MMA measured in excess of 80 mils. It was obvious that the thicker mil rate of the MMA would add life to the stripe in high wear areas. The extra thickness was not chipped or peeled by snow grader damage. One area showed a poor allocation rate and was completely worn down to the pavement. The overall condition of traffic marking in this site was excellent. This was a good site to observe two different types of traffic markings.

Site 6. The striping showed good reflectivity. The thickness measured 60 to 65 mils. Inner edge of curves showed a thickness of 55 mils. Some wear was showing but good bead reflection existed. A poor application in one area showed a thickness of 25 mils and about 30% of the aggregate showing through the stripe. Good edge definition through out the project. The overall appearance of the project was excellent.

Site 7. This was a concrete slab with MMA sprayed on the centerline and 3M preformed tape inlaid on the shoulders. The asphalt of the shoulders appeared to be higher than the concrete and revealed excessive snow grader wear. The concrete had deep marks similar to rumble strips and the MMA showed adhesion.

Site 8. The entire project had a good thickness, exceeding 60 mils. A fuzziness that appeared along the edges might be explained by the extra thickness. The MMA showed little wear on the inside shoulders, but appeared to have sharper edges, perhaps due to the wearing of the fuzzy edges. The overall appearance was excellent.

Site 9. This project had logistics problems; apparently the proper equipment was not available for the application. Wavy centerline stripes were obvious to the eye and many stripes throughout the project were less than 7.62 cm (3 in.) wide and less than 45 to 60 mils thick. In the areas where 60 mil thickness occurred and the stripe was 4" wide, the appearance was good to excellent. One area showed 7.62 cm (3 in.) with 25 mil thickness and high aggregate visibility. Overall the job was rated good to poor, on a range of very poor, poor, fair, good, and excellent.

Second Field Subjective Survey in Alaska

This survey was performed in the central region in October, 1994 and April, 1995, respectively. The reason for conducting this survey before and after the winter was to check the relatively deteriorating degrees of the traffic markings after one winter season. This may provide information to compare the relative service lives between these traffic marking types. The markings surveyed included traffic paints, MMA, and preformed tapes. Seven survey sites were selected, and all of the sites were installed during the summer 1994, except the preformed tapes on test site 1, which was installed in the summer 1994. Selection of the survey sites was based on a variety of traffic marking materials installed under similar traffic and environmental conditions. During the field survey, all pavement surfaces were clean and dry. Geometrical locations of the sites are shown in Appendix A of this report.

Five subjective ratings (very poor, poor, fair, good, and excellent) were used in the survey to evaluate edge (white) and central (yellow) lines. The appearance and reflectivity were the basis for the subjective rating. Table 5 summarizes the results. The results and comments, made by the field staff during the survey in October, 1994, indicated that the preformed tapes and MMA provided the best results in terms of appearance and reflectivity. The subjective rating of traffic paints was lowest, compared with preformed tapes and MMA. However, the survey results obtained in April, 1995 indicated that the preformed tapes deteriorated faster, compared with MMA. Although preformed tapes had relatively better initial appearance and reflectivity, its relatively high initial and life cycle costs may limit the wide use of preformed tapes in Alaska. One important comment made by field staff was that the MMA traffic marking provided the brightest reflectivity, even on wet pavement surfaces.

Test sites 5 and 7 were not surveyed in April, 1995 due to snowfall and wet/muddy surface conditions.

Subjective Field Survey in Idaho

North Idaho has experienced traffic marking failures year after year. The existing specified traffic paint is applied two to three times a year. However, by December of each year, the paint is worn off and cannot be replaced until April or March. Lane identification is completely lost. This is a serious safety problem to the traveling public. Since 1985, the Idaho Transportation Department has tried several traffic marking products to see if improved markings can be identified. The products tried in the field included thermoplastics, 3M Stamark preformed tapes, and Methyl Methacrylate (Dura-Stripe AC). In July, 1991, the department initiated a comparative experiment to assess the performance of traffic paints, preformed tapes, thermoplastics, and Methyl Methacrylate. They installed the following experimental traffic markings:

- 0.537 km (1/3 mile) of 90-mil Methyl Methacrylate
- 0.537 km (1/3 mile) of 125-mil hot sprayed thermoplastic
- 0.537 km (1/3 mile) of 90-mil Methyl Methacrylate with Visibeads
- 0.537 km (1/3 mile) of "skip-line" preformed tape (3M Stamark 380)
- 0.537 km (1/3 mile) of "skip-line" paint
- 0.537 km (1/3 mile) of "skip-line" 40-mil Methyl Methacrylate with Visibeads

After installing the experimental traffic markings, Idaho Transportation Department field staff went to the experimental sites to subjectively survey the performance of these traffic markings in 1992, 1993, and 1994. Drawing on reports [22 - 25] documenting the field results, the subjective survey results were:

1992 Survey — It appeared the Methyl Methacrylate would provide satisfactory performance for another several years. The paint lines and the thermoplastic line were visible. However, the paint and thermoplastic were not as apparent as the Methyl Methacrylate.

1993 Survey — The Methyl Methacrylate continued to show good performance. The paint lines, repainted in 1993, and the thermoplastic line were visible. However, they did not compare to the Methyl Methacrylate. The preformed tape (3M Stamark 380) still had good reflectivity readings, but the reflectivity from vehicle headlights was not as good as the Methyl Methacrylate.

1994 Survey

The Methyl Methacrylate continued to show good performance. The Idaho Transportation Department concurred with FHWA recommendations that Methyl Methacrylate be used at all high traffic volume areas.

CHAPTER 6. REFLECTIVITY PERFORMANCE OF TRAFFIC MARKINGS

The reflectivity of a traffic marking is a major concern for night driving. Currently, a retro-reflectometer, an instrument that measures retro-reflectivity, is the main means of objectively evaluating a traffic marking's nighttime reflectivity. Historical changes in the reflectivity of a traffic marking can be monitored by periodically measuring the retroreflectivity with the retroreflectometer. In this study, reflectivity data were provided from a project conducted by the Idaho Transportation Department (ITD) and collected from field measurements in Alaska's central region. The two data sets provided comparative results of reflectivity performance for various traffic markings, including preformed tapes, thermoplastics, MMA, and traffic paints.

Idaho Data

In 1991, the Idaho Transportation Department initiated a four year project to compare the new traffic marking, Methyl Methacrylate (Dura-Stripe AC or MMA), with other available traffic marking materials [22 - 25]. The following materials were installed in the field during the summer of 1991:

- Preformed tape (3M Stamark 380),
- Sprayed MMA (40 mil and double-drop of standard beads (AASHTO M-27) and Visibeads (MMA-14),
- Extruded MMA (90 mil and standard beads),
- Extruded MMA (90 mil and double-drop of standard beads and Visibeads),
- Sprayed MMA (90 mil and double-drop of standard beads and Visibeads),
- Standard traffic paints, and
- Hot sprayed thermoplastics (125 mil).

These traffic markings were installed as skip lines or edge lines on I-90 westbound (M.P. 37 - 38). Idaho Transportation Department field engineers collected reflectivity data every several months for the following three years. A Mirolux reflectometer measured the retroreflectivity in the field. Several readings were taken for each test.

In our study, the readings measured at a given time were averaged to produce a single value that reflects the reflectivity performance of a test traffic marking material. Table 6 presents the average reflectivity data. Several points should to noted:

1. The service life of traffic paints is usually less than one year. During the four-year project, the test traffic paints were repainted several times, but no such information was documented. Therefore, reflectivity of test traffic paints cannot be compared with other test traffic markings.

2. The first readings of all MMA test materials were much smaller than the second readings (see Table 6). This phenomena is practically impossible. A possible explanation is that the first reflectivity measurements of test MMA materials were not reliable. To reasonably evaluate the reflectivity performance, the first readings of test MMA materials were not used in the study.

3. Reflectivity data on the test thermoplastics did not correlate well with the amount of time that passed. No information is available to explain this.

Historical changes in reflectivity (reflectivity vs. time) are presented in Figures 7 - 12. The curve fitting method was used in this study to predict or statistically represent such changes. The fitting equations have the following mathematical form:

$$\text{Reflectivity} = a + b\,e^{(c\ \text{Time})}$$

where "Reflectivity" is the dependent variable with unit $mcd/m^2/lux$ and "Time" is the independent variable with unit "month." The constants a, b, and c are parameters to be estimated. This natural exponential form has been used to represent decreasing processes of physical objects. This form can be used to describe the reflectivity changes of traffic markings over time.

The resulting curve-fitting equation for each type of test material is shown in the corresponding figures (Figures 7 - 12). Figure 13 presents the fitting curves of all MMA test materials. The curves shown in Figure 13 can be averaged to obtain a single curve that typically represents the reflectivity change of a MMA material over time. Figure 14 shows the curves of reflectivity vs. time for preformed tape, MMA, and thermoplastic. The MMA curve was obtained by averaging the reflectivity data for all MMA test materials. Mathematical forms for these curves are as follows:

Preformed Tape: $\text{Reflectivity} = 191.4 + 584.3\,e^{(-0.125\ \text{Time})}$

MMA: $\text{Reflectivity} = 198.3 + 494.8\,e^{(-0.252\ \text{Time})}$

Thermoplastic: $\text{Reflectivity} = 167.5 + 72.3\,e^{(-0.100\ \text{Time})}$

Figure 14 indicates that preformed tapes and MMA present excellent or good reflectivity performance during the first three years, based on the definition given in the Chapter 3, but thermoplastics show only a good or fair reflectivity performance during the same time period. If the factor of life-cycle cost is taken into consideration, MMA is a more cost-effective traffic marking material, due to its lower cost, than preformed tapes.

Alaska Data

In October 1994 and April 1995, reflectivity data of traffic markings, including traffic paints, preformed tapes (3 M Stamark 380), and MMA in Alaska's central region, was gathered in field surveys. An instrument called Mirolux 12, made by Miro-Bran Assemblers, Inc., collected the reflectivity data. The same survey sites (sites 1-7) used for the subjective survey served to collect reflectivity data. Geometrical locations and site configurations of the survey sites are shown in Appendix A.

To obtain reliable data, several measurement spots were selected for each test section. The length of each section was about 152.5 to 305 meters (500 to 1000 feet). Three subsections (beginning, middle, and end) were selected from each test section. Each subsection was about 1.525 to 4.575 meters (5 to 15 feet) long. Three measurement spots in each subsection were selected, and three repeated measurements were taken from each spot. Thus, 27 measurements were recorded for each traffic marking line in each test site. For each test section, solid or dashed yellow lines (central lines) and white lines (edge and/or fog lines) were measured. Researchers averaged reflectivity data from each site to obtain two statistical values (averaged reflectivity data) to represent the reflectivity performance of yellow and white lines, respectively. A detailed test plan appears in Appendix B.

Table 7 summarizes averaged reflectivity data and other information. Generally, the white lines presented a better reflectivity performance (higher reflectivity value) than the yellow lines. As indicated in Table 7, the performed tapes site 1 had a lower averaged reflectivity value, probably because the tapes at that site 1 were installed about one year earlier than the traffic markings on other sites. The table indicates that winter traffic operations and conditions (snow removal, sands, and studded tires) significantly deteriorated the reflectivity performance of preformed tapes and traffic paints because the averaged reflectivity values of preformed tapes and traffic paints were significantly reduced after one winter. However, the MMA did not show the same reduction in reflectivity. To statistically prove this conclusion, the same type of traffic markings were combined to get the averaged reflectivity data for each traffic marking type, but the data from sites 1, 5, and 7 were not included, because the site 1 traffic markings were installed one year earlier and no measurements were taken from sites 5 and 7 in April, 1995. The available results are summarized in Table 8 and shown in Figures 15 and 16, for yellow and white lines respectively. Table 8 and Figures 15 and 16 show that the percent reduction rates in reflectivity values of traffic paints and preformed tapes after one winter season were significantly larger (21 to 62% for traffic paints and 65 to 69% for preformed tapes) than that of MMA (8 to 13%). Although the preformed tapes may have better initial appearance and reflectivity performance, they may deteriorate faster than MMA.

Table 6. Averaged Reflectivity Data (Collected from Idaho Transportation Department's Project).

	Skip Line			Edge Line			
Time (Months)	3M Stamark 380	Sprayed MMA (40 mil & Double-Drop)	Standard Traffic Paints	Extruded MMA (90 mil & Standard Beads)	Extruded MMA (90 mil & Double-Drop)	Sprayed MMA (90 mil & Double-Drop)	Hot Sprayed Thermoplastics (125 mil)
0	740	294	N/A	275	194	309	161
4	693	390	251	477	373	358	233
7	318	202	162	261	241	222	158
10	347	214	192	274	248	254	192
13	293	197	168	260	224	236	241
20	247	200	181	223	222	235	150
25	219	178	146	191	210	227	193
32	223	176	147	183	194	196	155

Table 7. Results of Reflectivity Measurements in Alaska's Central Region.

Survey Sites	Locations	Installation Time	AADT	Traffic Markings	Ave. Reflectivity ($mcd/m^2/lx$) Yellow Oct. 94	Yellow Apr. 95	White Oct. 94	White Apr. 95
1	Glenn Hwy Phase I-C (Project # 58720)	1993 summer	15,900	Preformed Tape (3M Stamark)	46	43	68	64
2	Glenn Hwy, N. Birchwood to Eklutna (Project # 51037)	1994 summer	17,400	Methyl Methacrylate	198	191	257	227
3	Glenn Hwy, S. Birchwood to N. Birchwood (Project # 50676)	1994 summer	20,600	Traffic Paint	76	50	117	44
4	Glenn Hwy Phase I-D (Old Gleen Interchange-SB Ramp) (Project # 59604)	1994 summer	1,400	Preformed Tape (3M Stamark)	259	91	352	110
5	Seward Hwy, @ MP 50 (Project # 59956)	1994 summer	3,300	Preformed Tape (3M Stamark)	155	N/A*	199	N/A*
6	Sterling Hwy, MP 57-71 (Project # 51041)	1994 summer	2,600	Methyl Methacrylate	250	221	279	236
7	Seward Hwy, @ MP 53 (Project # 59956)	1994 summer	3,300	Preformed Tape (3M Stamark)	320	N/A*	337	N/A*

* Unable to test due to snowfall and wet/muddy surface conditions.

