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DEPARTMENT OF TRANSPORTATION
MATERIALS OFFICE

PERMANENT LANE MARKING

(Recessed Lane Edge Stripe)

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16. Abstract

The project goal was to evaluate different methods of cutting recessed skip stripe grooves, and to evaluate various pavement marking materials placed into the recesses. The project objective was to find a marking system for our mountain pass highways that would tolerate snowplowing and sanding operations, studded tires, and chain wear.

Three methods of pavement grooving and three types of marking materials were evaluated over a four-year period. The grooving methods were evaluated with regard to production rate, the quality of the finished groove, and cost. The marking materials were checked for ease of installation, cost durability, and visibility.

Only one method of grooving was found that produced the desired recess shape at a reasonable cost and in a timely manner. All three of the marking materials were durable enough to survive for three years, but none produced the desired wet-daytime or wet-night visibility needed for adequate lane delineation. This loss of visibility under wet conditions was due to the lack of retroreflectance from the marking materials.

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SYNOPSIS

The project objective was to evaluate different methods of cutting recessed skip-stripe grooves, and to evaluate various pavement marking materials placed into the recesses in the hope of finding a permanent marking system for our mountain pass highways.

Only one method of grooving was found that produced the desired recess shape at a reasonable cost and in a timely manner. All three of the marking materials were durable enough to survive for three years, but none produced the desired wet-daytime or wet-night visibility needed for adequate lane delineation. This loss of visibility under wet conditions was due to the lack of retroreflectance from the marking materials.

PERMANENT LANE MARKING

(Recessed Lane Edge Stripes)

INTRODUCTION

The Washington State Department of Transportation, Highway Division, has had extreme difficulty in maintaining lane edge striping in mountain pass areas that will retain its visibility throughout the winter months. Conventional traffic paint cannot tolerate sanding operations, studded tire wear, chain wear, and snowplowing. Eight years ago on I-90, Lake Keechelus to Easton Hill, experiments were conducted using a thermoplastic tape placed into recesses ground to a depth of 1/4 inch with diamond saws. The plastic tape failed, was replaced one year later, and failed again. Subsequently, a white epoxy resin glass bead system developed in the Materials Laboratory was placed into some of the existing recessed grooves, and this system performed effectively. The remainder of the recessed grooves were filled one year later with a hot thermoplastic (Cataphote) material which cracked badly and popped out.

It became apparent that what was needed was a trial installation of available marking materials that could be monitored under controlled conditions for a specific time period. It was also decided that this installation should be combined with an evaluation of other available methods, other than the diamond saw, of cutting the recesses in the pavement. What resulted was the inclusion of the above-described project in Contract 9996, Lower Crossing to National Forest Boundary.

PROJECT DESCRIPTION

Contract 9996, located on I-90 thirty-seven miles east of Seattle, was proposed for grooving of approximately 31,600 actual feet of pavement with a stripe skip interval of 10 feet per 40 feet, thus yielding about 7,900 feet of proposed grooving and stripe material placement. The finished facility is a six-lane divided PCC highway with a length of 4.4 miles.

The project objective was to evaluate different methods of cutting recessed skip-stripe grooves, and to evaluate various pavement marking materials placed into these pavement recesses. The evaluation was to include cost data for both the cutting of the recesses and the installation of the marking materials. Visual and photographic records were also to be kept over a three-year span on the durability and the visibility of the marking materials under the various environmental combinations of day-night-dry-wet. The evaluation of the construction phase would be done by the Project Engineer assigned to Contract 9996, with the follow-up evaluations done by the Special Projects Section of the Materials Laboratory.

PAVEMENT GROOVING

The four methods of pavement grooving chosen for evaluation are listed below. After a trial period with each method, a decision was made on which was the best method based on cost and satisfactory cutting pattern. The remainder of the project would then be completed with the chosen method.

Grooving Methods

1. High-pressure water jet
2. Heavy-duty grinder
3. Cold-planer (cold-milling) machine
4. Diamond saw

The high-pressure water jet manufactured by Flow Industries was first to be evaluated. The equipment included a trailer-mounted 60,000-psi intensifier powered by a diesel generator. This was pulled by an articulated front-end loader which had the 4-inch-diameter, two-nozzle, rotating cutting tool. An externally mounted chain and sprocket regulated forward speed which in turn determined the depth of cut (see Figures 1 and 2).

