25. PAVEMENT GROOVING ON HIGHWAYS

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INTRODUCTION

Several years ago California Division of Highways accident analysis showed that some sections of concrete highways, especially on curves, were having an unusual number of accidents during rainy weather. Pavement grooving was applied to the surface of the roadway in an attempt to reduce the number of wet-pavement accidents. The project was financed by the U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. The opinions, findings, and conclusions expressed in this paper are those of the author and not necessarily those of the Bureau of Public Roads.

CHARACTERISTICS OF GROOVING

Various grooving patterns have been applied to California highways. Widths and depths of the grooves vary from 1/4 inch to 1/8 inch, and spacing of the cuts varies from 3/8 to 1 inch center to center. All grooving is longitudinal.

The oldest grooving in California (project A) was placed in 1960. The pattern was 1/8 inch by 1/8 inch on 3/8-inch centers. After 8 years of heavy traffic wear there is very little deterioration of the grooves (fig. 1). Figure 2 illustrates the change in friction values of portland cement concrete (PCC) pavement after grooving of various projects in California. At project A the coefficient of friction is increasing with age. The friction values shown are for the California tester, 0.25 being the critical value for remedial action.

California has had very little experience with the freeze-thaw cycle effect on pavement grooving. In a mountainous area, where snow chains are used, the pavement is subjected to considerable wear. A grooving pattern of 1/8 inch by 1/8 inch on 1-inch centers placed in this area shows a tendency to round over between the grooves.

There is no effect on PCC grooving from high temperatures. Much of our grooving has been done in areas with daily summer temperatures in the 90° to 100° F range. High temperatures will affect grooving on asphalt concrete (AC). Only AC pavement with exposed aggregate and aged asphalt is suitable for grooving.

BENEFITS OF GROOVING

The increase in coefficient of friction after grooving changes the friction values from below critical to above critical. The measurements are taken longitudinally. However, the benefit to the vehicle is the ability of the grooves to prevent sideways skidding, which is not being measured by skid testers.

Before-and-after accident studies of grooved areas have clearly shown the benefit of pavement grooving to the motorist. The longitudinal grooves act as "tracks," resisting lateral movement and stabilizing the vehicle. They also serve as quick surface drains to minimize any water buildup on the pavement.

Figure 3 shows the results of grooving on I-5, 50 miles north of Los Angeles. This grooving, 1/8 inch by 1/8 inch on 1/2-inch centers, was completed in 1963. ADT in this area is 17 000. Cost of the work was $2,500. There were nine wet-pavement accidents during the 2 years before the grooving and none during the 5 years after the grooving.

Figure 4 shows the results of grooving on I-5 at Laguna Canyon Road just off the west end of the El Toro Marine Base runway. The grooving was completed in 1966, using a pattern of 1/8 inch by 1/8 inch on 1/2-inch centers. The ADT in this area is 45 000. The radius of curvature is 2000 feet. Before grooving, friction tests averaged 0.25 with a low of 0.17; after grooving, friction tests averaged 0.30 with a low of 0.27. Accident data at this location are as follows:

1963	No wet accidents
1964	8 wet accidents
1965	47 wet accidents
1966	1 wet accident
1967	1 wet accident

This study illustrates how rapidly the wet-pavement accident problem can develop.

Figure 5 shows the before-and-after accident diagram for grooving of 1/8 inch by 1/8 inch on 1-inch centers on I-405 near Bellflower Boulevard in the City of Long Beach. The grooving was done in 1966 and the ADT here is 131 000. Before grooving, friction tests averaged 0.20 with a low of 0.14; after grooving, friction tests averaged 0.24 with a low of 0.17. One and one-half years after, friction tests averaged 0.20 with a low of 0.14. There were 20 wet-pavement accidents during the year before grooving and none for the next 2 years from the grooved section. This is a tangent section of roadway and the skidding started at the sag point where the vehicles started to accelerate as they approached the Bellflower Boulevard overcrossing.

A broader approach to pavement grooving is shown in figure 6, where 1 mile of the southbound I-405, also in Long Beach, was grooved. There were two curves in the mile, one with a radius of 2800 feet and 4 percent superelevation and the other with a radius of 2500 feet and 6 percent superelevation. The ADT at this location is 148 000. The grooving, 1/8 inch by 1/8 inch on 3/4-inch centers, was done in 1966 at a cost of $25 000 for four lanes of freeway. Before grooving, friction tests varied from 0.12 in the right lane to 0.38 in the median lane; after grooving, friction tests varied from 0.26 to 0.44, respectively. There were 61 wet-pavement accidents during the year before grooving (60 percent occurring in the two median lanes) and three in the year following the grooving. A comparative study of accidents was made on the northbound freeway lanes, where there were seven wet-pavement accidents in the year before and five the year after grooving. There was no significant change in the number of dry-weather accidents.