Table 8. Averaged Reflectivity Values and Percent Reduction in Reflectivity.

Traffic Markings	Ave. Reflectivity ($mcd/m^2/lx$)					
	Yellow			White		
	Oct. 1994	Apr. 1995	Reduction	Oct. 1994	Apr. 1995	Reduction
Traffic Paints	76	50	21%	117	44	62%
Preformed Tapes	259	91	65%	352	110	69%
Methyl Methacrylate	224	206	8%	268	232	13%

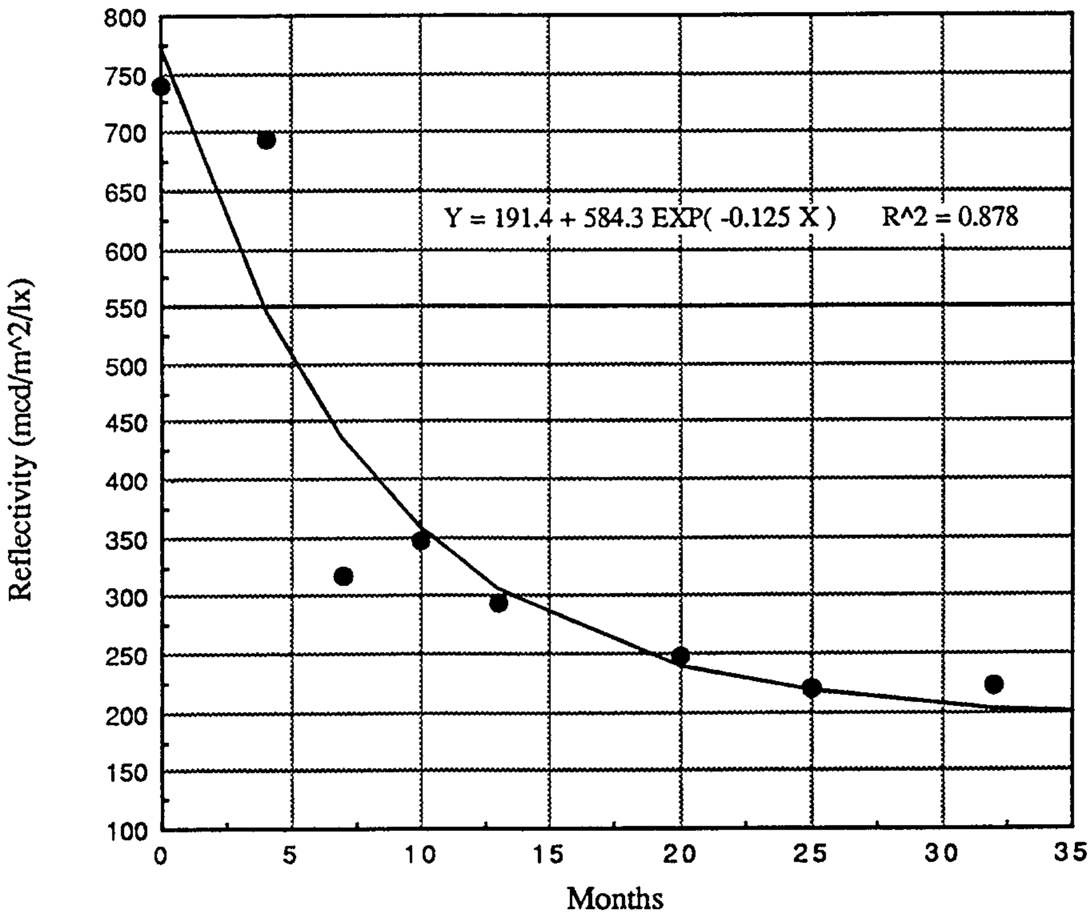

Figure 7. Reflectivity Measurements and Curve Fitting of the Preformed Tape (3M Stamark 380) [22-25].

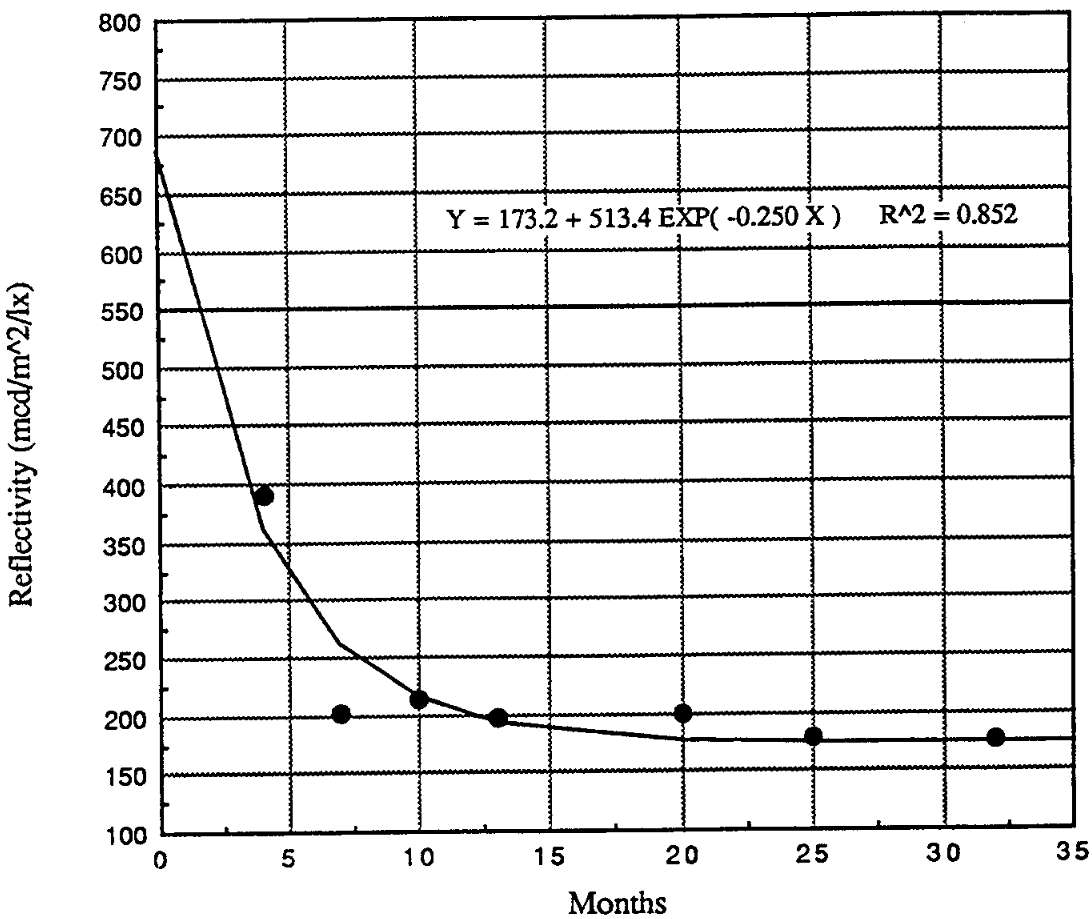

Figure 8. Reflectivity Measurements and Curve Fitting of Sprayed MMA (40 mil and Double-Drop of Standard Beads and Visibeads) [22-25].

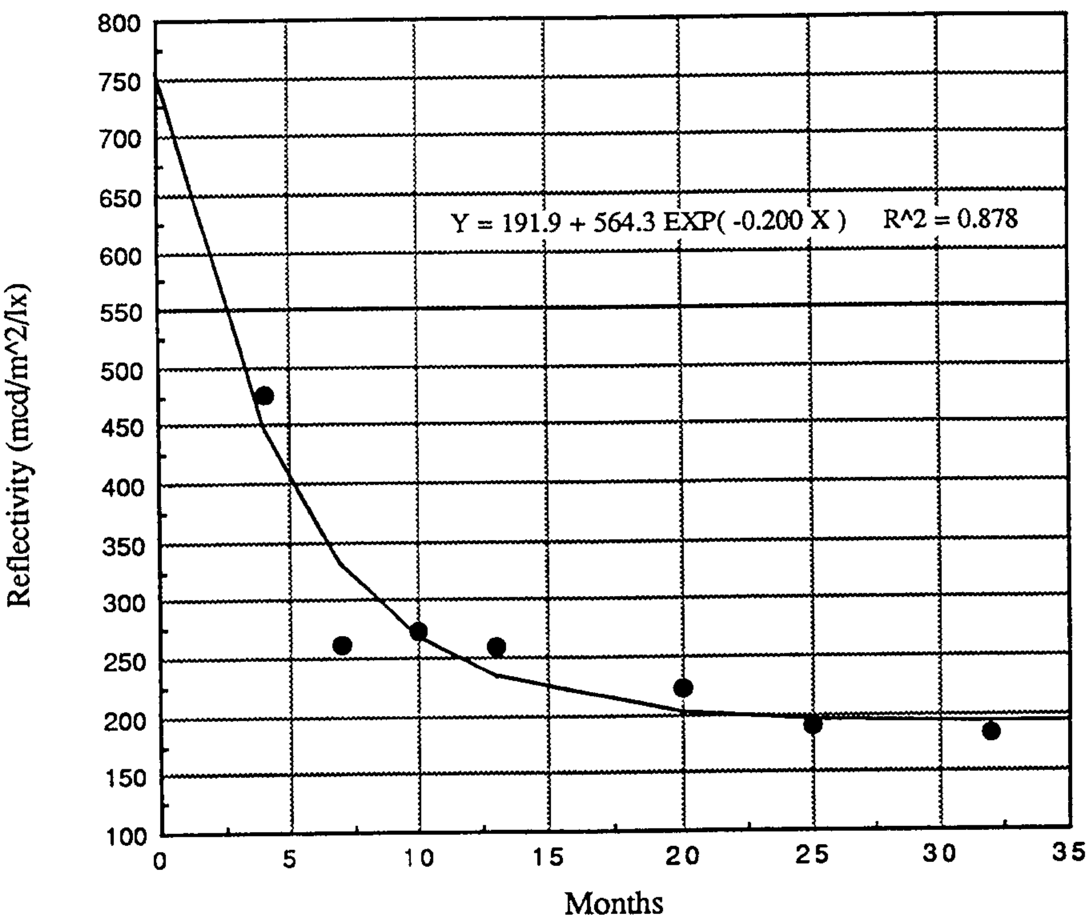

Figure 9. Reflectivity Measurements and Curve Fitting of Extruded MMA (90 mil and Standard Beads - AASHTO M-247) [22-25].

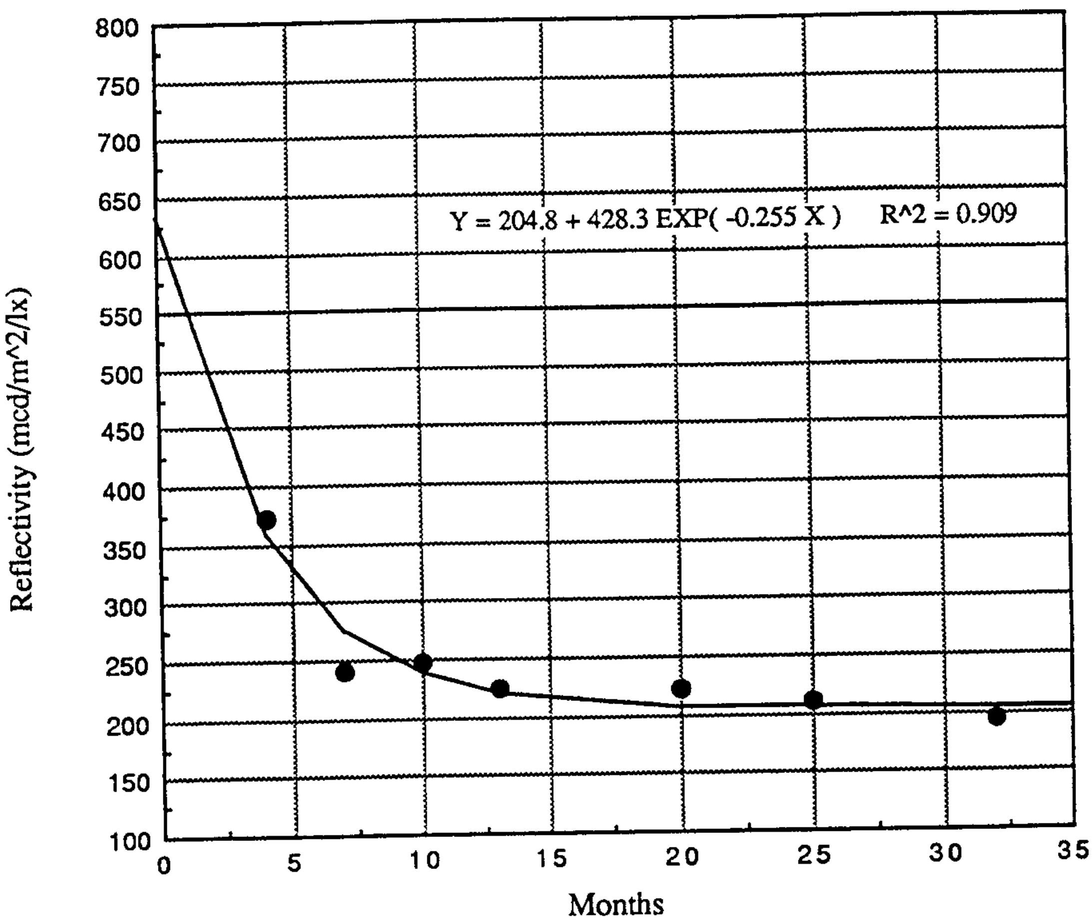

Figure 10. Reflectivity Measurements and Curve Fitting of Extruded MMA (90 mil and Double-Drop of Standard Beads and Visibeads) [22-25].