The results from the water jet method were less than satisfactory. The articulating movements of the front-end loader being hydraulically operated resulted in a jerky movement that made straight-line cutting very difficult (see Figure 3). The 60,000-psi intensifier was not powerful enough to cut as fast and as deep as the Flow Industries' personnel had anticipated. Two attempts at cutting a 1/2-inch-deep recess proved unsatisfactory, and these sections were later re-cut with the diamond saw. Although the design of the rotating cutting tool provided a true 4-inch width, the edges were always cut deeper than the center areas because of the longer cutting time due to the overlapping of the jets at the edges as the tool rotated. One day's production was only 14 sections (140 lineal feet). The personnel from Flow Industries stated that they felt they could produce a satisfactory rate of cutting with a non-articulating prime mover and their larger 150,000-psi intensifier.

The grinder, a Tennant Heavy-Duty Model G, was the second method tried. Figure 4 shows the operation of the machine which required two men due to the difficult job it is to control. The cutting head, Figure 5, has offset carbide-tipped star washers which chip at the pavement. These washers wear unevenly, resulting in an uneven fracturing of the pavement as shown in Figure 6. The first set of cutters was replaced after only 18 sections (180 lineal feet) of 1/2-inch grooving. In all, only 24 sections of 1/2-inch depth and 4 sections of 1/4-inch depth were accomplished in one day's work. A trial cut in the asphalt shoulder had equally poor results.

The third method, the cold-planer or cold-milling machine, was never accomplished. A search for such a machine, which covered the U.S. and Canada, resulted in the knowledge that no manufacturer of such machines makes a 4-inch width head or a head that can be adapted to cut 4 inches.

The fourth and by far best method of cutting the grooves was the diamond saw. The machine used was a Concut with a 1-foot head adapted to a 4-inch cutting width. It was self-propelled, compact, and yet heavy enough to drag the water supply hose without affecting the alignment control (Figure 7). Production rates varied with the depth of cut, but for a 1/4-inch groove, it averaged 100 to 120 lineal feet (10-12 sections) per hour (Figure 8). All remaining grooving was accomplished with this method.

A final accounting of the production from each of the three methods shows the following:

Diamond Saw		4760 lineal feet
Tennant Grinder		280 lineal feet
Water Jet		140 lineal feet
	Total	5180 lineal feet

MARKING MATERIALS INSTALLATION

The three materials chosen for backfilling the grooves were:

1. White cement with Ottawa sand and reflective glass beads
2. Cleanosol, a hot extruded thermoplastic
3. Adhesive Engineering Concresive 1064, white, with reflective glass beads

A strip map shows the areas of the project in which each of the three materials was placed. The white cement, Ottawa sand, and glass bead system was first installed in a 2 parts sand, 1 part cement, 1 part beads ratio on 20 sections. It became the consensus of the Contractor and State personnel that this mixture was too lean, so an adjustment was made to 2 parts sand, 1½ parts cement, and 1 part beads. The 20 sections filled with the 2:1:1 mixture were later removed and replaced with a 2:2:1 mixture. This same 2:2:1 mix was also used on 24 other sections, while six other sections were filled with a 3:2:1 mixture. The white grout system thus varied from 2:1½:1 to 2:2:1 to 3:2:1 in the components of sand, cement, and beads. The locations of each variation in mix proportions are shown on an inset on the strip map.

Cleanosol is a hot extruded thermoplastic product from Sweden. It comes as a solid component which is liquified by heat and dispensed at about 175°C into a small hand applicator as shown in Figures 9 and 10. A filling of the applicator would cover approximately 100 lineal feet of the 1/4-inch-deep recesses. The material cools rapidly to a solid and is ready to accept traffic in a very short time. A total of 75 sections was filled with the Cleanosol material, all 1/4-inch deep.

The installation of the third material, Adhesive Engineering's Concresive 1064 white, was delayed one year by our desire to have a two-white-component epoxy. The standard Concresive epoxy mix is a combination of one black and one white component, yielding an end product which is grey in color. A special factory order had to be made with the two-white-component mixture because of our desire for the whitest stripe possible. This special order of material did not arrive on the project site until the late fall of 1977 which was past the time when daytime temperatures were warm enough to properly cure the epoxy mixture. In March and June of the following year, 371 sections (3710 lineal feet) were filled with the Concresive 1064 mixture using the procedure shown in Figures 12, 13, 14, and 15.

A final accounting of the amount of grooving backfilled with each system and installation dates are shown below:

1. White Cement Grout, 720 lineal feet (10/3/77 and 10/5/77)
2. Cleanosol, 750 lineal feet (11/8/77)
3. Concresive 1064, 3710 lineal feet (3/22/78, 3/27/78, 6/7/78, and 6/8/78)

The project fell short by about 2720 lineal feet of grooving and backfilling because of the low production rates of both the high-pressure water jet and the Tennant grinder. The 5180 lineal feet of grooving and backfilling was 66 percent of the proposed project goal of 7900 lineal feet.