Figure 7 presents a study on a 1000-foot-radius curve on I-10 about 5 miles east of Los Angeles. This curve is on the westbound roadway. It has a superelevation of 5 percent and an ADT of 164 000. The grooving pattern used here was 1/8 inch by 1/8 inch on 3/4-inch centers. Before grooving, friction tests averaged 0.27 with a low of 0.17; no tests were made after grooving. There were 26 wet-pavement accidents the year before grooving and two in each of the next 2 years after. The after-grooving accidents were occurring at the beginning of the curve before reaching the grooved area, which begins at the BC of the curve. On curves to the left, where the crossfall of the roadway is reversed by the superelevation, it is necessary to begin the grooving on the tangent in the supertransition area. There is a concentration of water flow in this area during periods of rainfall which may cause tire hydroplaning to occur.

RECOMMENDED GROOVING PATTERNS

The depth of the grooves varies from 1/8 inch to 1/4 inch. A minimum depth of 1/8 inch seems to be acceptable.

The spacing of the grooves varies from 3/8 inch to 1 inch center to center. The closer the grooves the more spalling of the pavement is likely to occur. Complete spalling occurs in a bump cutting pattern where the blades are very close. Some spalling occurs on PCC pavement with 3/8-inch and 1/2-inch spacings. There is very little spalling between cuts with 3/4-inch spacing and no spalling with 1-inch spacing. On AC pavement there is extensive spalling on 1/2-inch spacing, but 3/4-inch and 1-inch spacings are satisfactory.

Increases in coefficients of friction vary indirectly with spacing. The 3/4-inch spacing produces an increase that is slightly less than that of the 1/2-inch spacing. The increase from 1-inch spacing is considerably less than from the 3/4-inch spacing.

The width of the groove is critical. After grooving of 1/4 inch by 1/4 inch on 1-inch centers was placed in one location, several complaints were received from drivers of light cars and motorcycles. The complaints were that the vehicle tended to "track" and appeared to be caught in a manner resembling being caught in streetcar tracks. The 1/8-inch grooving has been acceptable in almost every location. To further reduce this tracking effect, grooves were made with a 0.095-inch-wide blade. Tests made on this grooving pattern (0.095 inch by 1/8 inch on 3/4-inch centers) indicate that it will be as effective as the 1/8-inch groove and more desirable from a tracking standpoint. Figure 8 is a photographic comparison of the 1/8-inch grooves and the 0.095-inch grooves.

Another pattern, which resembles bump cutting with grooves, has been placed experimentally at several locations. This pattern can be produced by the diamond-studded cylinder type of cutter or by diamond saw blades. This pattern is a series of grooves 0.095 inch wide by 1/8 inch deep on 3/4-inch centers with four grooves 0.095 inch wide by 1/32 inch deep spaced evenly between each pair of the 1/8-inch-deep grooves. Figure 9 shows this pattern as placed on PCC pavement. Use of this pattern is recommended for pavement that is very smooth, where grooving alone will not produce the desired coefficient of friction. This pattern has not been in place long enough to determine its wear characteristics. The coefficients of friction for PCC pavement were 0.22 before and 0.37 after this pattern was placed. On the same pavement, the coefficient of friction was 0.31 for grooves of 1/8 inch by 1/8 inch on 3/4-inch centers.

The cost of grooving 1/8 inch by 1/8 inch on 3/4-inch centers is approximately 10 cents per square foot. The combination pattern is estimated to cost about 25 percent more.

THE FUTURE

The Highway Safety Program Standards issued by the National Highway Safety Bureau, Federal Highway Administration, dated June 27, 1967, call for each State to have a program for improvement of skid resistance of the pavement surfaces.

An initial phase of this program is the development of minimum friction requirements and a testing program using the ASTM two-wheel trailer which logs the existing friction values on all highways. The use of this information will be valuable in taking action before an accident problem develops.