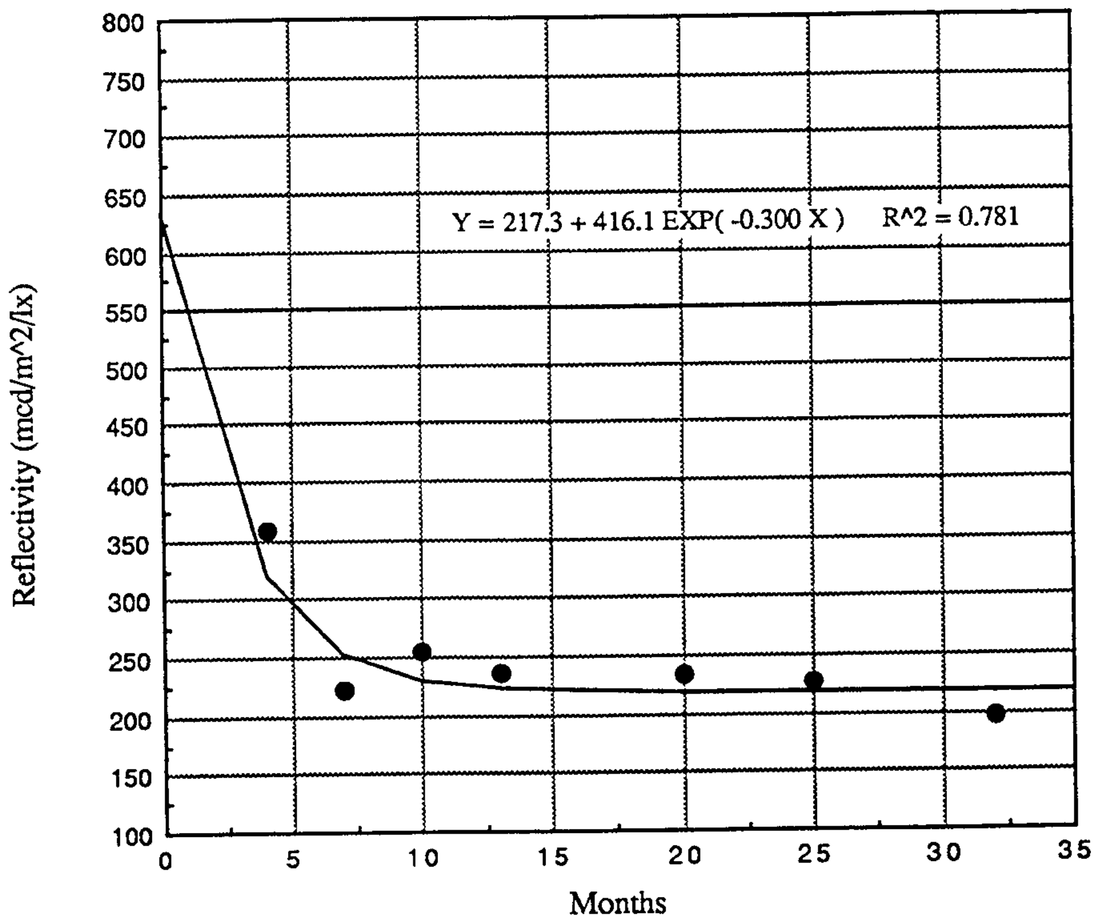

Figure 11. Reflectivity Measurements and Curve Fitting of Sprayed MMA (90 mil and Double-Drop of Standard Beads and Visibeads) [22-25].

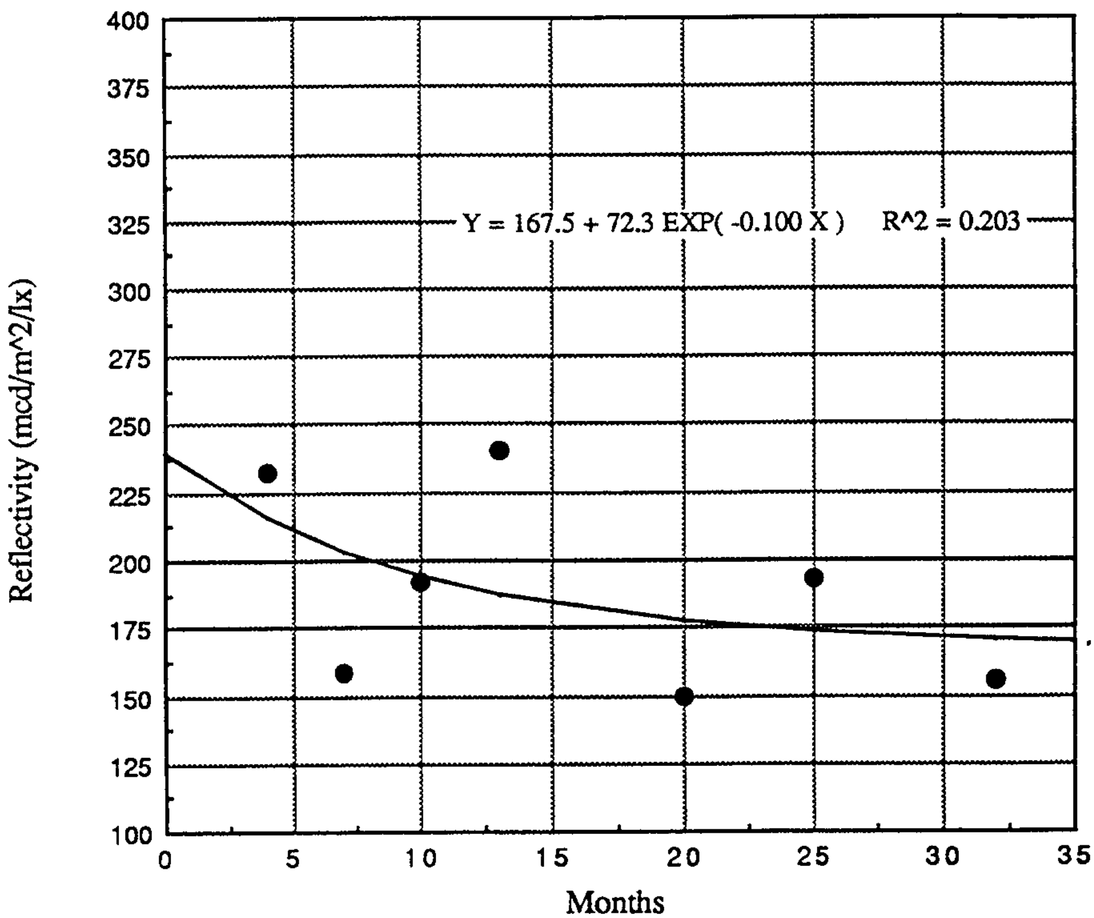

Figure 12. Reflectivity Measurements and Curve Fitting of Sprayed Thermoplastics (125 mil) [22-25].

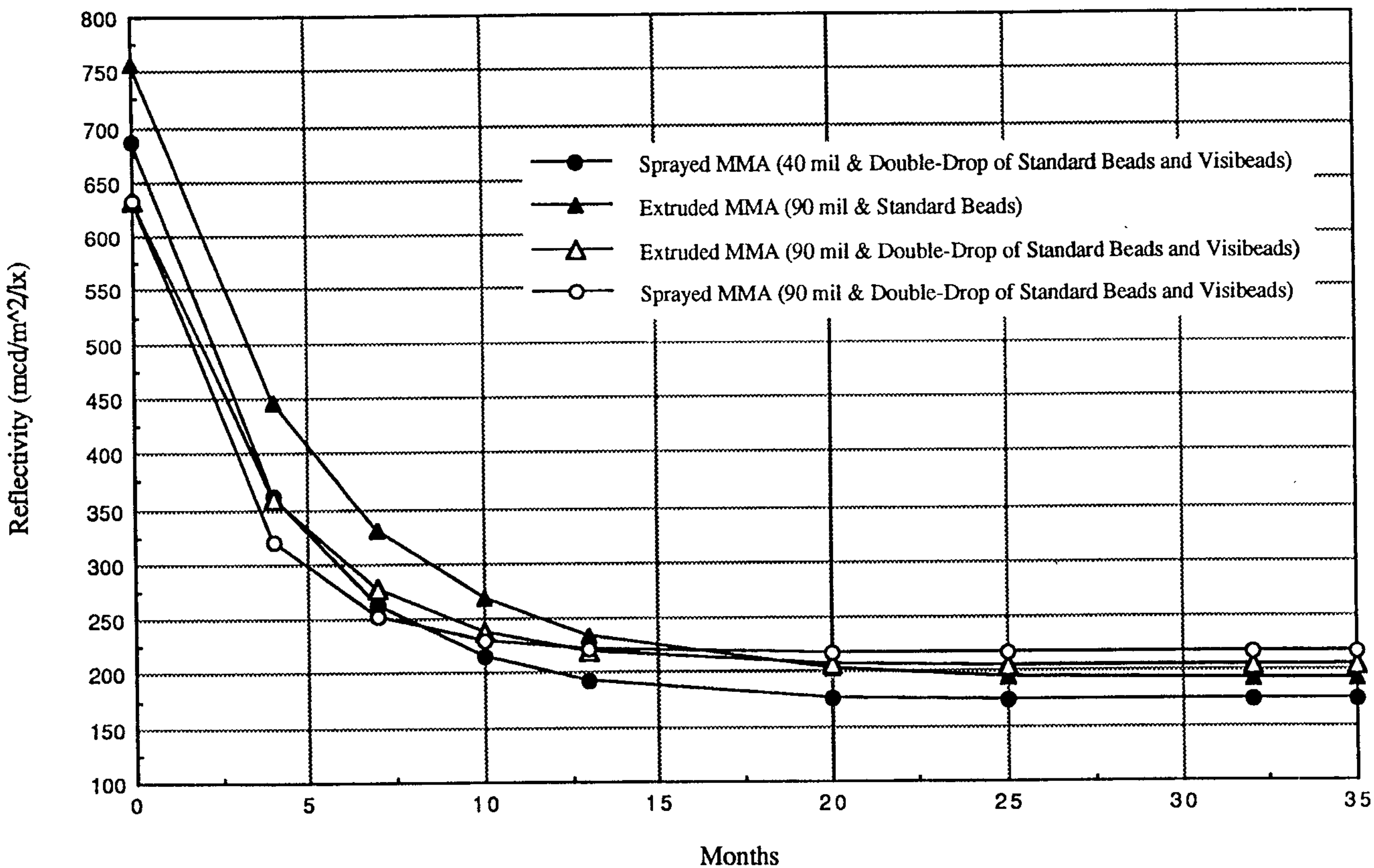

Figure 13. Reflectivity Curves of Test MMA Traffic Markings.

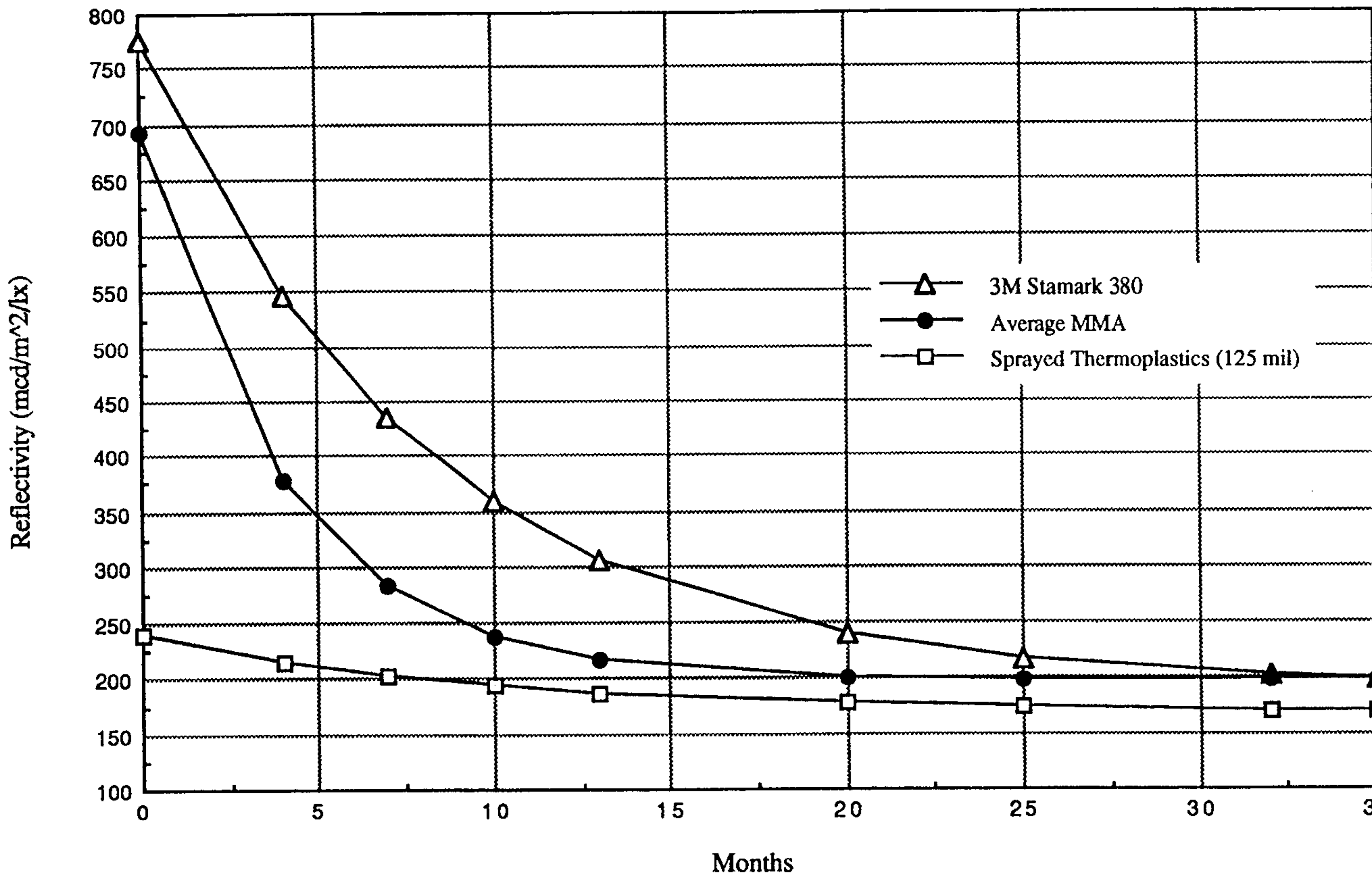

Figure 14. Comparison of Reflectivity Curves (Reflectivity vs. Time).