COSTS OF GROOVING AND MARKER MATERIALS

Cost data was monitored for each type of grooving and for each method of backfilling. The costs shown do not include such items as traffic control or mobilization and modification of equipment. The cost shown for the Flow Industries water jet system is excessive due to the prototype nature of the equipment and its operation. Average costs were shown for the backfilling methods except for Cleanosol which was at unit price by agreement.

Grooving Costs

1. High-Pressure Water Jet, 1/4-in. depth - in excess of $5.00 per lineal foot
2. Tennant Grinder, 1/2-in. depth - $1.33 per lineal foot
3. Diamond Saw, 1/4-in. depth - $1.04 per lineal foot
   3/8-in. depth - $1.56 per lineal foot
   1/2-in. depth - $1.95 per lineal foot

Backfilling Costs

1. White Cement Grout, 1/2-in. depth - $1.76 per lineal foot
2. Concresive 1064, 1/4-in. depth - $1.38 per lineal foot
   3/8-in. depth - $1.79 per lineal foot
3. Cleanosol, 1/4-in. depth - $1.00 per lineal foot

EVALUATION

The evaluation process consisted of visual examinations supplemented with day and night photographs. The original plan called for a three-year evaluation period, but due to the one-year delay in the installation of the Concresive 1064 material, the actual evaluations took place over a four-year span from December of 1977 to June of 1981.

The visual performance of the various backfill materials can be categorized under the various viewing conditions.

Dry-Daytime Visibility

All three permanent systems are more visible than the standard paint stripe. Initially, the Concresive 1064 was the equivalent in whiteness to the white cement and Cleanosol systems, but after 1½ years it became discolored to a creamy white. The Cleanosol and white cement materials are now much whiter than the Concresive 1064 as shown in Figures 15 and 16.

Wet-Daytime Visibility

All of the systems suffer in visibility under wet conditions. The stripes virtually disappear when there is a water film over them. It disrupts the reflectance from the stripes so much that their visibility is only in the range of about 50 feet. If the pavement is merely damp, then the visibility is equal to the existing paint stripe.

Dry-Night Visibility

All of the systems are the equal of paint stripes in the dry-night condition. This is similar to their performance during dry-daytime viewing.

Wet-Night Visibility

The wet-night visibility of the systems can only be described as poor. The Cleanosol stripes were the only ones that provided any noticeable delineation on our nighttime photographs and their effectiveness was only fair. Again, the water film cuts the reflectance of the stripes to a visible range of about 50 feet which is only about three car lengths in front of a vehicle. Wet-night photographs verify the poor performance of the stripes, with almost zero contrasts discernible between the stripes and the surrounding darkness. In fact, the visibility of the stripes is so minimal that the photos, if reproduced in this report, would show only vast expanses of darkness.

Durability

The durability of all three backfill materials has been outstanding. It remains to be seen what the total life of these materials will be, but at present they show very little evidence of imminent failure. Hairline cracking is present in the stripes of all three materials, but no popping out or loss of material has been observed. The white cement grout material seems to be more prone to this type of defect. The Cleanosol stripes have a Swiss cheese appearance (see Figure 15) which apparently is the result of gas bubbles present in the hot liquid material during installation. The thin caps over these bubbles have now worn off, leaving the holey appearance evident in the photo.

Cost Comparison

The permanent lane marking systems are obviously more expensive than paint striping. The current bid prices for centerline paint stripe is about $0.05 per lineal foot. The stripes are repainted on the mountain pass highways two to three times per year which means a maximum yearly expense of $0.15 per lineal foot of stripe. The most economical method of grooving, diamond saw, combined with the cheapest backfilling material, Cleanosol, results in a total cost of $2.04 per lineal foot. The permanent lane markings will have to last 14 years in order to amortize their cost as compared with paint stripes ($2.04 per lineal foot divided by $0.15 per lineal foot per year).

DISCUSSION

The final answer to our problem of providing a durable and visible pavement marking system for our mountain pass highways has yet to be found. The marking systems tested in this study passed the durability test but failed the wet-night visibility test. This failure had nothing to do with the whiteness or brightness properties of the materials, nor did it stem from a loss or lack of reflective glass beads. The failure of the systems can be traced directly to a lack of retroreflectance from the marking materials when they are submerged under a film of water.

This problem of marking stripe retroreflectance was addressed in a previous research project. WSDOT participated in an FHWA research project which involved the installation of strips of injection molded plastic elements that were specifically designed to capture and reflect optimum amounts of light at large angles of incidence. These low-profile markers were epoxy-bonded into diamond-sawed grooves so that the top surface of the elements was slightly below or flush with the adjacent pavement surface. The top surface of the reflectors, which was soon scratched by traffic wear, provided no dry-night delineation, but if water filled in the scratches during rainy periods, it, in effect, repaired the marking strip, and the wet-night reflectance was restored. The only problem with these reflector strips was durability--they could not survive the studded tire wear, chain wear, snowplowing, or sanding which occurs on our highways during the winter months.