BIBLIOGRAPHY

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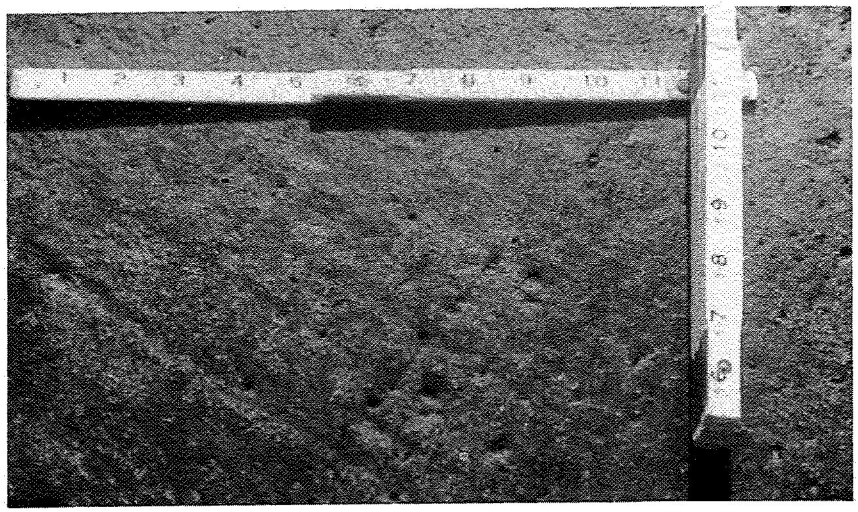
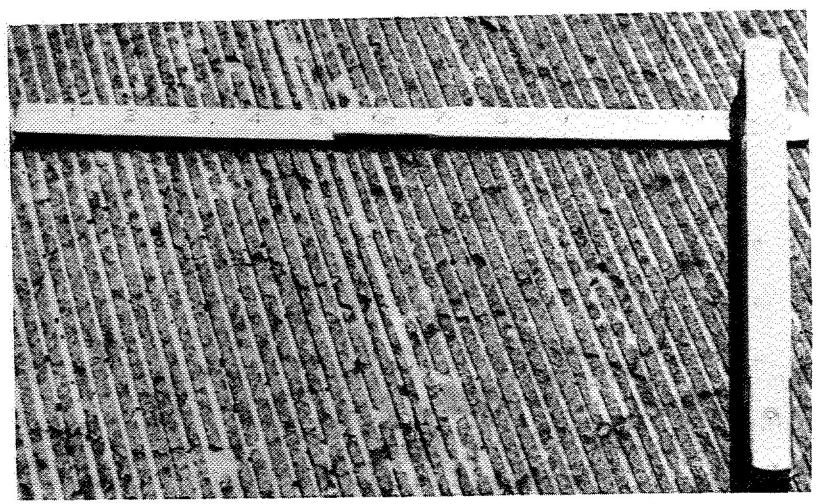
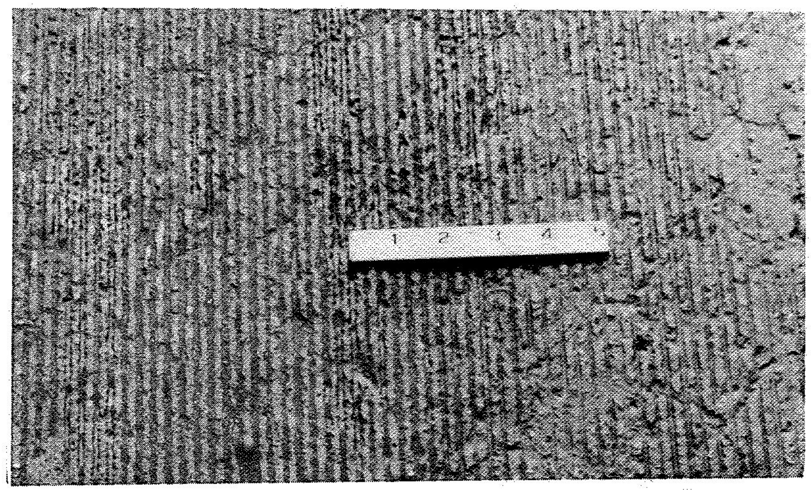
2. Williams, G. M.: Instructional Memorandum, 21-3-68, 32-01, Federal Highway Administration, Apr. 29, 1968.



Portland cement concrete before grooving, 1959



After grooving, 1960



After grooving, 1968

Figure 1.- Grooving Project A, U.S. 99 at Turlock O.H., 1/8-inch by 1/8-inch grooves on 3/8-inch centers.

