EFFECTS OF AGGREGATE SEAL COATS ON SKID INDEX NUMBERS & ACCIDENT RATES OF LOW VOLUME ROADS IN UTAH

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EXECUTIVE SUMMARY

Friction deficient sections of highway exist, and sometimes contribute to elevated accident rates. Agencies address this problem by applying friction courses to deficient roadway sections. This paper examines whether chip seal friction courses are an effective accident counter-measure on low volume, rural highways. This was accomplished by looking at chip sealing operations in District 3 of the Utah Department of Transportation. Data from this district indicate that there is no definite relationship between accident rates and skid numbers on roads that were chip sealed. The general trend was a decrease in the accident rate with an increase in skid numbers. However, the linear and non-linear relationships found in previous studies were not appropriate to describe the observed trend.

On the assumption that the relationship between accident rate and skid number is non-linear, accident rate reduction after the application of a chip seal surface treatment was calculated using three methods. The first two methods did not consider the change in skid number. These two methods, estimated average reductions in accident rate of 63% and 61% respectively. However, when the before and after treatment accident rates were compared, differences were found to be statistically significant at levels below 85%. This suggests that the expected reductions will be lower than the above estimates. The third method is more hypothetical. It produced an estimated average accident reduction of 39%.

CHAPTER 1

INTRODUCTION

Currently, the technique most commonly used in the United States to measure skid resistance is method E 274 of the American Society for Testing and Materials (ASTM). This method measures the sliding friction force developed between a tire of standardized design and the wetted roadway surface measured at a constant speed of 40 mph. This measurement is then expressed as the skid number (SN_{40}).

The skid index of dry pavement is normally high. Therefore, skids on clean, dry pavement, are rare even at higher vehicle speeds. However, as the skid number drops, the risk of skidding increases greatly on wet pavements. The fact that skid number drops over time due to a reduction or smoothing of pavement surface texture means the risk of skidding and wet weather accidents can be expected to increase.

How low then should the skid resistance be allowed to fall before corrective action is taken? When a survey of several states was done by the National Cooperative Highway Research Program (NCHRP), the general consensus was that a skid number equal to or greater than 40, measured at 40 mph provides adequate surface characteristics for normal wet weather driving conditions. Skid numbers below 40 indicated roads that needed further study or corrective action to improve skid resistance (Halstead, 1983). NCHRP Report 37 suggests that a skid number of 37 is the minimum acceptable (Kummer & Meyer, 1967). Most state Departments of Transportation have established their own minimum skid number requirements, usually between 35 and 45. The Utah Department of Transportation (UDOT) uses a value of 35 as their critical skid number for designating sub-standard roads while skid numbers between 35 and 45 are considered marginal.

There are several corrective actions that can be taken to improve skid resistance on pavement sections. On low volume roads, UDOT uses aggregate seal coats. An aggregate seal coat or "chip seal" is applied by spreading a layer of bituminous material on the existing roadway, covering it with a layer of aggregate, and rolling it. This type of seal increases the skid resistance of the roadway by replacing the polished aggregate of the original roadway with new, roughly textured aggregate particles (Harwood, et al., 1978). Aggregates used in seal coats must meet certain criteria. They must (1) be resistant to abrasion and polishing and (2) be clean and relatively free of fine materials. As long as an aggregate meets these criteria, almost any type of aggregate can be used successfully in seal coat projects (Highway Research Board, 1972).

This study was undertaken to determine the effectiveness of aggregate seal coats as an accident countermeasure. Like most state Departments of Transportation, UDOT invests considerable resources each year on roadway maintenance. In 1992, UDOT spent close to $12 million on chip seal projects alone. These projects were chosen primarily on the basis of the bi-annual pavement condition survey or special requests. The latter selection criterion for chip seal treatment is usually related to safety. In other words, priority treatment may be programmed if the accident histories indicate a high risk situation.

Although UDOT has collected considerable information and examined the effectiveness of chip seals on pavement life, their effect on safety and other operational variables are relatively unknown. Thus, the primary objective of the study was to evaluate the safety effect of chip seals by focusing on the chip sealing projects completed between 1987 and 1992 in one of UDOT's 6 districts.