The marking materials evaluated in this study are durable--they have all lasted at least three years and some four years--but they lack the property of reflectance necessary for effective wet-night delineation.

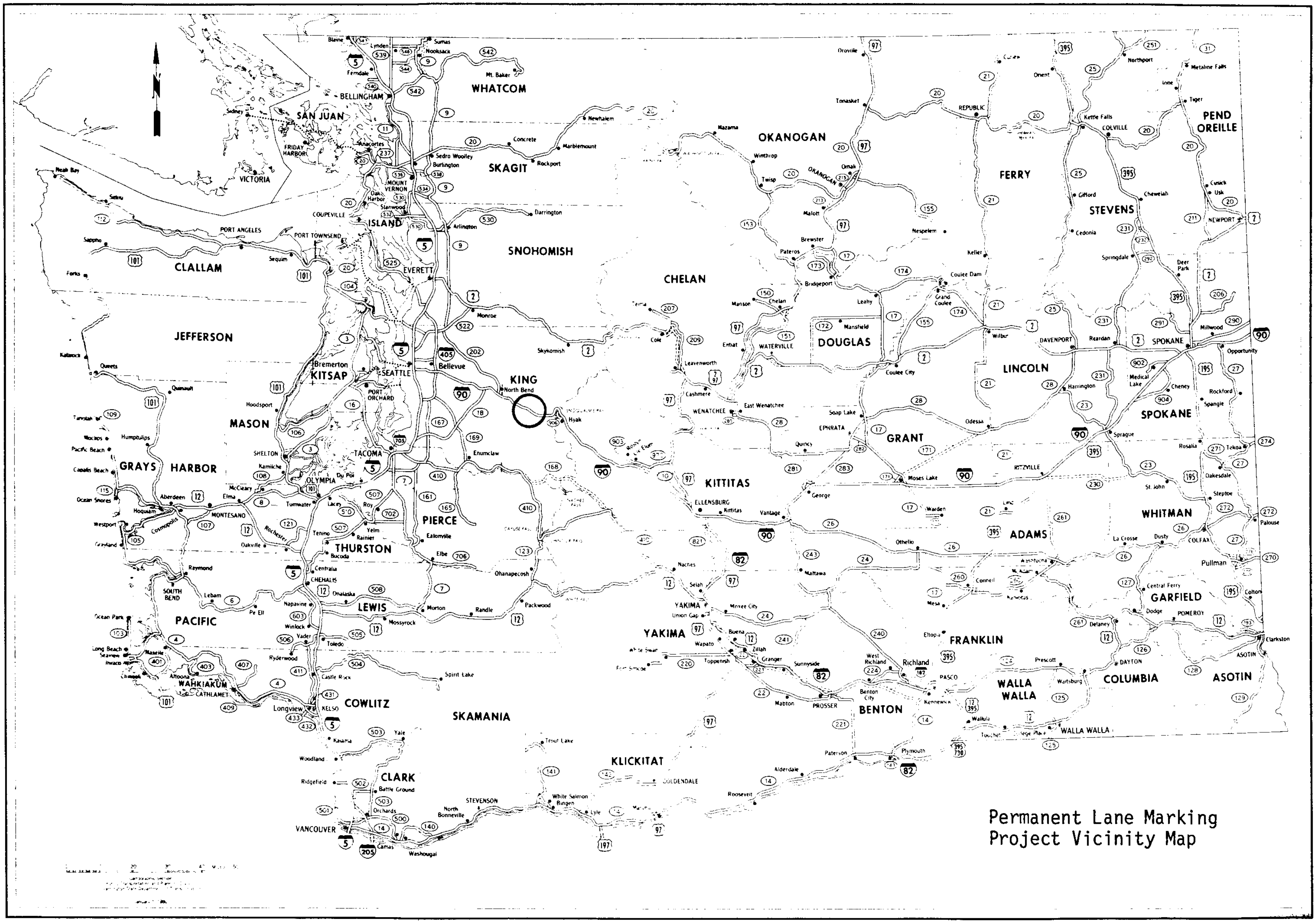
CONCLUSIONS

1. Cleanosol, white cement grout, and Concresive 1064 (white) are backfill materials capable of withstanding the effects of sanding operations, studded tire wear, chain wear, and snowplowing for three years without damage or loss of material.
2. The diamond saw is presently the fastest and most economical method of cutting recesses in PCC pavement.
3. The Cleanosol material was the fastest and easiest to install.
4. There were no discernible differences in visibility or durability of any of the systems that could be attributable to the depth of materials installed or the method of grooving.
5. None of the three backfilling materials provided adequate wet-night delineation.
6. All of the backfilling materials provided adequate dry-daylight and dry-night delineation.