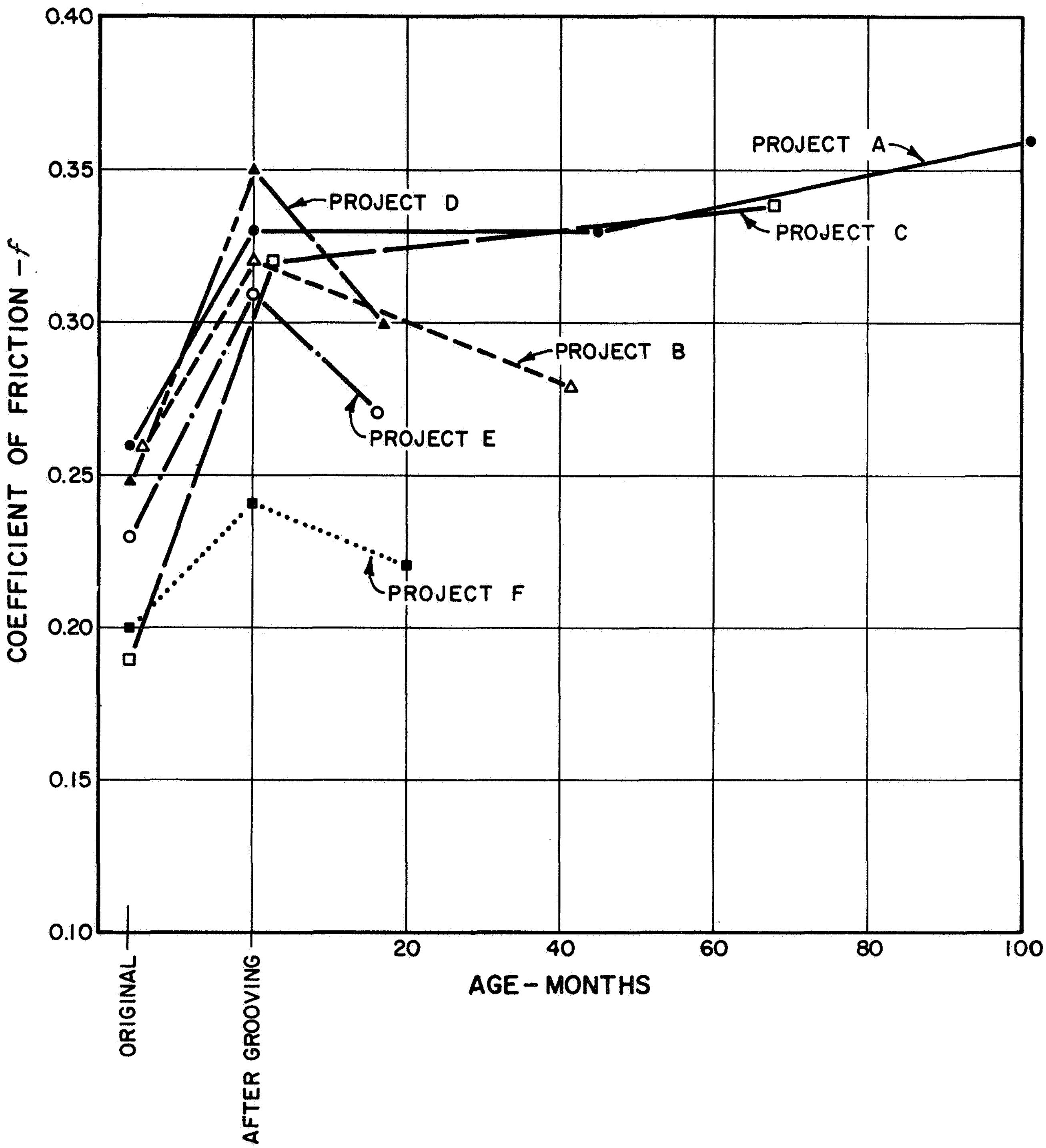
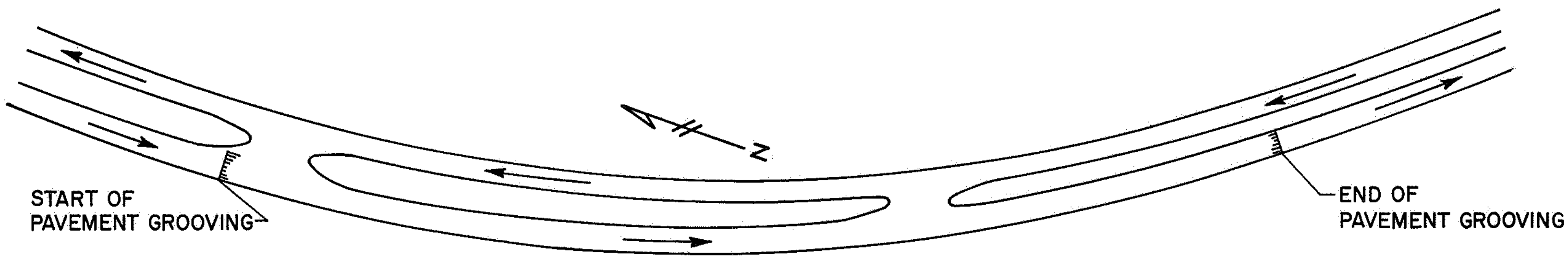


Figure 2.- Friction values before and after grooving of portland cement concrete pavements.