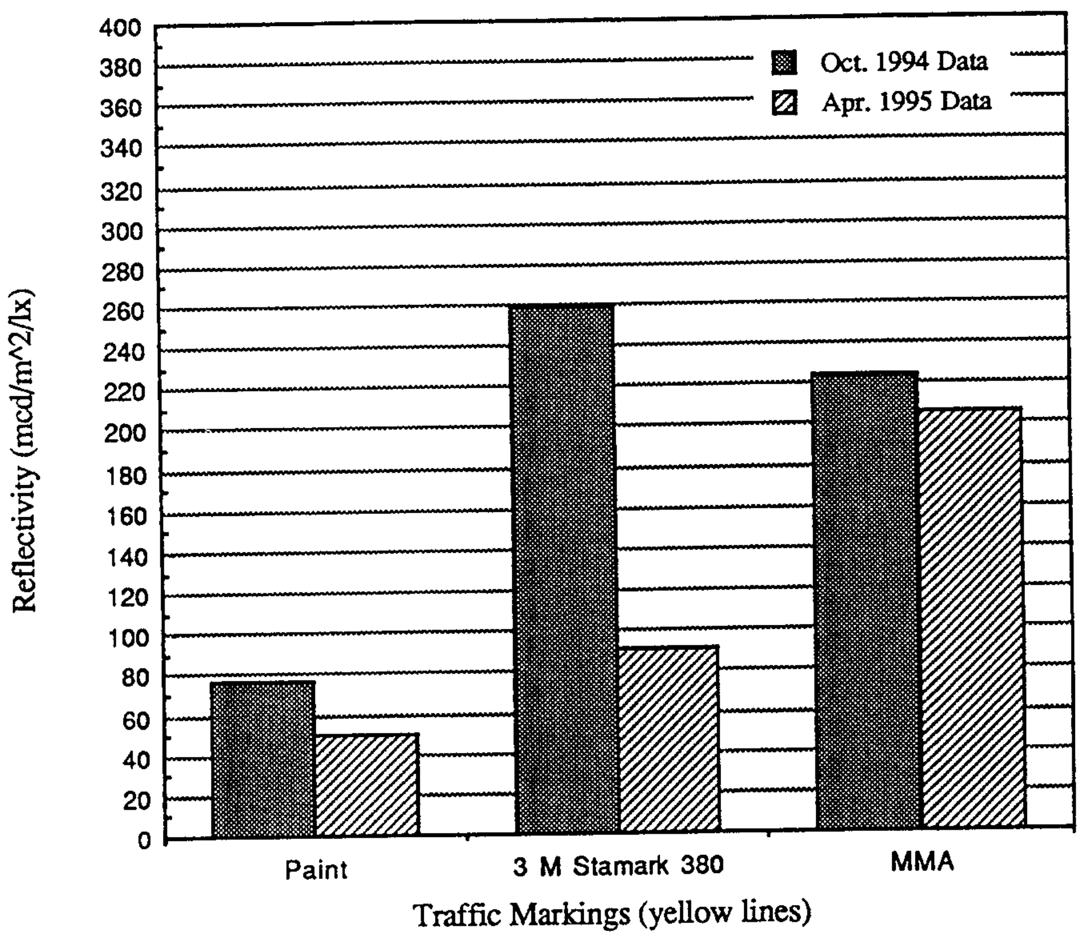

Figure 15. Averaged Reflectivity Data of Yellow Lines (central) Collected from Alaska's Central Region.

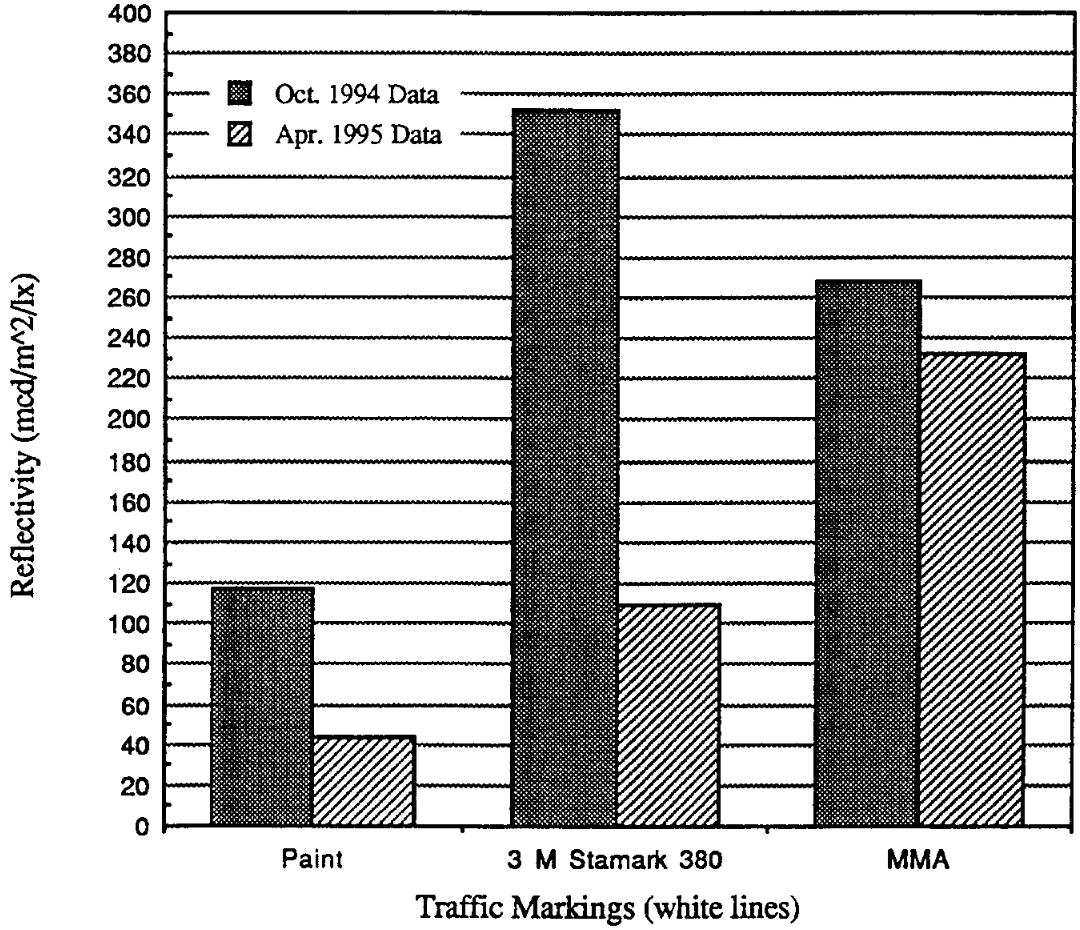

Figure 16. Averaged Reflectivity Data of White Lines (edge & fog) Collected from Alaska's Central Region.

CHAPTER 7. SUBJECTIVE OPINION SURVEY OF TRAFFIC MARKING

Background

One of the major purposes of this study was to compare the Methyl Methacrylate (MMA) with other traffic markings (traffic paints, preformed tapes, and thermoplastics) by reviewing past studies, existing research reports, and other publications. Searching available information resources, revealed no formally published reports, but identify a few documents that record field data and survey comments. These documents were mostly the work of engineers from the Idaho Transportation Department and the Alaska Department of Transportation and Public Facilities. So little information on MMA exists primarily becauses it is a relatively new product, developed and put into use about 5 years ago. Barring some field applications in the northwestern states, no major research study on MMA performance has been conducted in last several years. However, as the result of field applications, many field engineers (including traffic and safety, materials, and maintenance engineers) and traffic marking sales persons have gained a certain knowledge about and experience with MMA. Their comments and views could be used to subjectively evaluate this new product. In this case, an opinion survey about traffic markings (preformed tapes, sprayed thermoplastics, extruded thermoplastics, sprayed MMA, extruded MMA, and traffic paints) could be a feasible way to evaluate and compare the performance of these traffic markings.

Survey Contents

Researchers designed subjective opinion survey forms on preformed tapes, thermoplastics, MMA, and traffic paints for this study. The survey questions focused on the three most important aspects:

1. Performance
   - Expected service life
   - Visibility (day time and night time)
   - Durability to studded tires and snow plowing
   - Cost (initial and life-cycle costs)
2. Applications
   - Main reasons for failure
   - Applicable traffic volume ranges (low, moderate, and high volumes)
   - Applicable lines (edge, central, lines, transverse, and other)
3. Installation
   - Best air temperature ranges for field placement
   - Drying time

The survey provided three types of answering methods: comments, scoring, and multiple choice. The survey forms and accompanying instructions are presented in Appendix C.

The forms were sent to many agencies that had used preformed tapes, thermoplastics, MMA, and traffic paints on their roadways. The agencies surveyed included: (1) Traffic and safety, Materials, and Maintenance divisions or sections in the Southeast, Central, and Northern regions of AKDOT&PF; (2) some city and/or state departments of transportation in Idaho, Oregon, and Washington; (3) some city and/or province departments of transportation in Canada; and (4) major traffic marking distributors (Morton International Inc. and Lafrentz Road Service Limited). Researchers made follow-up calls to the agencies to ensure that the survey forms were received, completed, and returned. Most forms were completed and returned to UAF/TRC within one month. Survey results are summarized in the next section.

Survey Results

The people surveyed have knowledge and experience related to traffic markings, specifically, preformed tapes, thermoplastics, MMA, and traffic paints. Their opinions may statistically represent performance ratings of the traffic markings. In this study, about a 60% return rate on the surveys was achieved. Survey results were summarized using statistical methods and are presented as follows.

1. Traffic Marking Performance

a. Expected service life

To obtain information on the expected service life of each traffic marking type, one question was asked for an estimated service life range for each traffic marking type. An averaged lower range and higher range were obtained and are shown as follows:

Traffic Marking Type	Expected Service Life	Mean
Preformed Tapes	2.7 to 5.4 years	4.1 years
Sprayed Thermoplastics	2.0 to 3.0 years	2.5 years
Extruded Thermoplastics	4.8 to 7.0 years	6.0 years
Sprayed MMA	3.6 to 8.3 years	6.0 years
Extruded MMA	4.5 to 8.2 years	6.4 years
Traffic Paints	6.6 to 12.8 months	0.8 years

Based on the survey results, extruded thermoplastics, sprayed MMA, and extruded MMA were expected to have longest service lives, and traffic paints the shortest, as compared with other traffic markings evaluated. A subjective score, symbolized by A_{SL}, can be used to evaluate the service life of each traffic marking material type. The expected service life was converted to the service life ranking by the following scale:

Mean Value of Expected Service Life:	0.5 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6 (years)
Subjective Score:	0	1	2	3	4	5

Subjective scores for the expected service life of each marking type are presented as follows:

Traffic Marking Type	Score (A_{SL})
Preformed Tapes	4
Sprayed Thermoplastics	2
Extruded Thermoplastics	5
Sprayed MMA	5
Extruded MMA	5
Traffic Paints	0

b. Visibility

The information on visibility was not based on retro-reflectivity measured by an instrument, but on the subjective opinions of the people surveyed. Six scores (0, 1, 2, 3, 4, and 5) were used in this survey. (A score of "0" represents the worst visibility rating and "5" the best). Scores checked by the survey respondents were averaged to get a summarized rating. The subjective ratings of visibility performance were divided into categories of "the first half of service life, daytime and nighttime" and "the second half of service life, daytime and nighttime." The following presents the summarized results:

Traffic Marking Type	1 st-half Service Life		2 nd-half Service Life		Mean (A_{VI})
	Day	*Night*	*Day*	*Night*	
Preformed Tapes	3.9	3.9	2.5	1.6	3.0
Sprayed Thermoplastics	3.8	3.5	2.0	2.0	2.8
Extruded Thermoplastics	4.1	3.9	2.8	2.6	3.4
Sprayed MMA	4.5	4.3	3.6	3.3	3.9
Extruded MMA	4.6	4.2	3.3	3.0	3.8
Traffic Paints	3.8	3.6	1.9	1.6	2.7