7. The failure of the material to provide wet-night delineation is due to a lack of retroreflectance of the stripes when they are submerged under water.

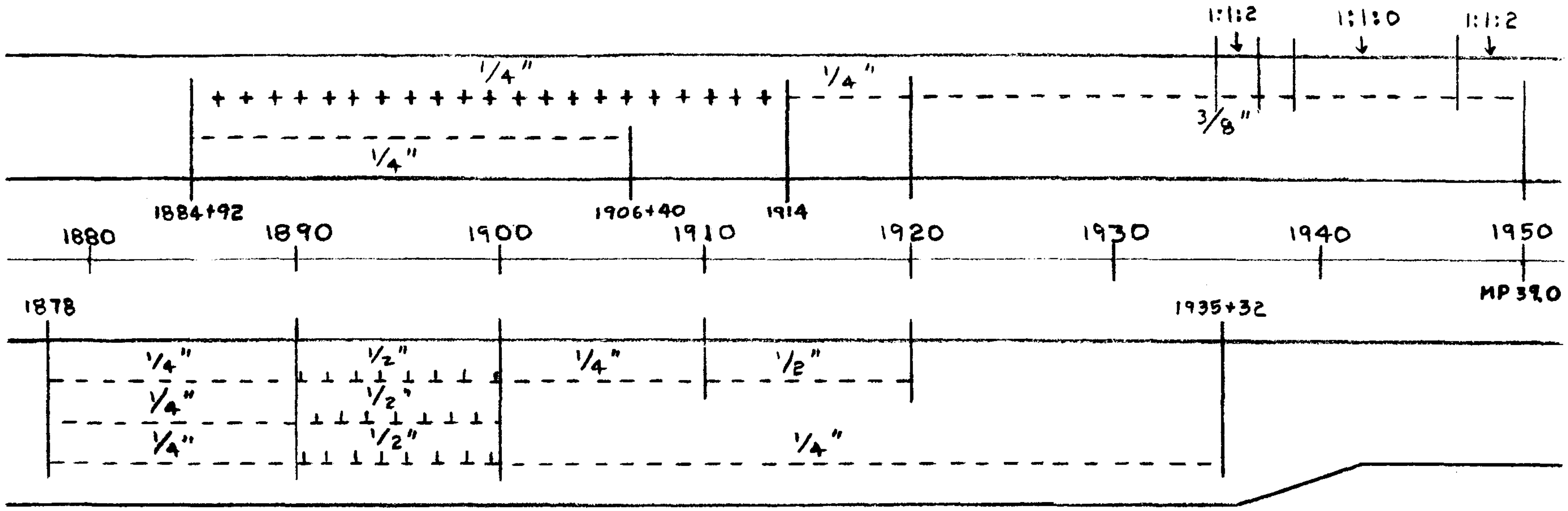
ACKNOWLEDGEMENTS

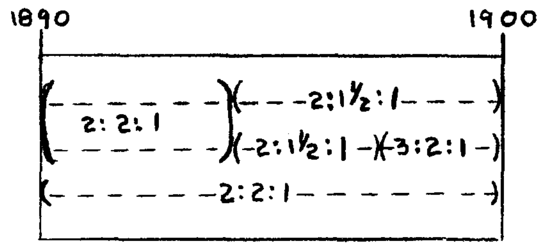
The author would like to acknowledge the fine work done by Project Engineer C. W. McHugh and his crew in the supervision and inspection of the construction phase of the permanent lane marker project and in the data compilation and writing of the post-construction report which provided most of the information used in this report.



Permanent Lane Marking
Project Vicinity Map

STRIP MAP





White Cement Grout Detail
Sand : Cement : Beads

LEGEND

Concresive 1064	- - - - -
Cleanosol	+ + + + +
White Cement Grout	⊥ ⊥ ⊥ ⊥ ⊥

NOTES

1. Stationing is imprinted every 5 stations at both shoulder edges.

2. Concresive mixture is one part A to one part B to one part beads unless otherwise noted. (1:1:1)
3. All Concresive and White Cement Grout sections recieved a final sprinkle of beads.

CONTRACT 9996
I-90

Permanent Lane
Marking Project
1977-78

Figure 1. Flow Industries' water jet cutting system which includes a water truck, a trailer-mounted 60,000-psi intensifier powered by a diesel engine and an articulated front-end loader. The pressurized water is conveyed through a small pipe from the trailer to the cutting head.

Figure 2. Close-up view of Flow Industries' cutting head and chain drive. The forward speed of the front-end loader regulates the depth of cut. This method is in the prototype stage.