CHAPTER 2

DATA SOURCES

UDOT's Planning Division conducts a bi-annual pavement condition survey. As part of this survey, the skid number of every mile of paved roadway in Utah is determined. These skid numbers are measured with a locked wheel skid trailer travelling at the posted speed limit, but not exceeding 55 mph. Each measured skid index is then adjusted to a standard SN_{40} using a computerized speed correction method. This data, along with information on structural adequacy, ride index, and pavement distress is combined into the pavement condition survey.

The information from this survey is given to each District Director. He or she then determines the cause of the low skid number measurements and selects an appropriate treatment. When a maintenance activity is completed, a maintenance record for the activity is created. This maintenance record includes information about the type of maintenance performed, road segment identification, date, materials used, and cost.

This study is based on an analysis of a combination of data from the sources described above as well as information from UDOT's Safety Division. More specifically, data from the following were used: (1) UDOT's bi-annual pavement condition surveys from 1987 to 1991, (2) District 3 Seal Coat Program maintenance records from 1987 to 1990, and (3) UDOT's Safety Division Accident Records from 1985 to 1992.

District 3 was chosen because ....

District 3 is located in the south-central part of Utah. It is primarily a rural system containing over 1000 miles of asphalt roads. The road system in District 3 is very stable with little new construction. Most projects consist of preventative maintenance activities and surface treatments. The current maintenance practice in District 3 is to chip seal one-sixth and rejuvenate one-third of the asphalt road miles in the system every year.

A sample of thirty-four, one-mile-long roadway sections in UDOT's District 3 was chosen for the analysis. These sections were chosen according to two criteria. The first criterion was that, according to District 3 maintenance records, the section received a chip seal treatment during either 1988, 1989, or 1990. The second criterion was that the skid number for the section was 40 or less during the bi-annual pavement survey done before the chip seal was applied. The sample sections that met these criteria, shown in Table 1, are all from non-interstate, low volume roadways.

CHAPTER 3

DATA ANALYSIS

The safety effects of chip seals can be measured in different ways. One way is to determine the rate of change in accidents as a function of the change in the skid index so that the safety benefits of chip seals can be computed over the life of the chip seal. Another is to perform a traditional comparison of accident rates before and after the application of a chip seal with no reference to skid indices. The latter approach, which is perhaps the most common measure of effectiveness, is simply an indicator of safety benefits that could be expected with any seal coat at any time (Federal Highway Administration, 1981).

Previous work by Smith (1976) and Beaton (1976) have examined the effectiveness of chip seals from a safety viewpoint by considering the ratio of wet pavement to dry pavement accidents. Holbrook (1976) found that the proportion of wet pavement accidents decreases almost exponentially as the skid number increases. However, most studies have revealed that there are several other factors contributing to wet weather accidents that are both time and surface condition dependent. For instance, Holbrook (1976) argues that the length of time a pavement is wet can change the friction index and, therefore, the accident potential. On the other hand, researchers at Midwest Research Institute have found that, regardless of the surface moisture level and road geometry, wet accidents decrease monotonically with increasing skid numbers. In the light of these conflicting findings, UDOT and many other agencies have formulated arbitrary bases for evaluating the effectiveness of their surface treatment activities.

As far as UDOT is concerned, the current practice is to assume that in all cases the accident rate after treatment is equal to the statewide average accident rate, particularly for the purposes of prioritizing projects for the skid correction program. This average rate is assumed to be independent of either the expected change in skid number or the skid numbers before and after the corrective action.

In the remainder of this paper, different methods of estimating chip seal effectiveness are compared and an attempt is made to highlight some of the difficulties associated with deriving a reliable and globally valid estimate of effectiveness.

Effect On Skid Index

The skid numbers for the sample sections measured before and after the application of the chip seal are shown in Table 2 and depicted in Figure 1. It can be seen that, on average, skid numbers in these sections increased by 24 points after the chip seal treatments. Additionally, the standard deviation in the skid numbers decreased by 1.60, from 6.53 to 4.93. However, no correlation was found between the skid number before and after the treatment. In other words, the ultimate skid number was not directly related to the prior skid number.

Effect on Accident Rates

Information about accident rate and pavement condition at the time of accident occurrence was obtained for each sample section for three years before and two years after chip seal treatment. The reported pavement conditions at the time of the accidents were divided into three categories: wet weather, dry weather, and other. The "other" category included conditions such as ice or snow which made the accident rate unrelated to the skid number of the road. For this reason, this category was not included in the accident analysis.