A_{VI} symbolizes the mean value of the visibility rating. Note that, in the above table, the sprayed and extruded MMA may have better visibility performance in the second half of service life. To statistically evaluate visibility performance, mean values of subjective scores for "the first half of service life, daytime and nighttime" and "the second half of service life, day time and night time" are also presented in the above table. From this table, one can conclude that MMA provided better service performance in terms of its visibility than other traffic marking types.

c. Durability

The survey also asked for subjective ratings about traffic markings' durability under studded tires and snow plowing. (The score "0" represents the worst durability and "5" the best). Averaged scores represent the durability performance of each traffic marking type. Results are as follows :

Traffic Marking Type	Averaged Durability Score (A_{DU})
Preformed Tapes	1.8
Sprayed Thermoplastics	0.8
Extruded Thermoplastics	3.0
Sprayed MMA	4.0
Extruded MMA	3.6
Traffic Paints	2.0

A_{DU} symbolizes the averaged durability score. According to the above results, the sprayed and extruded MMA presented the best durability ratings, and the sprayed thermoplastics the worst. The poor durability of sprayed thermoplastics may be one of the main reasons that they are seldom used in cold regions such as the northwestern states.

d. Cost

Subjective ratings for each traffic marking type's cost consisted of initial, life cycle, and over all cost ratings. The scores from 0 to 5 were used to evaluate cost performance ("0" representing the cheapest and "5" the most expensive). Cost scores were averaged and presented as follows:

Traffic Marking Type	Initial Cost	Life Cycle Cost	Overall Cost (A_{OC})
Preformed Tapes	4.1	3.6	3.5
Sprayed Thermoplastics	2.3	2.3	2.8
Extruded Thermoplastics	4.0	2.9	2.9
Sprayed MMA	4.1	2.0	2.1
Extruded MMA	4.3	2.3	2.4
Traffic Paints	1.0	2.9	2.6

Responses to this survey suggest that preformed tapes, extruded thermoplastics, and sprayed and extruded MMA may have relatively higher initial costs than traffic paints and sprayed thermoplastics. However, based on the subjective ratings, preformed tapes may have highest life cycle cost. If the overall cost ratings are used, traffic paints and MMA may cost least, preformed tapes the most. The overall cost score, symbolized by A_{OC}, represents the statistical performance of each traffic marking type.

e. Summarized performance ratings

To summarize, these performance averages (A_{SL}, A_{VI}, A_{DU}, and A_{OC}) can be averaged to create an index that can indicate the overall performance rating of each traffic marking type. The simplest way to provide this index is to generate an equally weighted average score that includes all performance ratings. This score, called the "summarized performance score," is symbolized by A_{SPS}. Mathematically, the summarized performance score can be obtained using the following equation:

$$A_{SPS} = \frac{A_{SL} + A_{VI} + A_{DU} + (5 - A_{OC})}{4}$$

where all variables have been defined previously. A higher value of A_{SPS} indicates better performance. The following gives the summarized performance score for each traffic marking type, using the above equation:

Traffic Marking Type	Summarized Performance Score (A_{SPS})
Preformed Tapes	2.58
Sprayed Thermoplastics	1.95
Extruded Thermoplastics	3.38
Sprayed MMA	3.95
Extruded MMA	3.75
Traffic Paints	1.78

Based on these subjective rating scores, the new product, MMA, has been considered the most cost-effective traffic marking material by transportation engineers in cold regions. Although the methods used in this survey may not accurately reflect the real performance ratings of each marking material type, the subjective rating scores presented do show a certain amont of statistical evidence about the performance of these traffic markings. In general, this survey indicates that MMA is a cost-effective traffic marking material suitable for cold regions, such as Alaska.

2. Application Aspects

a. Main reasons for failure

To answer this question, each person surveyed was required to list one or more main reasons for the failure of each traffic marking type, such as abrasion, shaving, bond failure, and so on. The frequency (percentage rate %) of each reason for failure listed by persons surveyed in this study was used as a way to summarize the main reasons for failure. The survey results are as follows:

Traffic Marking Type	Percentage Rates (%)			
	Abrasion	*Shaving*	*Bond Failure*	*Pavement Failure*
Preformed Tapes	67%	58%	33%	0%
Sprayed Thermoplastics	100%	33%	0%	0%
Extruded Thermoplastics	56%	11%	44%	33%
Sprayed MMA	71%	43%	43%	0%
Extruded MMA	78%	22%	22%	0%
Traffic Paints	83%	25%	8%	0%

The survey results statistically indicate the main reasons for failure of each traffic marking type. By reviewing the percentage rates, the following conclusions can be made:

Traffic Marking Type	Main Reasons For Failure
Preformed Tapes	abrasion, shaving, and bond failure
Sprayed Thermoplastics	abrasion and shaving
Extruded Thermoplastics	abrasion, bond failure, and pavement failure
Sprayed MMA	abrasion, shaving, and bond failure
Extruded MMA	abrasion, shaving, and bond failure
Traffic Paints	abrasion and shaving

b. Applicable traffic volumes

This question was designed to find whether a traffic marking material type had, in the respondent's experience, been used successfully with low, moderate, or high traffic volumes. If a traffic marking material type can be used for a roadway with high traffic volume, it can also be used for a roadway with moderate or low traffic volumes. The frequency (percentage rate %) of a traffic volume type checked by persons surveyed was used to summarize such evaluation, and the results are presented as follows:

Traffic Marking Type	Percentage Rates (%)		
	Low Volume	*Moderate Volume*	*High Volume*
Preformed Tape	7%	57%	36%
Sprayed Thermoplastics	75%	25%	0%
Extruded Thermoplastics	22%	33%	56%
Sprayed MMA	13%	25%	88%
Extruded MMA	11%	22%	78%
Traffic Paints	69%	69%	56%

The results shown above indicate that preformed tapes had, in the respondent's experience, been used successfully on roadways with moderate traffic volumes; sprayed thermoplastics on roadways with low traffic; extruded thermoplastics on those with high traffic; sprayed and extruded MMA on roadways with high traffic; and traffic paints on all kinds of roadways.

c. Applicable line type

This question was designed to find what types of traffic marking lines for which each material type had, in the respondent's experience, been used successfully. Again, the frequency rate was used. The following presents the survey results:

Traffic Marking Type	Percentage Rates (%)			
	Central Line	*Edge Line*	*Lane Line*	*Transverse*
Preformed Tapes	91%	64%	82%	55%
Sprayed Thermoplastics	33%	67%	33%	33%
Extruded Thermoplastics	56%	67%	67%	78%
Sprayed MMA	100%	88%	88%	50%
Extruded MMA	67%	56%	56%	67%
Traffic Paints	100%	100%	100%	79%

Basically, the above results indicate that all traffic markings evaluated had been used successfully for all kinds of purposes (central, edge, lane, and transverse lines or letters).

3. Installation Aspects

a. Air temperature

During field installation, an adequate air temperature range should be given to ensure the traffic marking installation quality. Practically, the lowest air temperature is most important. Installation at too cold an air temperature may result in a reduced service life. In this study, all persons surveyed were asked to indicate the lowest air temperature for successful installation, or a range of adequate air temperature for each traffic marking material type. To statistically summarize the survey results, the averaged lowest air temperature for each traffic marking type was obtained. The following presents these survey results:

Traffic Marking Type	Ave. Lowest Air Temperature for Installation (^oC)
Preformed Tapes	13 (57 ^oF)
Sprayed Thermoplastics	14 (58 ^oF)
Extruded Thermoplastics	9 (49 ^oF)

Sprayed MMA	-1 (30 ^{o}F)
Extruded MMA	-5 (24 ^{o}F)
Traffic Paints	7 (45 ^{o}F)

The survey results indicate that sprayed and extruded MMA can be installed in a cold environment [as low as -5 (24 ^{o}F)]. This characteristic may make MMA most applicable to Alaska's environments, where there is a need for marking materials that can be successfully installed during colder seasons such as spring and fall.

b. Drying time

Drying time is an important index for the necessary traffic control during field installation of traffic markings. The survey forms listed several choices, such as instant dry (less than 30 sec.), quick dry (30-120 sec.), fast dry (2-7 min.), and conventional (more than 7 min.). If the frequency (percentage rate %) checked by persons surveyed for each drying time group is used, the following results can be obtained :

Traffic Marking Type	Percentage Rates (%)			
	Instant Dry	*Quick Dry*	*Fast Dry*	*Conventional*
Preformed Tapes	63%	12%	0%	25%
Sprayed Thermoplastics	0%	50%	50%	0%
Extruded Thermoplastics	0%	0%	63%	37%
Sprayed MMA	14%	0%	14%	72%
Extruded MMA	13%	13%	0%	74%
Traffic Paints	25%	50%	25%	0%

The definition of drying time for preformed tapes may not have been clear to some survey respondents; several did not correctly respond to this question. In fact, performed tapes require no drying time, but they should be rolled. The rolling procedure may take a certain amont of time before the road section can be opened to traveling public. Some respondents may have equated "drying time" with "use delay." To correctly interpret the survey results, preformed tapes are not included in this evaluation category. Based on the summary results, the drying time for each traffic marking type (except preformed tapes) are shown as follows:

Traffic Marking Type	Drying Time
Sprayed Thermoplastics	quick to fast dry
Extruded Thermoplastics	fast to conventional dry
Sprayed MMA	conventional dry

Extruded MMA	conventional dry
Traffic Paints	instant to fast dry

4. Overall Rating

In each survey form, the last question was "what is your overall rating (combining all factors)?" The score scale was 0 to 5, with "0" representing the worst and "5" the best. The purpose of such a question was to generate a rating score for each traffic marking type if all factors (including performance, applications, and installation) were taken into consideration. The rating scores can statistically and practically represent applicabilities of these traffic markings in cold regions, and they may be used as a reference for selecting traffic marking materials.

Researchers averaged the rating scores from all survey forms to obtain an overall rating for each traffic marking type. The following table shows the survey results:

Traffic Marking Type	Averaged Overall Rating Scores
Preformed Tapes	2.52
Sprayed Thermoplastics	1.75
Extruded Thermoplastics	3.11
Sprayed MMA	4.00
Extruded MMA	4.00
Traffic Paints	2.33

The overall rating scores give some idea about the raters' preferences when selecting a traffic marking material. Based on the above results, both sprayed and extruded MMA were rated highest by survey respondents.

Survey Summary

A subjective opinion survey is a useful way to evaluate traffic markings if no sufficient data is available. In our study, the persons surveyed included traffic and safety engineers, highway materials engineers, highway maintenance engineers, and major traffic marking distributors in northwest states and some provinces of Canada. Most of those surveyed have a good background and experience in applying traffic markings, specially preformed traffic tapes, thermoplastics, MMA, and traffic paints. The survey results, therefore, statistically and practically reflect the applicabilities of these traffic markings used in cold regions. Such results will be useful for decision makers involved in Alaska's highway operations.

Three question categories were surveyed: performance, applications, and installation. The first category was important in reaching a conclusion about the performance of the surveyed types of traffic marking materials. The second and third categories resulted in useful information on the usage and installation practices used for these traffic marking materials.

Two important conclusions were obtained: a summarized performance and an overall rating. Based on the rating scores that resulted from the summarized performance and overall rating, the following ranks can be assigned if the traffic marking materials are ranked according to their rating scores:

Summarized Performance Rank	Overall Rating Rank	Rank
Sprayed MMA	Sprayed and Extruded MMA	1 (best)
Extruded MMA	Extruded Thermoplastics	2
Extruded Thermoplastics	Preformed Tapes	3
Preformed Tapes	Traffic Paints	4
Sprayed Thermoplastics	Sprayed Thermoplastics	5
Traffic Paints		6 (worst)

These two conclusions are very similar, except for the rank positions of traffic paints and sprayed thermoplastics. It can be concluded that sprayed and extruded MMA are well recognized by transportation engineers in cold regions and can be successfully applied in Alaska.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study evaluated the performance of traffic markings used in Alaska and other northwestern states, including Washington, Idaho, and Oregon States. Primarily, this study was conducted by reviewing existing reports, past studies, and information databases; conducting a field survey that subjectively rated existing traffic markings in Alaska's central region; conducting field measurements of retro-reflectivity of traffic markings using a reflectometer in Alaska's central region; and conducting a subjective opinion survey about the performance of traffic markings, including preformed tapes, thermoplastics, Methyl Methacrylate (MMA), and traffic paints.

One of the main functions of traffic markings is guiding the traveling public. It has been proven that marking patterns affect drivers' behavior, in items of vehicle speed, vehicle lateral position and placement, and number of encroachments any given vehicle might make. Traffic markings that perform adequately, therefore, are necessary to maintaining roadways safety performance.

Reflectivity, the most important performance quality of a traffic marking, can be measured by a reflectometer. Currently, no standard specifications have been made to require minimum reflectivity for markings. However, a minimum reflectivity of 100 $mcd/m^2/lx$ has been recognized by many researchers and transportation engineers. If a traffic marking has a reflectivity lower than 100 $mcd/m^2/lx$, generally, it is considered unacceptable in the field and should be replaced.

Various traffic marking materials (including preformed tapes, thermoplastics, MMA, and traffic paints) have been applied in the northwestern states. The MMA is a new product recently introduced. This product has been well recognized by transportation engineers due to its good reflectivity performance, long service life, reasonable cost, and low application temperature. Based on results from the general evaluation of traffic markings, the following general performance can be concluded:

> Traffic paints, preformed tapes, and MMA are suitable for severe winter conditions. Thermoplastics are not suitable for cold regions.
>
> Traffic paints have the shortest service lives (4 months to 1 year). The other materials (preformed tapes, MMA, and thermoplastics) have about the same service life range. In addition to material type, other factors such as installation procedure, traffic volume, winter snow removal operations, and studded tires contribute to service lives.