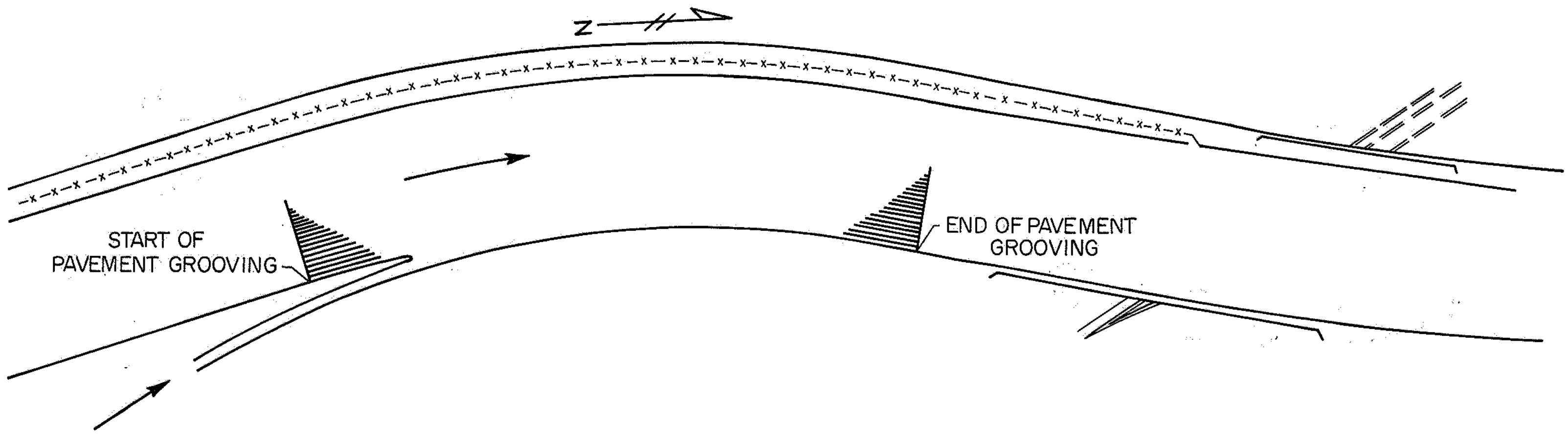


Accident Summary																	
	Year	No. of accidents		Damage class			Elements			Day-light	Dark	Course of vehicle			No. of persons		Rain days
		Total	Wet pavement	Fatal	Injury	Property	Pedes-trian	2 or more vehicles	Single car			Hit object	Ran off road	Over-taking	Killed	Injured	
Before[a]	61-62	15	9	1	7	7	0	7	8	9	6	9	0	6	1	15	29
After[b]	63-64	3	0	0	0	3	0	2	1	3	0	1	0	2	0	0	42
	65	8	0	1	3	4	0	6	2	8	0	2	0	6	5	6	24
	66	8	0	0	2	6	0	4	4	5	3	4	0	4	0	2	12
	67	4	0	0	2	2	0	3	1	2	2	1	0	3	0	3	26

[a]Before grooving: 1-16-61 to 1-15-63.

[b]After grooving: 1-25-63 to 1-26-68.

Figure 3.- Highway I-5, 50 miles north of Los Angeles.



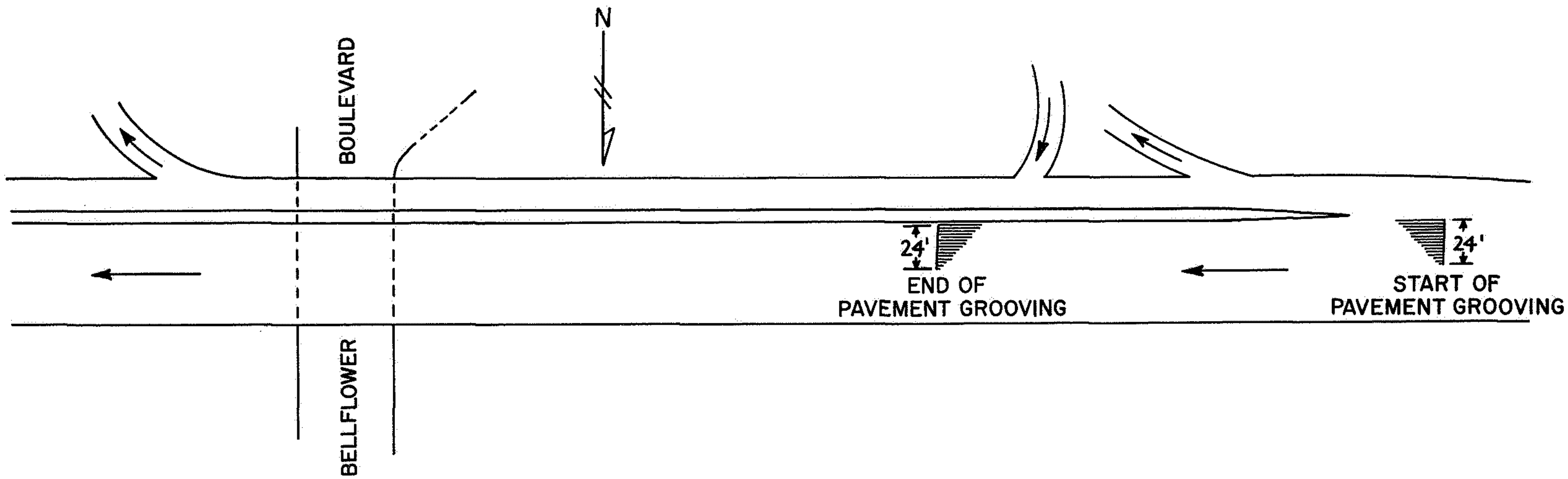
Accident Summary

	Year	No. of accidents		Damage class			Elements			Daylight	Dark	Course of vehicle			No. of persons		Rain days
		Total	Wet pavement	Fatal	Injury	Property	Pedestrian	2 or more vehicles	Single car			Hit object	Ran off road	Overtaking	Killed	Injured	
Before[a]	1963	7	0	0	5	2	0	3	4	4	3	5	0	2	0	12	24
	1964	13	8	0	7	6	0	2	11	6	7	12	0	1	0	9	18
	1965	52	47	0	19	33	0	11	41	36	16	42	0	10	0	35	30
After[b]	1966	8	1	0	5	3	0	4	4	4	4	4	0	4	0	9	15
	1967	4	1	0	2	2	0	3	1	3	1	1	1	2	0	3	20

[a]Before grooving: 1-1-63 to 12-31-65.

[b]After grooving: 2-1-66 to 1-31-68.

Figure 4.- Highway I-5, near El Toro Marine Base.