Three methods were used in determining the change in accident rate after chip seal treatment at each site. The first method was a direct comparison of the before and after treatment accident rates. The second method was a comparison of projected accident rates if there were no treatment and actual after treatment accident rates. The third method compared the observed accident rate after the treatment to the expected accident rate expressed as a function of the before treatment accident rate and the before and after skid numbers.

Method 1. The three year average wet and dry weather accident rate (accidents per million vehicle miles) before chip seal treatment and the two year average wet and dry weather accident rate after chip seal treatment for each section sample are shown in Table 3.

According to this method, the chip seal effectiveness was estimated by averaging the observed changes in accident rates at each site after the treatment. This was done for both dry and wet weather accidents. When all sites were considered, it was found that the mean dry weather accident rate decreased 51.5% and the mean wet weather accident rate decreased 63.6%. The 95% confidence interval for the change in wet weather accident rate was found to be between -0.22 and 0.56 accidents per million vehicle miles.

Figures 2 and 3 show the distribution of accident rates before and after treatment respectively. When the two distributions are compared, a noticeable change in the distribution can be seen. Specifically, after treatment, there is a higher percentage of sections with low accident rates than before treatment.

To determine the magnitude of the difference between the distributions, the root mean square of the difference was computed with Equation 1 as follows:

$$RMSD = \sqrt{\frac{\sum_{i=1}^{N} (AR_{ib} - AR_{ia})^2}{N}} \qquad (1)$$

AR_{ib} = *accident rate before treatment at site i*
AR_{ia} = *accident rate after treatment at site i*
N = *total number of sample sites*
i = 1,2,..,N

Method 2. The expected accident rate if there was no treatment E(X) was computed using the Bayesian approach as described by Pendleton, et. al (1991). According to this method, the expected reduction in accidents was computed as opposed to the observed reduction, which is more likely to be influenced by random and data related uncertainties. The following expression, Equation 2, was used to compute the expected accident rate E(X):

$$E(X) = TYA + \frac{[SAAR * (SAAR - TYA)]}{S^2} \qquad (2)$$

TYA = *three year average wet /dry accident rate of a section before treatment*
$SAAR$ = *statewide average wet/dry accident rate for a particular functional class of road*
S = *standard deviation of the accident rates used for computing statewide average accident rates for each functional class*

The input variable TYA in Equation 2 was taken from Table 3. The variable Statewide Average Accident Rate (SAAR) was calculated in the following manner. First, the three-year average rates of wet accidents and dry accidents were calculated as a percentage of total accident rate. It was found that the average wet weather accident rate is approximately 8% and the average dry weather accident rate is about 92% of the total accident rate. The statewide average total accident rate given in Table 4 for each functional class of road was the n multiplied by these two percentages to get the SAARs.

The variable S in Equation 2, or the standard deviation of accident rates for the different classes of roads was unavailable from UDOT. Therefore it was necessary to assume that S is equal to the standard deviation of the three year average accident rates before treatment.

The expected accident rate in each section shown in Table 5 was computed using Equation 2. When the expected accident rates were compared to the observed accident rates after treatment, it was found that the average dry weather incident rate taken over all sites decreased by approximately 51% and the average wet weather rate decreased by 61%. The 95% confidence interval for the change in wet weather accident rates was between -0.179 and 0.489 accidents per million vehicle miles.

Also, it can be seen from Figures 3 and 4 that the distributions of wet and dry weather accident rates after treatment are significantly different from the distributions of expected accident rates on wet and dry pavements if no treatment was initiated. The root mean square of the differences between expected accident rates and the observed accident rates in wet weather was found to be 0.96 accidents per million vehicle miles. This suggests that chip seals have had a significant impact on the wet weather accidents, as indicated by the percentage change in mean accident rate of 61% noted earlier.

Method 3. In the two previous methods, the effectiveness was computed independently of the skid number. However, if the effectiveness of the chip seal treatments is to be assessed, the change in the accident rate should be viewed in relation to the change in skid number because of the correlations between skid number and accident rate.