Based on the cost analysis, high initial costs accompany preformed tapes and extruded MMA; medium to high initial costs for thermoplastics; medium initial costs for sprayed MMA; and low initial costs for traffic paints. However, if a seven-year life cycle is considered, preformed tapes have the highest life cycle costs, and the others have relatively similar costs.

MMA can be installed in the field at a temperature as low as -1 ^{o}C (30 ^{o}F). Other traffic marking materials require more moderate temperatures. MMA can be applied during the cold season in cold regions, such as Alaska.

Two field subjective surveys were conducted to evaluate traffic marking performance in Alaska. In the first survey, conducted in May, 1994 to evaluate MMA traffic markings, MMA traffic markings installed in 9 sites were subjectively surveyed by engineers from AKDOT&PF. The surveyors concluded that MMA had provided good performance quality and still presented good visibility and appearance during the survey time. The second survey, planned in this study and conducted in October, 1994 and April, 1995, evaluated preformed tapes, MMA, and traffic paints that were installed to form edge (white) and central (yellow) lines. Five subjective ratings (very poor, poor, fair, good, and excellent) were used in the survey. Appearance and reflectivity were used as the basis for the subjective rating. The results and comments made by field staff during the survey in October, 1994 indicated that the preformed tapes and MMA provided the best results in terms of appearance and reflectivity. The subjective rating of traffic paints was lowest. However, the survey results obtained in April, 1995 indicated that the preformed tapes deteriorated faster, compared with MMA. One important comment made by field staff was that the MMA traffic marking provided the brightest reflectivity, even on wet pavement surfaces.

A four-year reflectivity data set was analyzed in this study. This data set included reflectivity data on preformed tapes, thermoplastics, MMA, and traffic paints. Analysis results indicated that preformed tapes presented the best initial reflectivity performance. However, MMA reflected as well as preformed tapes and presented much better reflectivity performance than thermoplastics and traffic paints. The reflectivity of preformed tapes dropped faster in the first three years, compared with MMA. In general, preformed tapes and MMA presented satisfactory reflectivity performances in the first four years.

A reflectometer also gathered data on preformed tapes, MMA, and traffic paints in Alaska's central region in October 1994 and April 1995. Most traffic markings evaluated were installed in the summer of 1994. Data analysis indicated that preformed tapes and MMA presented very good initial reflectivity, compared with traffic paints. However, the reflectivity of preformed tapes dropped much faster than MMA. The data obtained in April 1995 indicated that the reflectivity performance of yellow preformed tapes, MMA, and traffic paints reduced 65%, 8%, and 21%, respectively, and the reflectivity performance of white preformed tapes, MMA, and traffic paints dropped 69%, 13%, and 62%, respectively, compared with the reflectivity performance measured in October 1994. According to this data, the MMA had a better reflectivity performance and a longer service life in terms of reflectivity requirement.

One of the key elements of this study was the subjective opinion survey on the performance of preformed tapes, thermoplastics, MMA, and traffic paints. The survey covered three question categories: performance, applications, and installation. The performance category was most useful in reaching a conclusion about performance of traffic markings surveyed. The second and third categories resulted in helpful information on the use and installation of these traffic marking materials. Based on scores from summarized performance and overall rating, the following ranks were obtained:

Summarized Performance Rank	Overall Rating Rank	Rank
Sprayed MMA	Sprayed and Extruded MMA	1 (best)
Extruded MMA	Extruded Thermoplastics	2
Extruded Thermoplastics	Preformed Tapes	3
Preformed Tapes	Traffic Paints	4
Sprayed Thermoplastics	Sprayed Thermoplastics	5
Traffic Paints		6 (worst)

In conclusion, sprayed and extruded MMA are well recognized by transportation engineers in cold regions and can be successfully applied in Alaska.

Recommendations

Results from this research project indicate that MMA showed satisfactory performance in the field. MMA will be a suitable traffic marking material in Alaska. To effectively adopt this new product in Alaska, field trials and experiments of MMA should be continued.

In the past, no reflectivity data and other performance ratings of traffic markings have been well documented in Alaska. To objectively and correctly evaluate the long term performance of various traffic markings, necessary information on traffic marking performance should be regularly measured and recorded to form a useful database. This database will help decision makers to correctly select a cost-effective material for traffic markings in Alaska.

An accelerated field experiment is recommended to compare the performance of various traffic marking materials to be used in Alaska. Traffic markings such as preformed tapes, MMA, and traffic paints should be installed in the same experimental site with the same given conditions. Reflectivity and other performance qualities should be closely monitored on a regular basis. Results obtained through such a field experiment may result in better understanding of traffic marking performance.

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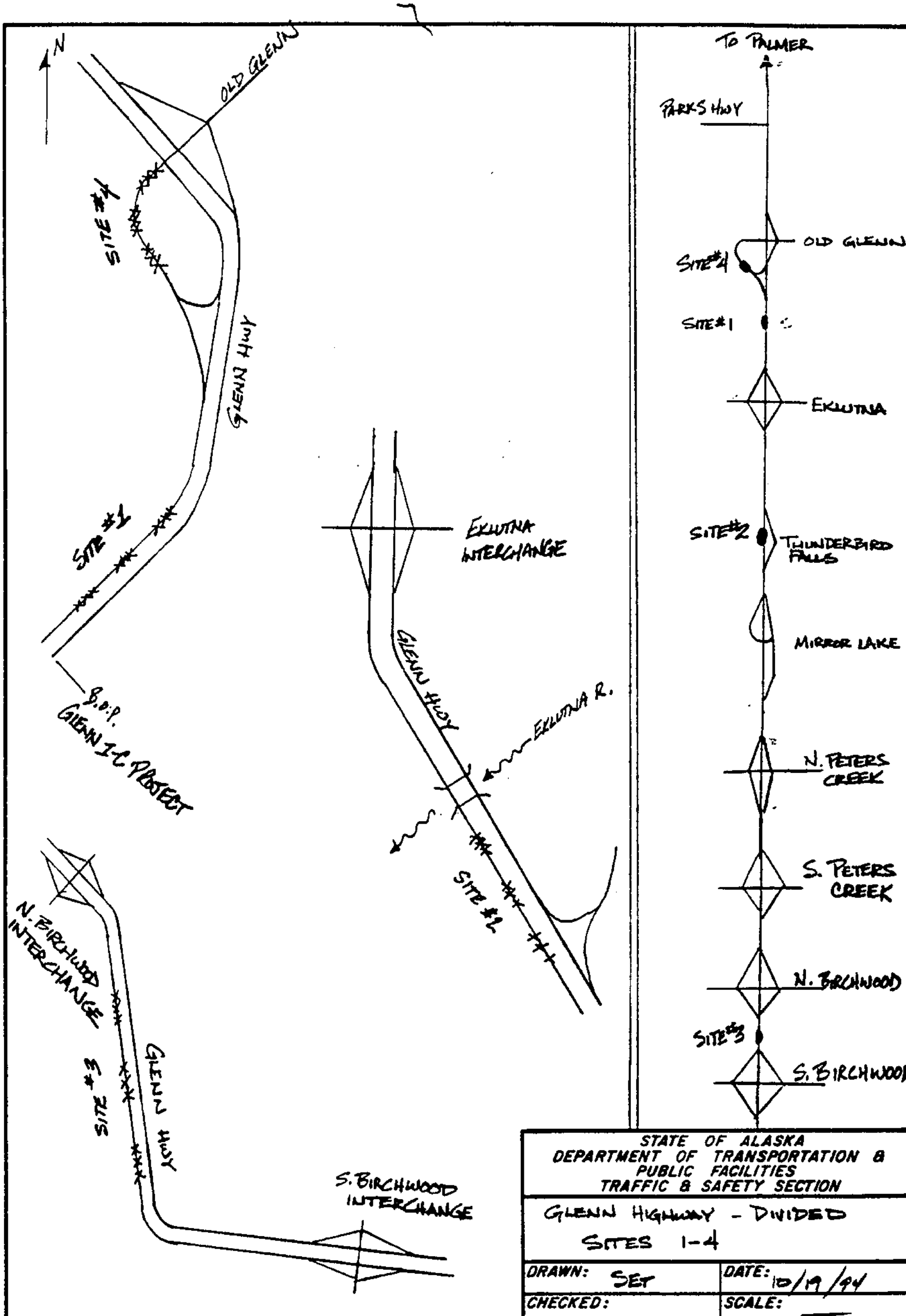
APPENDIX A

Geometrical Locations of Field Survey Sites in Alaska's Central Region


N
OLD GLENN
SITE #4
GLENN HWY
SITE #1
B.O.P.
GLENN I-C PROJECT
EKLUTNA INTERCHANGE
GLENN HWY
EKLUTNA R.
SITE #2
N. BIRCHWOOD INTERCHANGE
SITE #3
GLENN HWY
S. BIRCHWOOD INTERCHANGE
TO PALMER
PARKS HWY
OLD GLENN
SITE #4
SITE #1
EKLUTNA
SITE #2
THUNDERBIRD FALLS
MIRROR LAKE
N. PETERS CREEK
S. PETERS CREEK
N. BIRCHWOOD
SITE #3
S. BIRCHWOOD
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES
TRAFFIC & SAFETY SECTION
GLENN HIGHWAY - DIVIDED
SITES 1-4
DRAWN: SET
DATE: 10/19/94
CHECKED:
SCALE: —

State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

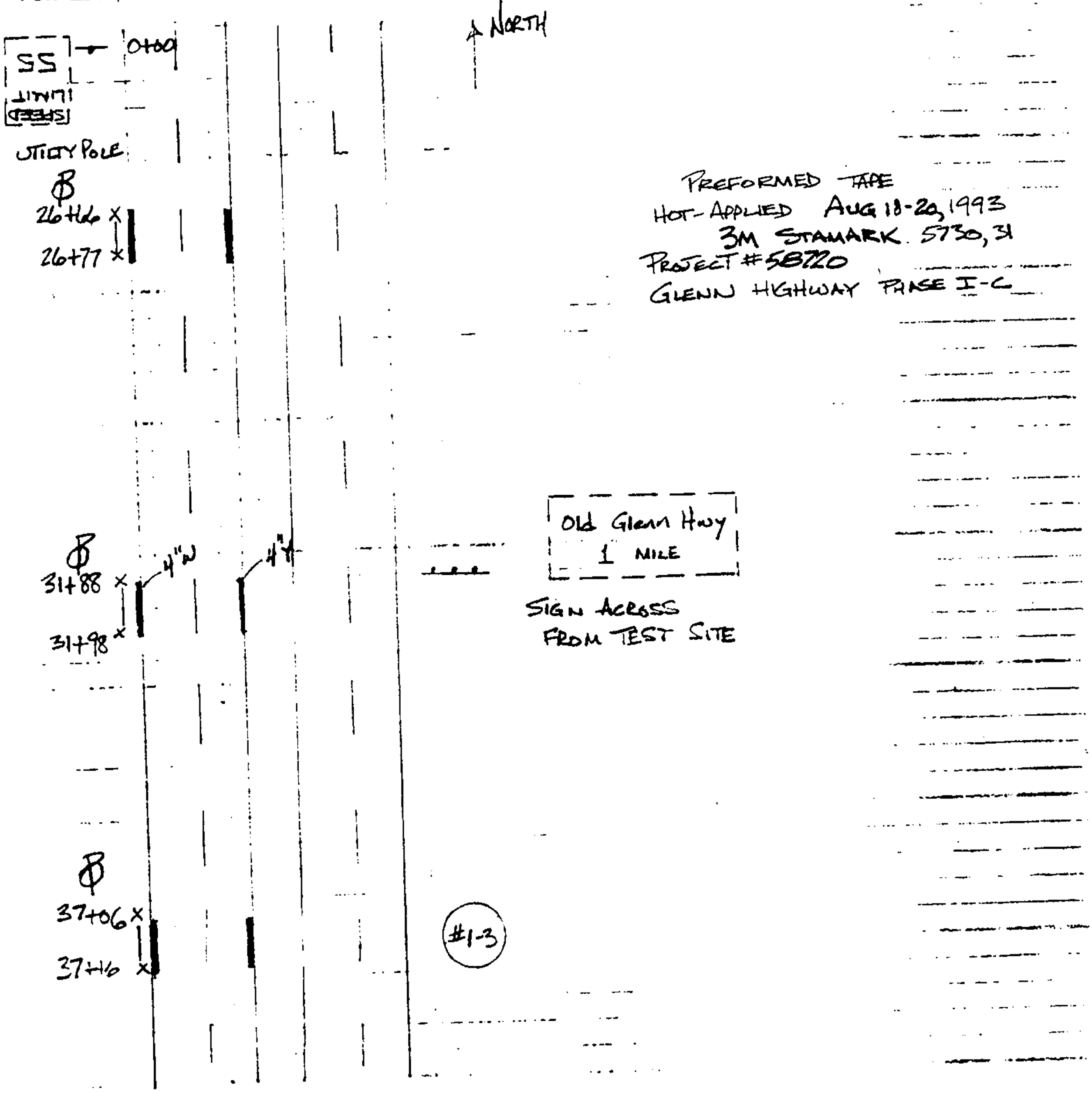
COMPUTATIONS

Item No. ________

Date WED 10/12/94
Project No. ________
Project Name ________
Calc. By SET/MB
Checked By ________

SITE #1

FOR GLENN HIGHWAY



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State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