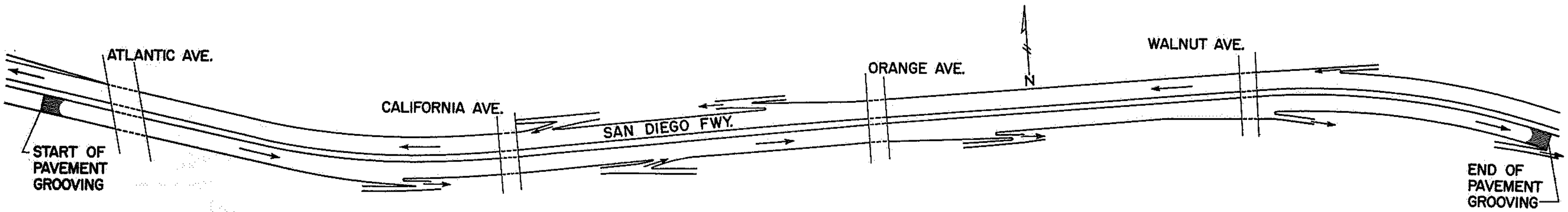
Accident Summary																	
	Year	No. of accidents		Damage class			Elements			Day-light	Dark	Course of vehicle			No. of persons		Rain days
		Total	Wet pavement	Fatal	Injury	Property	Pedes-trian	2 or more vehicles	Single car			Hit object	Ran off road	Over-taking	Killed	Injured	
Before[a]	65-66	30	20	0	13	17	0	10	20	14	16	18	0	12	0	21	29
After[b]	66-67	11	0	0	6	5	0	9	2	5	6	3	0	8	0	10	15
	67-68	10	[c]2	1	5	4	0	3	7	6	4	7	0	3	1	8	27

[a]Before grooving: 2-1-65 to 1-31-66.

[b]First year after grooving: 3-1-66 to 2-28-67; second year after grooving: 3-1-67 to 2-29-68.

[c]In ungrooved lane.

Figure 5.- Highway I-405 (San Diego Freeway), Long Beach at Bellflower Boulevard.



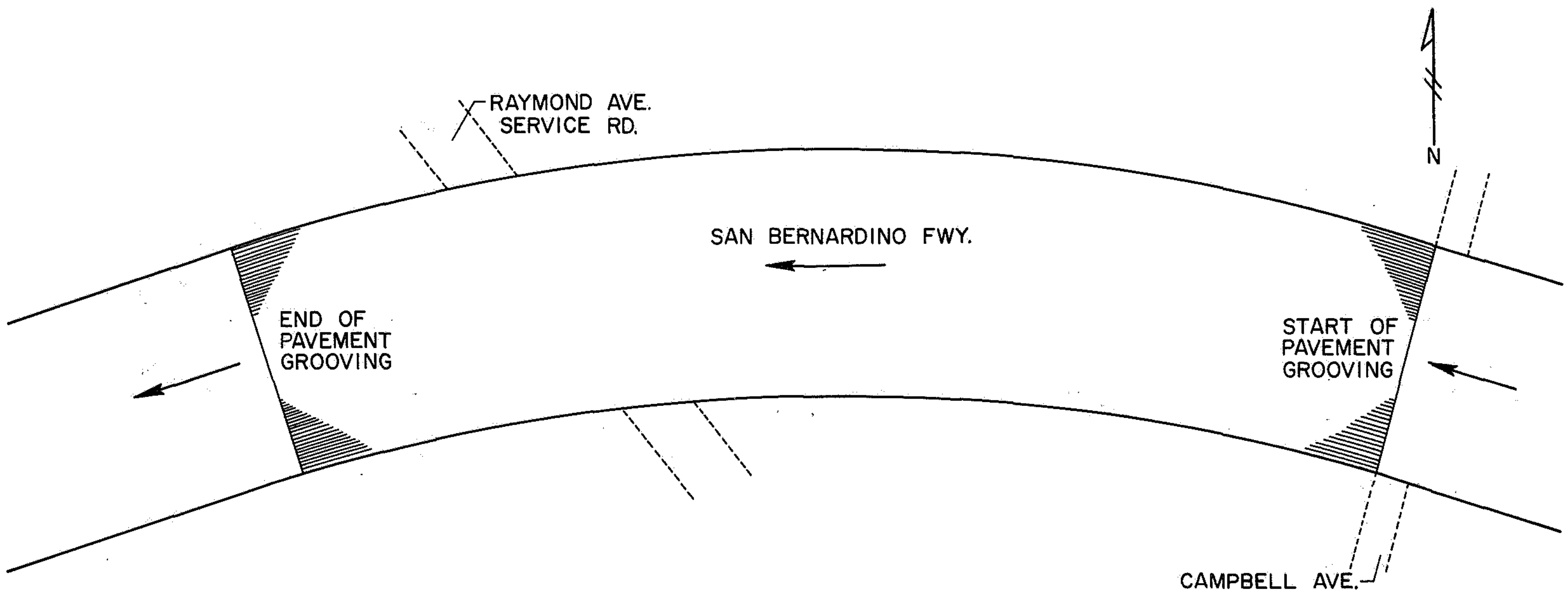
Accident Summary Northbound (Never Grooved)																
Year	No. of accidents		Damage class			Elements			Day-light	Dark	Course of vehicle			No. of persons		Rain days
	Total	Wet pavement	Fatal	Injury	Property	Pedes-trian	2 or more vehicles	Single car			Hit object	Ran off road	Over-taking	Killed	Injured	
66-67	21	7	0	10	11	0	10	11	6	15	7	4	10	0	18	20
67-68	22	5	0	10	12	0	10	12	7	15	6	0	16	0	11	17
66-67	Wet pav't	7	0	2	5	0	3	4	3	4	4	0	3	0	2	20
67-68		5	0	2	3	0	5	0	0	5	0	0	5	0	3	17