Figure 3. Recess formed by the Flow Industries' high-pressure water jet system. Note the ragged edges.

Figure 4. Tennant heavy-duty grinder (Model G). The operator of the machine could not keep true alignment; hence the laborer aided in guiding the machine.

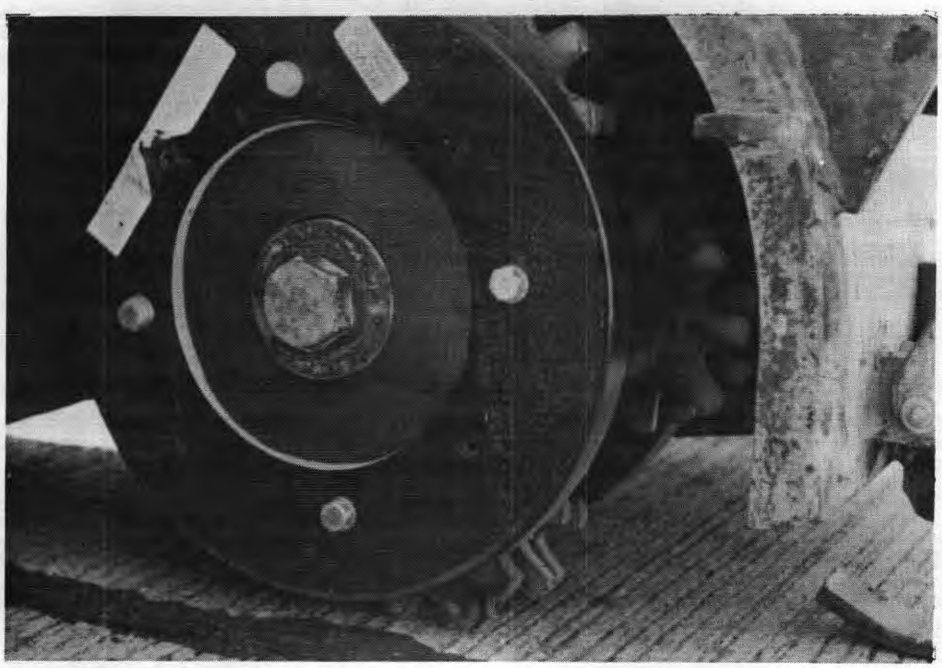


Figure 5. Tennant grinding head showing star washers which chip at the concrete. Edge alignment and depth of cut are extremely hard to control. The star washers wear unevenly which causes the machine to jump.

Figure 6. Recess formed by Tennant grinder. Note the uneven edges and variable cutting depth. A test cut in the asphalt shoulder had the same results.

Figure 7. Concut diamond saw. This self-propelled machine was easy to operate, easy to keep in alignment, and made a very uniform recess. The truck on the left supplied the water to the saw via a hose.

Figure 8. Recess formed by the Concut diamond saw. This method produced the truest vertical edges of the three methods used.

Figure 9. Trailer-mounted heating vat for liquifying Cleanosol. Solid ingots of Cleanosol are visible in the cardboard boxes behind the heater. The applicator machine is filled from the dispenser on the rear of the vat.