UDOT assumes that the accident rate on non-interstate roadways declines almost exponentially between skid numbers 25 and 40 and then levels off as skid number increases beyond 40. In the present case, it was difficult to observe such a trend. Nevertheless, in order to incorporate the effects of the improvement in skid resistance, it was assumed that the accident rate before treatment should be reduced in proportion to the change in skid number as a result of the treatment. But it should also have some relationship to the skid number before the treatment. Hence the following equation was postulated for the expected accident rate as a function of the before treatment accident rate:

$$E(AR) = AR_b * \frac{SN_b}{SN_a} \tag{3}$$

AR_b = *accident rate before treatment*
SN_b = *skid index before treatment*
SN_a = *skid index after treatment*

The expected wet and dry weather accident rates computed with this equation are shown in Table 6 and their distributions are depicted in Figure 5.

It can be seen, by comparing Figures 3 and 5, that the expected accident rates calculated with Equation 2 are reasonably close to the actual after treatment values. To quantify the predictability of Equation 3, the root mean square of the differences (RMSD) between expected wet weather accident rates estimated above and the observed after treatment wet weather accident rates was computed. Despite the fact that a correlation between change in skid number and accident rate was not evident when a regression analysis was performed, the relatively low RMSD value of 0.306 suggests that Equation 3 gives a reasonable estimate of the expected accident rate. On this basis it can be reasonably concluded that the effectiveness of the treatment in the present case is approximately a 39% average reduction in wet weather accident rates. This rate of effectiveness is almost half of that estimated using methods 1 and 2. However, if the variation in skid numbers after treatment are widely dispersed, the expected accident rates after the treatment may be estimated as follows:

$$E(AR) = AR_b * \left(\frac{SN_b}{SN_a}\right) \left[1 + (CV_{SN_a})^2\right] \tag{4}$$

where (CV_{SV_a}) = coefficient of variation of after treatment skid numbers

CHAPTER 4

DISCUSSION OF RESULTS

Ideally, after the application of a well controlled chip seal, the skid number of all treated sections should increase to approximately the same level, regardless of the prior skid index. In other words, if chip seals contain the same materials and are applied in the same region on similar classes of roads, the variation in the after treatment skid number at the different sites should be fairly small. In the present case, the after skid numbers of the sample sites had a range of about 20 points as seen from Table 2.

Such variations, although attributable to measurement errors and differences in materials, makes the estimates of safety effects of chip seals all the more uncertain. For instance, if the variations were small, the expected accident rates after treatment should also be fairly stable. This would be indicated by a strong correlation between accident rates and skid number. But, as seen from previous work and the present case, the correlation is not definite. Until these variations can be fully explained and controlled and new data can be collected, the safety effects of chip seals will have to remain tentative.

Even if the variations in skid number can be measured reasonably accurately, the method used to compute effectiveness will introduce a large element of uncertainty. It was seen in the previous section that the average percent reductions in accident rate can be as high as 66% depending on the method used. But, when the skid number is brought into the picture, it drops down to 39%.

The latter method of estimation (i.e. method 3) seems to be the more logical choice. It should provide a better estimate since the underlying assumption is that when the before treatment skid number is low and the after treatment skid number is fairly stable, the expected reduction can be much larger than when the before treatment skid number is high.

CHAPTER 5

CONCLUSIONS

This study has shown that there is no definite relationship between skid number and accident rate in the road sections that underwent chip seal treatment. Although the average accident rate at the sites seems to have decreased by as much as 60% when the before and after rates were compared, it is insufficient to conclude that the improvement is totally attributable to the increase in skid number.

The first two methods used to estimate the effectiveness suggest that the reduction in accident rate in some cases is as high as 0.564 accidents per million vehicle miles at the 95% level of confidence. However, the difference in the mean accident rates before and after are not statistically significant at the 5% level. The critical level of significance was 19% for wet weather accidents and 13% for dry weather accidents. Moreover, estimates of accident reduction so calculated do not reflect the effects of the improvement in skid resistance.

When the accident rates are adjusted to reflect the changes in skid number, it was found that the wet weather accident reduction drops to 39% and the dry weather accident reduction drops to 45%. These values calculated with method 3 seem more realistic even though data was inadequate to verify Equation 3.