Accident Summary Southbound																	
	Year	No. of accidents		Damage class			Elements			Day-light	Dark	Course of vehicle			No. of persons		Rain days
		Total	Wet pavement	Fatal	Injury	Property	Pedes-trian	2 or more vehicles	Single car			Hit object	Ran off road	Over-taking	Killed	Injured	
Before[a]	66-67	102	61	0	29	73	0	56	46	62	40	41	8	53	0	58	20
After[b]	67-68	47	3	0	16	31	0	30	17	26	21	16	2	29	0	29	17
Wet before[a]	66-67		61	0	17	44	0	32	29	38	23	29	1	31	0	28	20
Wet after[b]	67-68		3	0	2	1	0	3	0	3	0	0	0	3	0	2	17

[a]Before grooving: 7-1-66 to 6-30-67.

[b]After grooving: 7-1-67 to 7-1-68.

Figure 6.- Highway I-405, Long Beach.



Accident Summary

	Year	No. of accidents: Total	No. of accidents: Wet pavement	Damage class: Fatal	Damage class: Injury	Damage class: Property	Elements: Pedestrian	Elements: 2 or more vehicles	Elements: Single car	Daylight	Dark	Course of vehicle: Hit object	Course of vehicle: Ran off road	Course of vehicle: Overtaking	No. of persons: Killed	No. of persons: Injured	Rain days
Before[a]	65-66	43	26	1	14	28	0	15	28	17	26	25	0	18	1	19	29
After[b]	66-67	8	2	0	3	5	0	3	5	2	6	2	2	3	0	2	16
	67-68	10	2	0	3	7	0	4	6	6	4	4	1	5	0	7	28

[a]Before grooving: 1-1-65 to 1-1-66.

[b]After grooving: 1-27-66 to 1-26-68.

Figure 7.- Highway I-10, about 5 miles east of Los Angeles.