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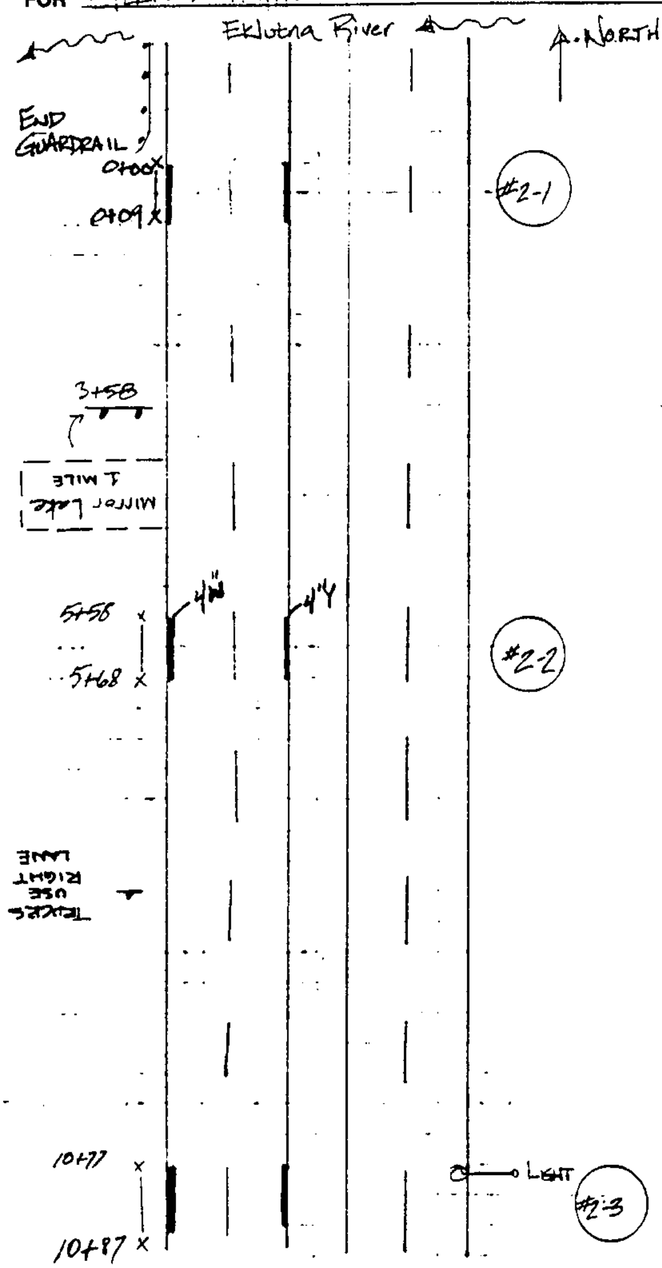

NORRIS
METHYL METHACRYLATE, TYPE V
60 MILS

PROJECT # 51037
GLENN HIGHWAY RUT REPAIR
N. BIRCHWOOD TO EKLUTNA

Sheet______of______Sheets

State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

COMPUTATIONS

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Project No. ______
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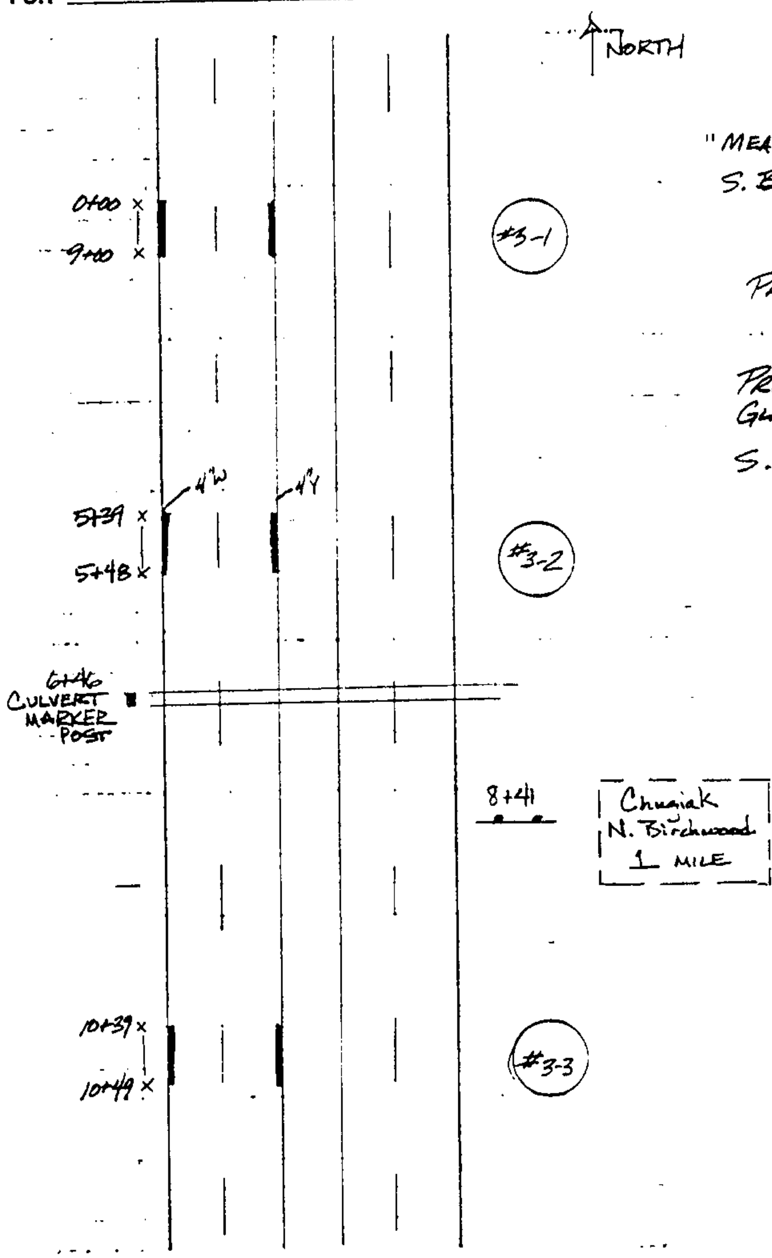
FOR SITE #3 GLENN HIGHWAY



"MEASURED MILE" BETWEEN S. BIRCHWOOD & N. BIRCHWOOD

PAINT w/BEADS

PROJECT # 50676
GLENN HIGHWAY RUT REPAIR
S. BIRCHWOOD TO N. BIRCHWOOD

Sheet ______ **of** ______ **Sheets**

State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

COMPUTATIONS

Item No. ________

Date Thu 10/13/94
Project No. ________
Project Name ________
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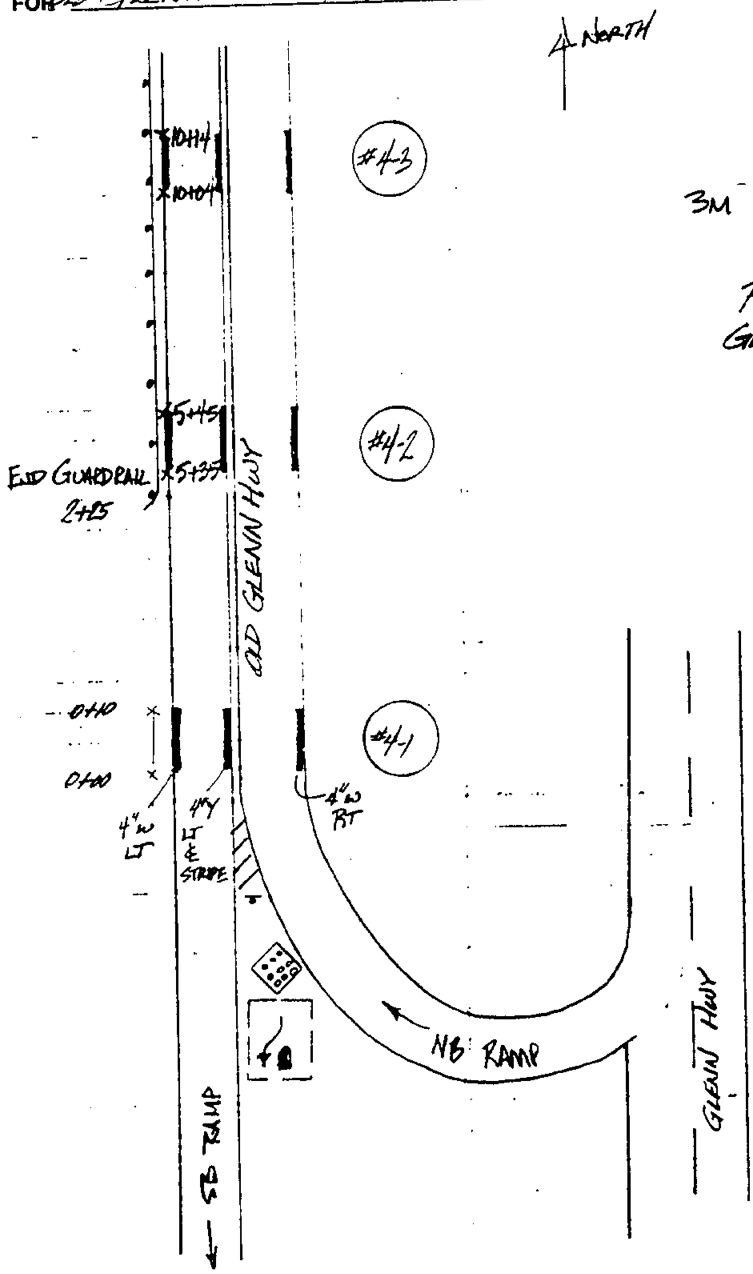
Checked By ________

Site #4
FOR OLD GLENN INTERCHANGE - SB RAMP



Stamark
3M Preformed Tape 5730, 31
Hot-Applied
Aug 3 & 4, 1994
Project # 59604
Glenn Highway Phase I-D

Sheet ____ of ____ Sheets

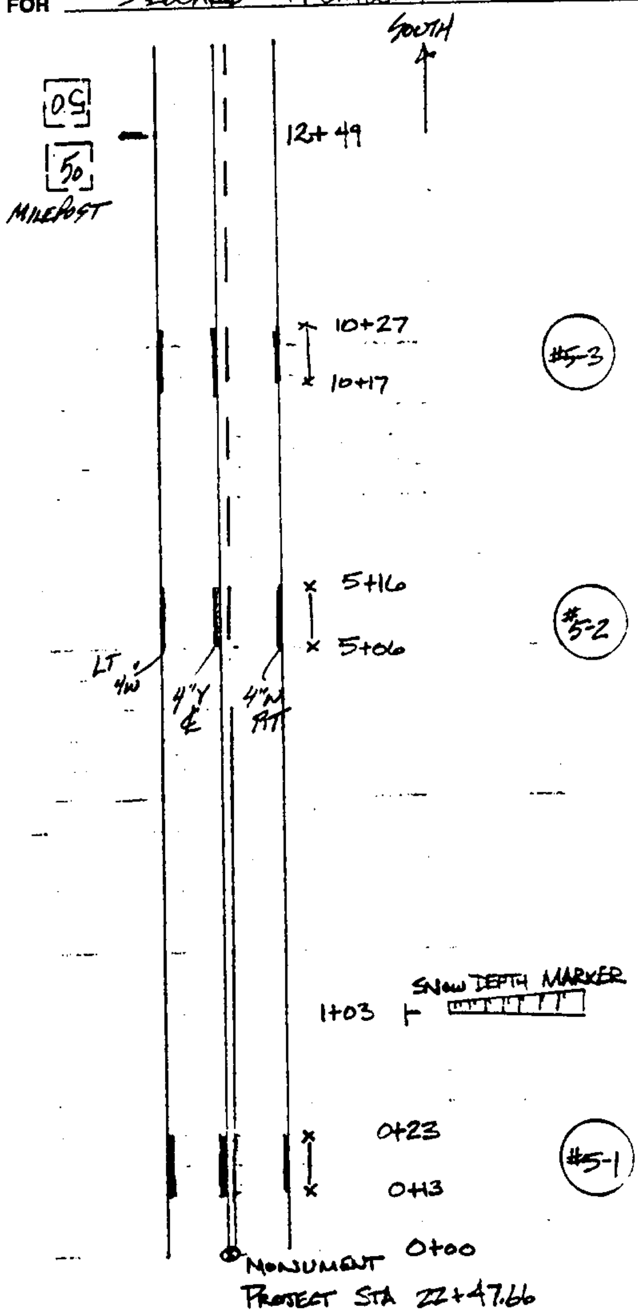
State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

COMPUTATIONS

SITE #5

FOR SEWARD HIGHWAY

Item No. ______
Date FRI 10/14/94
Project No. ______
Project Name ______
Calc. By SET / MB
Checked By ______