All three methods used to measure the safety effects of chip seals showed a reduction in both the wet and dry weather accident rates. The fact that the dry weather accident rate was reduced along with the wet weather accident rate suggests that factors other than just the chip seal needs to be examined prior to determining the net effectiveness of chip seals. Additionally, since the reduction in the mean wet weather accident rate due to chip sealing is only significant at the 19% level, the likelihood of achieving a 63% reduction in the accident rate is much lower than 81%. Thus, the expected accident rate reduction will certainly be lower than the 63% obtained with method 1 and the 61% obtained with method 2.

In general, chip seals were found to result in lower accident rates, but the extent of the reduction is likely to be less than those estimated with methods 1 and 2. From this point of view, UDOT should continue with their chip seal program, but should focus more on sections with low skid numbers as opposed to those with higher skid numbers.

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APPENDIX A

TABLE 1. ROADWAY SECTIONS CHOSEN FOR ANALYSIS

DISTRICT 3				
SECTION #	ROUTE #	BEGINNING MILEPOST	ENDING MILEPOST	FUNCTIONAL CLASS
1	89	5.00	6.00	2
2	89	6.00	7.00	2
3	12	27.00	28.00	6
4	12	110.00	111.00	6
5	12	111.00	112.00	6
6	12	112.00	113.00	6
7	12	113.00	114.00	6
8	12	114.00	115.00	6
9	24	53.00	54.00	6
10	24	54.00	55.00	6
11	24	55.00	56.00	6
12	24	76.00	77.00	6
13	89	116.00	117.00	6
14	89	123.00	124.00	6
15	89	132.00	133.00	6
16	89	133.00	134.00	6
17	89	134.00	135.00	6
18	89	135.00	136.00	6
19	89	136.00	137.00	6
20	89	137.00	138.00	6
21	72	14.00	15.00	7
22	72	16.00	17.00	7
23	72	18.00	19.00	7
24	72	20.00	21.00	7
25	72	22.00	23.00	7
26	72	24.00	25.00	7
27	72	26.00	27.00	7
28	72	28.00	29.00	7
29	72	30.00	31.00	7
30	72	31.00	32.00	7
31	72	32.00	33.00	7
32	72	33.00	34.00	7
33	143	48.00	49.00	7
34	143	49.00	50.00	7

TABLE 2. SKID INDICES BEFORE AND AFTER CHIP SEAL TREATMENT

DISTRICT 3		
SECTION #	SKID # BEFORE SEALING	SKID # AFTER SEALING
1	38	59
2	39	58
3	28	50
4	35	51
5	38	47
6	39	53
7	39	53
8	39	52
9	30	44
10	25	50
11	22	48
12	30	59
13	29	53
14	31	56
15	40	55
16	36	51
17	38	56
18	32	56
19	40	59
20	40	58
21	24	54
22	22	59
23	28	60
24	26	59
25	33	58
26	30	60
27	37	60
28	27	64
29	20	58
30	28	61
31	26	61
32	19	61
33	34	60
34	40	65
MEAN	31.35	56.12
STDEV	6.53	4.93

TABLE 3. ACCIDENT RATES BEFORE AND AFTER CHIP SEAL TREATMENT

DISTRICT 3				
SECTION #	DRY ACC RATE BEFORE	WET ACC RATE BEFORE	DRY ACC RATE AFTER	WET ACC RATE AFTER
1	2.190	0.000	0.916	0.000
2	2.072	0.000	0.892	0.000
3	2.435	0.000	1.539	0.000
4	0.000	0.000	0.000	0.000
5	6.690	0.000	0.000	0.000
6	4.807	4.807	0.000	0.000
7	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000
9	0.919	0.000	0.000	3.333
10	2.728	0.000	3.468	0.000
11	4.621	0.000	3.468	0.000
12	0.000	0.000	0.000	0.000
13	1.742	0.000	1.390	0.000
14	2.747	0.000	3.761	0.000
15	0.841	0.000	0.624	0.000
16	3.095	0.000	1.374	0.000
17	6.758	0.000	1.374	0.000
18	2.262	1.124	2.089	0.000
19	0.562	0.562	0.000	0.000
20	0.000	0.000	0.000	0.000
21	0.000	0.000	27.397	0.000
22	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000
26	26.093	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000
28	26.093	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000
33	2.468	2.647	0.000	0.000
34	4.807	0.000	2.174	0.000
MEAN	3.057	0.269	1.484	0.098
STDEV	6.170	0.941	4.713	0.572