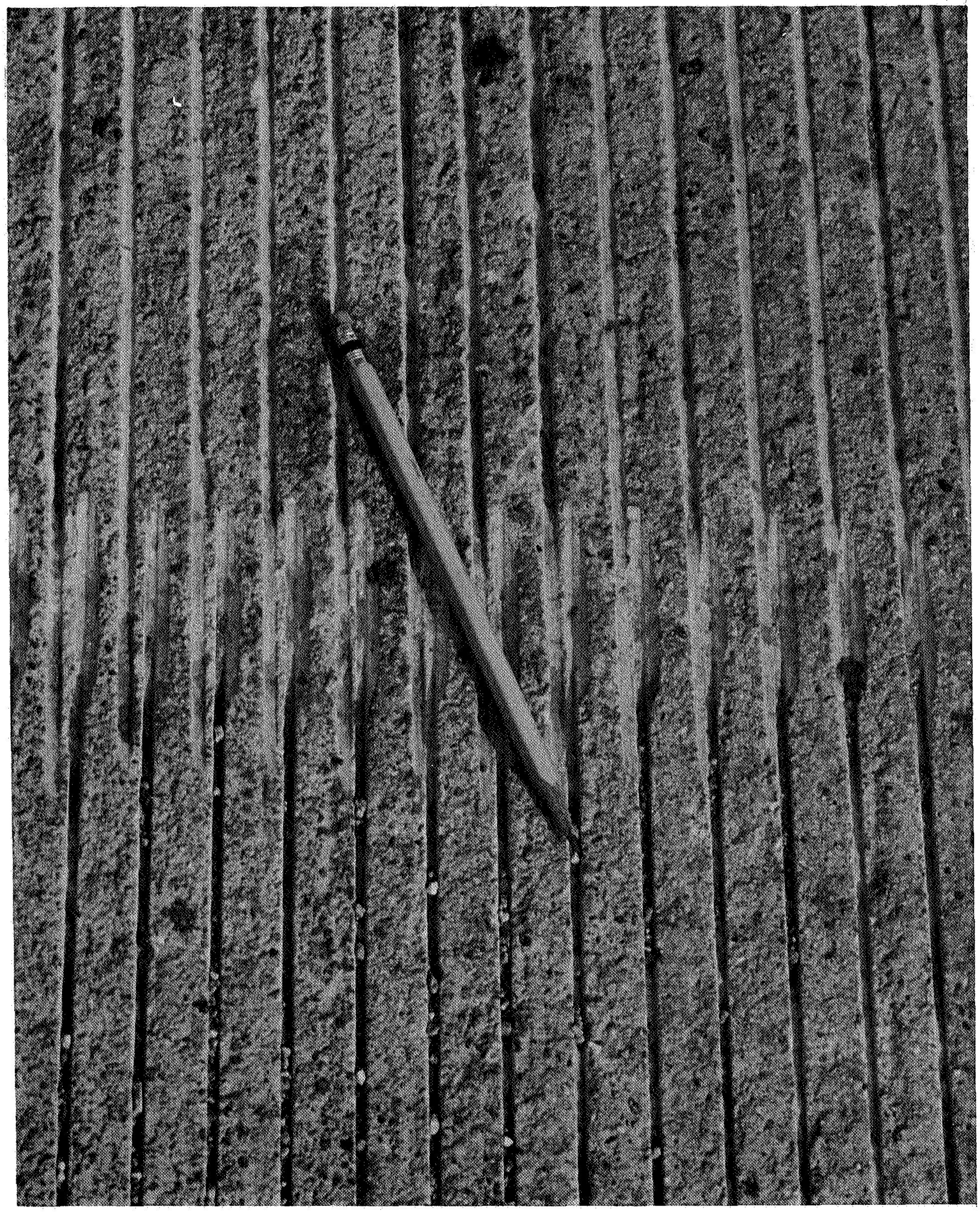


Figure 8.- Pavement with 1/8-inch-wide grooves at top and 0.095-inch-wide grooves at bottom.

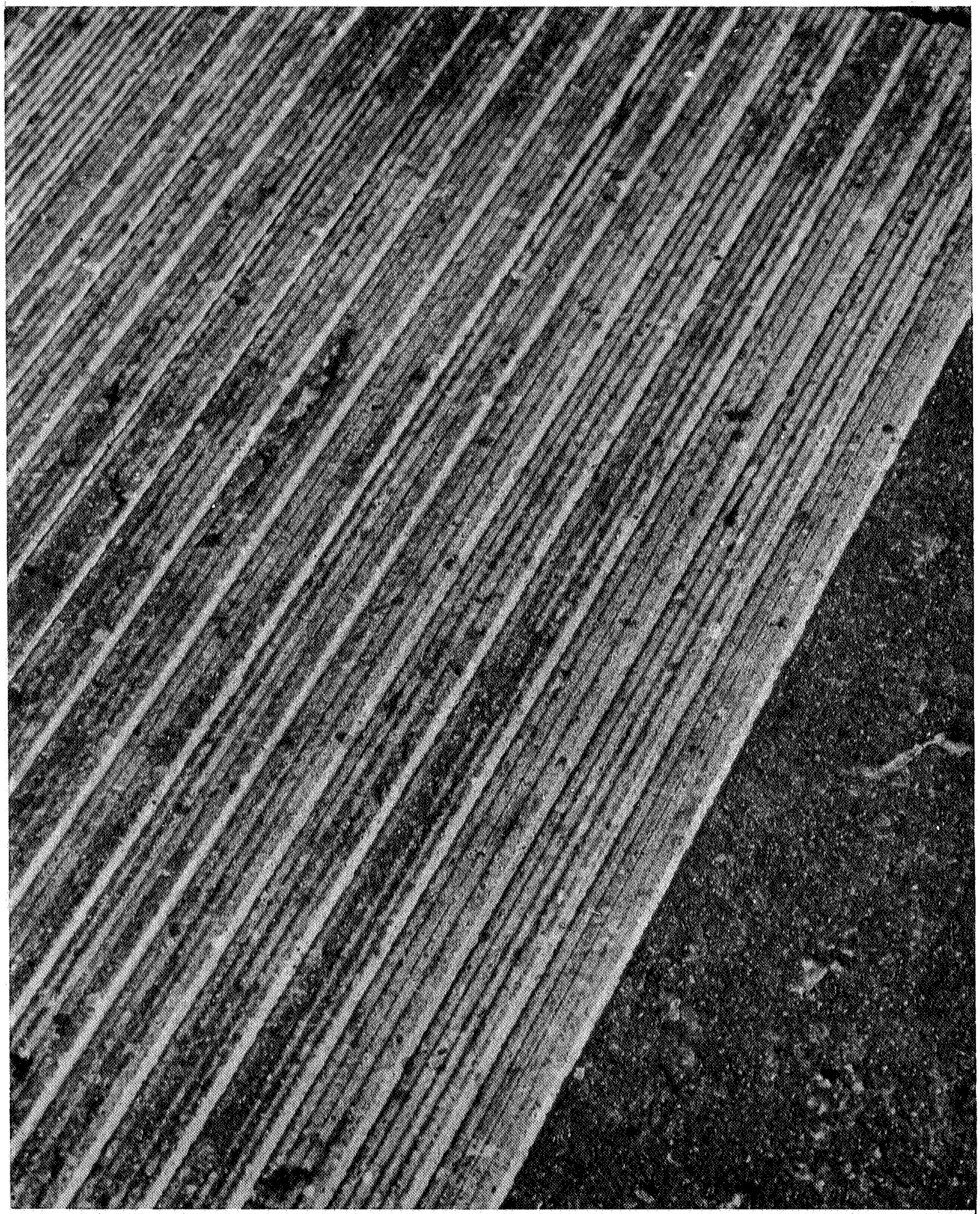


Figure 9.- Combination bump-cutting and grooving pattern.