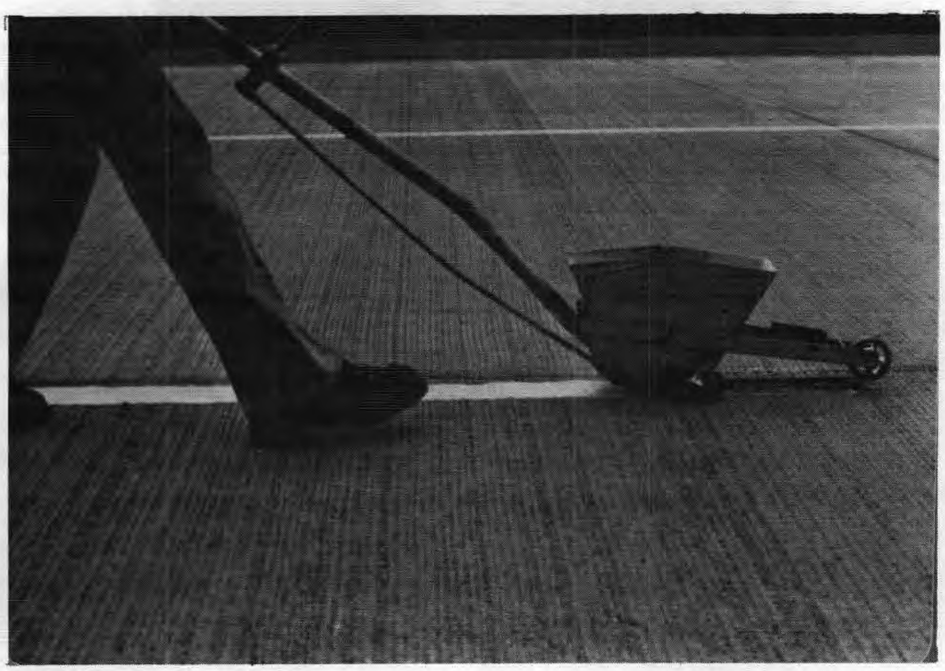


Figure 10. Placement of the liquid Cleanosol using the 4-in.-wide applicator. Forward speed determines the amount dispensed. An experienced operator can fill 10 sections in approximately 5 minutes. The Cleanosol solidifies rapidly and is ready for traffic in a matter of minutes.

Figure 11. Two-part Concresive 1064 components, glass beads, and 5-gallon mixing bucket.

Figure 12. Mixing of Concresive 1064 components and glass beads using a drill with mixer attachment. A generator in the trailer provided the power for the drill.

Figure 13. Workmen spreading Concresive 1064 material into a grooved pavement recess. The workman in foreground is using a trowel to spread the liquid epoxy. On a grade as shown (3%), it took extra care to distribute the epoxy and maintain a full-depth section throughout the recess.

Figure 14. Workman sprinkling a topical application of glass beads over a completed section of Concresive 1064. Cure time on the epoxy is temperature-sensitive which means more traffic disruption on cool days.

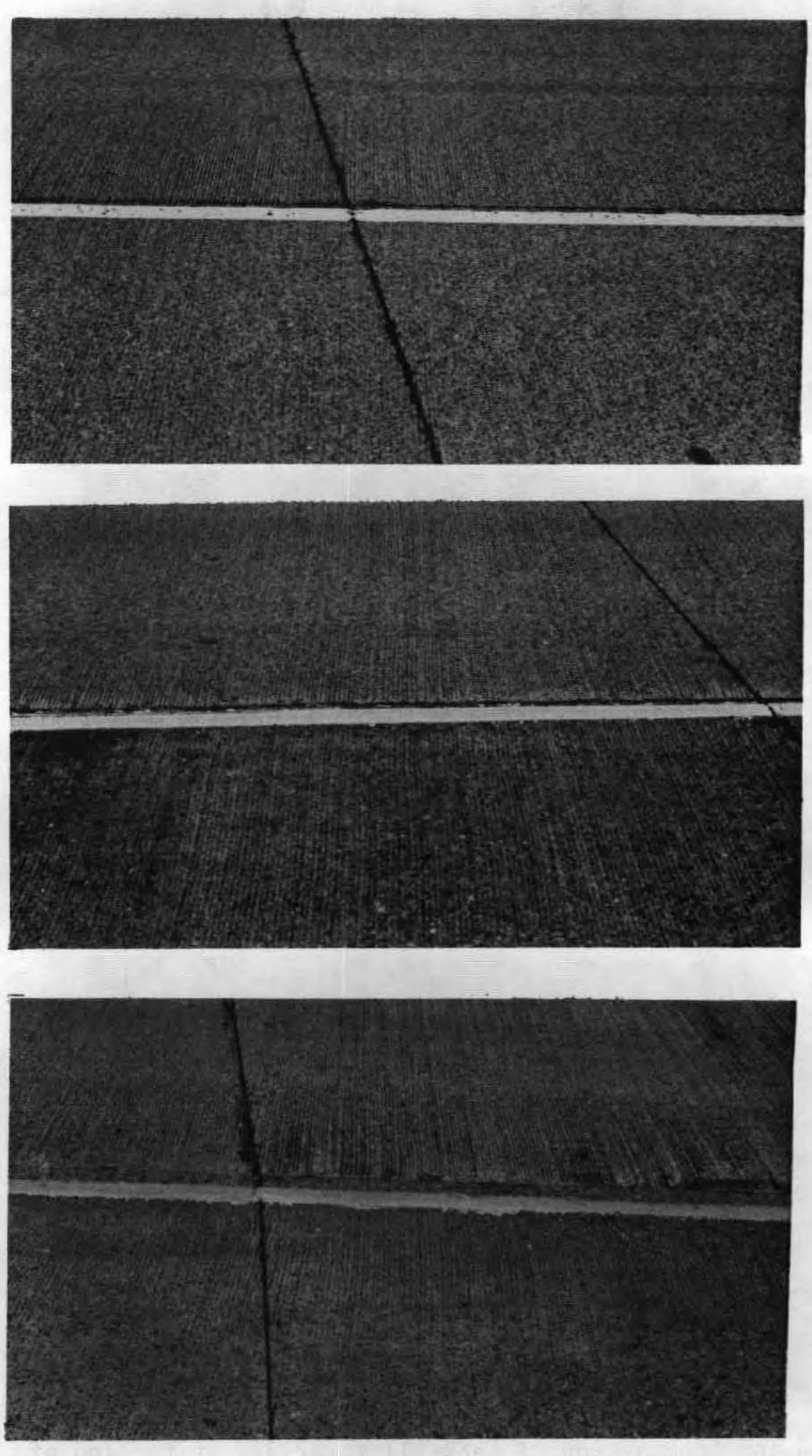


Figure 15. Comparison of backfill materials at the end of the evaluation period. Top to bottom: Cleanosol, white cement grout, and Concresive 1064.