STAMARK
3M PREFORMED TAPE 5730, 31
HOT APPLIED SEPT 1994

PROJECT #59956
SEWARD HIGHWAY MP 50-53

Sheet ______ of ______ Sheets

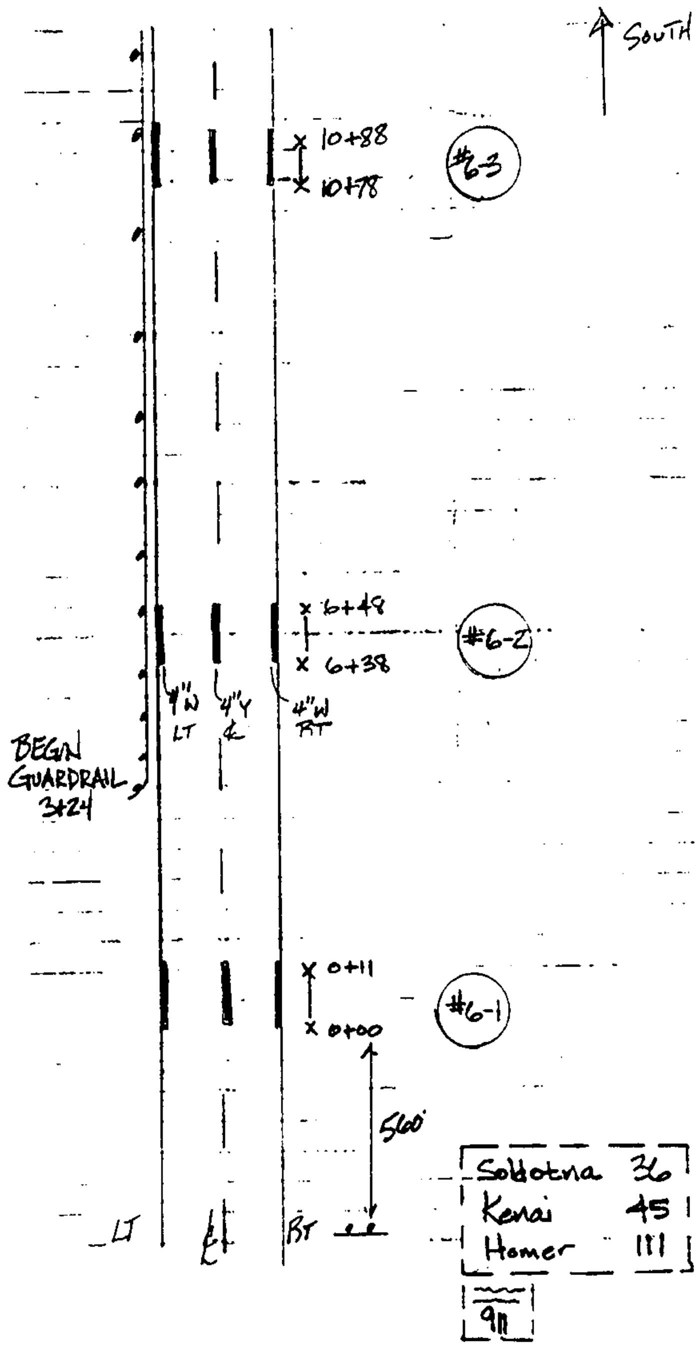
State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

COMPUTATIONS

Item No. ________

Date FRI 10/14/94
Project No. ________
Project Name ________
Calc. By SET/MB
Checked By ________

SITE #6
FOR STERLING HIGHWAY



NORRIS
METHYL METHACRYLATE, TYPE V
60 MILS

PROJECT # 52041
STERLING HIGHWAY MP 57-71
APPLIED SEPT 15, 1994

Sheet ______ of ______ Sheets

State of Alaska
DEPARTMENT OF TRANSPORTATION
& PUBLIC FACILITIES

COMPUTATIONS

SITE #7

FOR SEWARD HIGHWAY

Item No. ______

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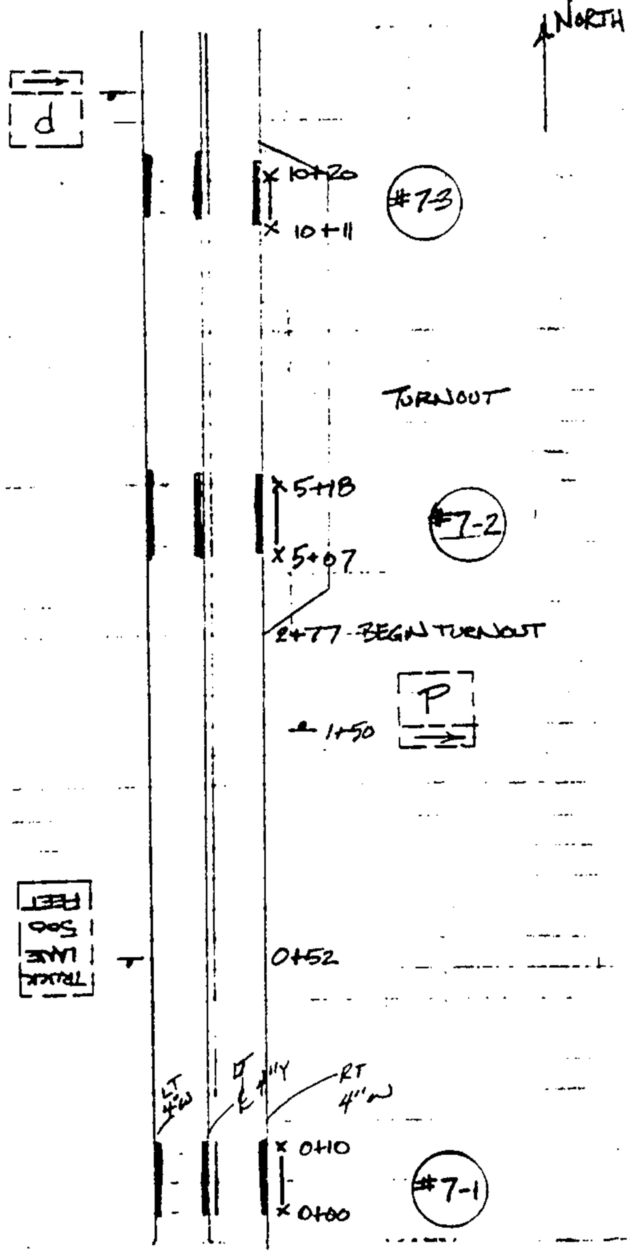
Project No. ______
Project Name ______
Calc. By SBT / MB
Checked By ______



3M STAMARK
PREFORMED TAPE 5730, 31
HOT-APPLIED ~~SEPTEMBER~~ 15 1994

PROJECT # 59956
SEWARD HIGHWAY MP 50-53

Sheet ______ of ______ Sheets

APPENDIX B

Description of Plan for Field Survey and Reflectivity Measurement

DESCRIPTION OF FIELD TESTS

1. Field Tests Locations

Southeast, Central, and Northern Regions of AKDOT&PF

2. Pavement Marking Types to be Tested

Preformed Tape
Thermoplastic Striping
Methyl Methacrylate
Paint

3. Field Information to be Collected

Retro-Reflectivity by Reflectometers
Engineer's Opinion (Subjective judgments, comments, recommendations, evaluation, etc.)
Photos

4. Pavement Surface Condition

As dry as possible (without snow, ice, and water)

5. Traffic Conditions (Traffic Volume, Studded Tire, Deicing Materials, Snow Plow)

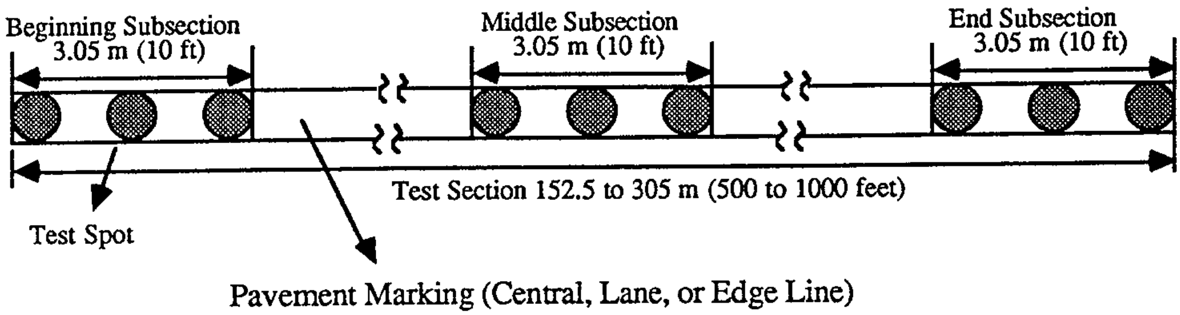
Traffic conditions of all test sites should be as close as possible to reduce the effects of traffic conditions.

6. Pavement Marking to be Tested

Central Lines, Lane Lines, and Edge Lines (If other lines are included, it would be better.)

7. Field Measurement Procedure

Each test site (one type of pavement marking only) will consist of one to three sections (depends on the length of the site.) Each section could be 152.5 to 305 m (500 to 1000 feet) long. The sections should be evenly distributed along the site. Each section should include three subsections which will locate at the beginning, middle, and end of the section. The length of each subsection could be about 3.05 m (10 ft). Readings (including reflectivities and photos) will be taken from three spots which locate at the beginning, middle, and end of the subsection, respectively. Three repeated readings (reflectivities only) and one photo will be taken at each spot. Subjective opinion about the pavement marking performance will be made by the field staff for each subsection. Conceptual configuration of a test section is shown in the following figure.



8. Field Test Table

A preliminary table is attached (next page). However, a better table can be made if more suggestion are provided. Let me know your suggestions about this table.

Recorder: ____________ Date/Time: ____________ Marking Type: ____________

Marking Service Life: ______ Weather Condition: ____________ AADT/ADT: ______

Section ID: ____________ Surface Condition: ____________ Photo Taken: Y / N

		Reflecto-meter Readings	Subjective Rating (Mark One)	Traffic Conditions (Studs, Volume Deicing, Snow Plow, etc.)	Opinion, Comments, Notes, Suggestions and Others (If necessary, use other side of the page)
Beginning Subsection	Beginning Spot		Very Good Good		
	Middle Spot		Fair		
	End Spot		Poor Very Poor		
Middle Subsection	Beginning Spot		Very Good Good		
	Middle Spot		Fair		
	End Spot		Poor Very Poor		
End Subsection	Beginning Spot		Very Good Good		
	Middle Spot		Fair		
	End Spot		Poor Very Poor		

APPENDIX C

Survey Forms and Instructions for Subjective Opinion Survey

Evaluation Survey on Pavement Markings

These forms are designed for the subjective evaluation of traffic pavement markings. The main pavement markings to be evaluated are as follows:

. Preformed Tape

. Thermoplastic Striping (extruded and sprayed)

. Dura-Stripe AC (Methyl Methacrylate) (extruded and sprayed)

. Paint

Please take several minutes to complete the attached survey forms and return them to the following address before March 15, 1995 or as early as possible. Your support is very important to the success of the study. If you have any question, please contact me at the numbers listed below. We appreciate your effort.

Return Address: Dr. Jian John Lu
Transportation Research Center
University of Alaska Fairbanks
Fairbanks, Alaska 99775
(907) 474-7025
(907) 474-6087 (fax)

Your Agency:____

Information About Yourself (optional): (Name, Title, and Phone Number)

Do you want a copy of the final research report? Yes No

Note 1. Evaluation ratings are relative in comparison to the other pavement marking types listed above.

Note 2. For this pavement marking type, the **Product** means the one which is most often or widely used by your agency. For example

Alkyd Quick-dry Paint Supplied by xxxx Company

Hot-extruded Thermoplastic Supplied by xxxx Company

3M Stamark Preformed Tape Supplied by xxxx Company, or

Sprayed Methyl Methacrylate Supplied by xxxx Company

(If a brand name is used, also provide the generic term.)

Note 3. You may make further comments about this type of pavement marking by using either the following space or extra pages.

Preformed Tape (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

During the first-half of the service life

	(worst) 0	1	2	3	4	(best) 5
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

During the second-half of the service life

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst)	1	2	3	4	5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest 0	1	2	3	4	most expensive 5
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0	1	2	3	4	(best) 5

Sprayed Thermoplastic (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

During the first-half of the service life

	(worst)					(best)
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

During the second-half of the service life

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst) 1 2 3 4 5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest				most expensive	
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0 1 2 3 4 5 (best)

Extruded Thermoplastic (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

<u>During the first-half of the service life</u>

	(worst) 0	1	2	3	4	(best) 5
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

<u>During the second-half of the service life</u>

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst) 1 2 3 4 5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest 0	1	2	3	4	most expensive 5
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0 1 2 3 4 5 (best)

Dura-Stripe AC (Methyl Methacrylate - Sprayed) (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

During the first-half of the service life

	(worst)					(best)
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

During the second-half of the service life

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst) 1 2 3 4 5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest				most expensive	
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0 1 2 3 4 5 (best)

Dura-Stripe AC (Methyl Methacrylate - Extruded) (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

During the first-half of the service life

	(worst) 0	1	2	3	4	(best) 5
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

During the second-half of the service life

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst) 1 2 3 4 5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest 0	1	2	3	4	most expensive 5
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0 1 2 3 4 5 (best)

Paint (see note 1 on front page)

1. What is the full name of the product and the distributor(s)? (see note 2 on front page)

2. What is the estimated service life of this type of pavement marking? (e.g. 2-3 years)

3. What are the main reasons for failure of this type of pavement marking? (e.g. abrasion, shaving, bond failure, ...)

4. What is the best air temperature range for field placement of this type of pavement marking? (e.g. 10° - 30°F)

5. Please give your opinion about the visibility of this type of pavement marking: (check one score for each.)

During the first-half of the service life

	(worst) 0	1	2	3	4	(best) 5
Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

During the second-half of the service life

Day Time	0	1	2	3	4	5
Night Time	0	1	2	3	4	5

6. How would you rank the marking's durability to studded tires and snow plowing? (check one)

0 (worst) 1 2 3 4 5 (best)

7. How much drying time is needed after field placement? (check one and/or make your comments.)

. Instant Dry (less than 30 sec.) . Quick Dry (30-120 sec.) . Fast Dry (2-7 min.) . Conventional (more than 7 min.)

8. For which of the following traffic volumes is the marking most applicable? (check and/or make your comments.)

. Low Traffic Volume . Moderate Traffic Volume . High Traffic Volume

9. What are the main applications? (check and/or make your comments.)

. Centerline . Edge Line . Lane Line . Transverse . Other (specify it)

10. What is the cost? (Check one score for each and/or make your comments.).)

	cheapest				most expensive	
Initial Cost	0	1	2	3	4	5
Life Cycle Cost	0	1	2	3	4	5
Overall Cost	0	1	2	3	4	5

11. What is your overall rating? (combining all the factors) (seen note 3 on front page)

(worst) 0 1 2 3 4 (best) 5