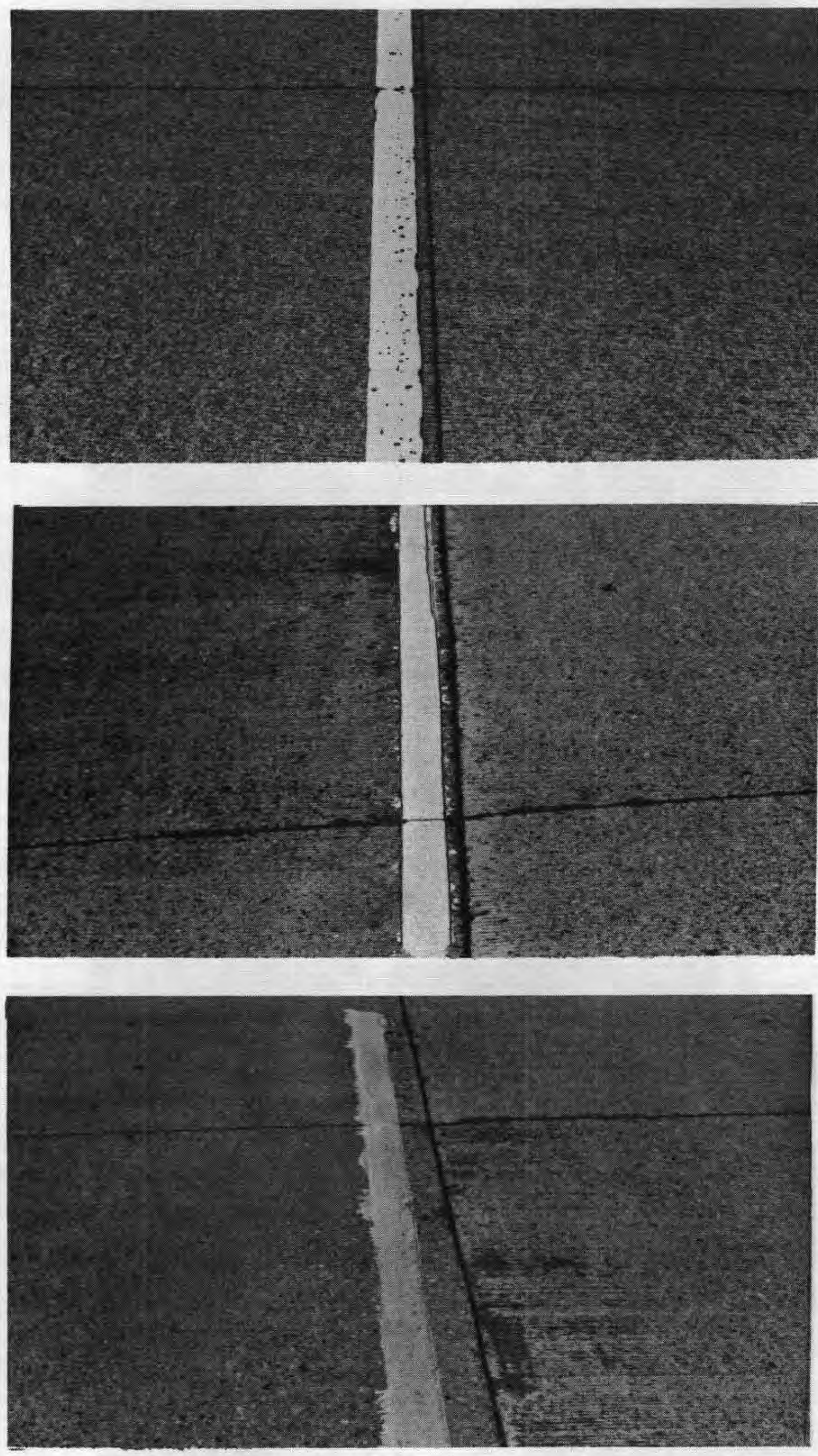


Figure 16. Comparison of backfill materials at the end of the evaluation period. Top to bottom: Cleanosol, white cement grout, and Concresive 1064.