TABLE 4. STATEWIDE AVERAGE ACCIDENT RATES

STATEWIDE--SUBJECT TO DISTRICT 3 WET & DRY WEATHER ACCIDENT %				
SECTION #	FUNCTIONAL CLASS	CLASS AVG ACC RATE	AVG DRY ACC RATE	AVG WET ACC RATE
1	2	1.64	1.507	0.133
2	2	1.64	1.507	0.133
3	6	2.28	2.096	0.184
4	6	2.28	2.096	0.184
5	6	2.28	2.096	0.184
6	6	2.28	2.096	0.184
7	6	2.28	2.096	0.184
8	6	2.28	2.096	0.184
9	6	2.28	2.096	0.184
10	6	2.28	2.096	0.184
11	6	2.28	2.096	0.184
12	6	2.28	2.096	0.184
13	6	2.28	2.096	0.184
14	6	2.28	2.096	0.184
15	6	2.28	2.096	0.184
16	6	2.28	2.096	0.184
17	6	2.28	2.096	0.184
18	6	2.28	2.096	0.184
19	6	2.28	2.096	0.184
20	6	2.28	2.096	0.184
21	7	2.63	2.417	0.213
22	7	2.63	2.417	0.213
23	7	2.63	2.417	0.213
24	7	2.63	2.417	0.213
25	7	2.63	2.417	0.213
26	7	2.63	2.417	0.213
27	7	2.63	2.417	0.213
28	7	2.63	2.417	0.213
29	7	2.63	2.417	0.213
30	7	2.63	2.417	0.213
31	7	2.63	2.417	0.213
32	7	2.63	2.417	0.213
33	7	2.63	2.417	0.213
34	7	2.63	2.417	0.213

TABLE 5. EXPECTED ACCIDENT RATES IF NO CHIP SEAL IS APPLIED

DISTRICT 3		
SECTION #	EXP DRY ACC RATE	EXP WET ACC RATE
1	2.163	0.020
2	2.050	0.020
3	2.417	0.038
4	0.115	0.038
5	6.438	0.038
6	4.657	3.845
7	0.115	0.038
8	0.115	0.038
9	0.983	0.038
10	2.694	0.038
11	4.482	0.038
12	0.115	0.038
13	1.761	0.038
14	2.711	0.038
15	0.910	0.038
16	3.040	0.038
17	6.502	0.038
18	2.253	0.928
19	0.646	0.483
20	0.115	0.038
21	0.153	0.051
22	0.153	0.051
23	0.153	0.051
24	0.153	0.051
25	0.153	0.051
26	24.591	0.051
27	0.153	0.051
28	24.591	0.051
29	0.153	0.051
30	0.153	0.051
31	0.153	0.051
32	0.153	0.051
33	2.465	2.063
34	4.655	0.051
MEAN	3.004	0.253
STDEV	5.787	0.739

TABLE 6. EXPECTED ACCIDENT RATES WHEN CHIP SEAL IS APPLIED

DISTRICT 3		
SECTION #	EXP DRY ACC RATE	EXP WET ACC RATE
1	1.410	0.000
2	1.393	0.000
3	1.364	0.000
4	0.000	0.000
5	5.409	0.000
6	3.537	3.537
7	0.000	0.000
8	0.000	0.000
9	0.626	0.000
10	1.364	0.000
11	2.118	0.000
12	0.000	0.000
13	0.953	0.000
14	1.520	0.000
15	0.612	0.000
16	2.185	0.000
17	4.586	0.000
18	1.293	0.642
19	0.381	0.381
20	0.000	0.000
21	0.000	0.000
22	0.000	0.000
23	0.000	0.000
24	0.000	0.000
25	0.000	0.000
26	13.046	0.000
27	0.000	0.000
28	11.008	0.000
29	0.000	0.000
30	0.000	0.000
31	0.000	0.000
32	0.000	0.000
33	1.399	1.500
34	2.958	0.000
MEAN	1.681	0.178
STDEV	2.972	0.657

APPENDIX B

FIGURE 1. SKID INDICES BEFORE AND AFTER CHIP SEAL APPLICATION

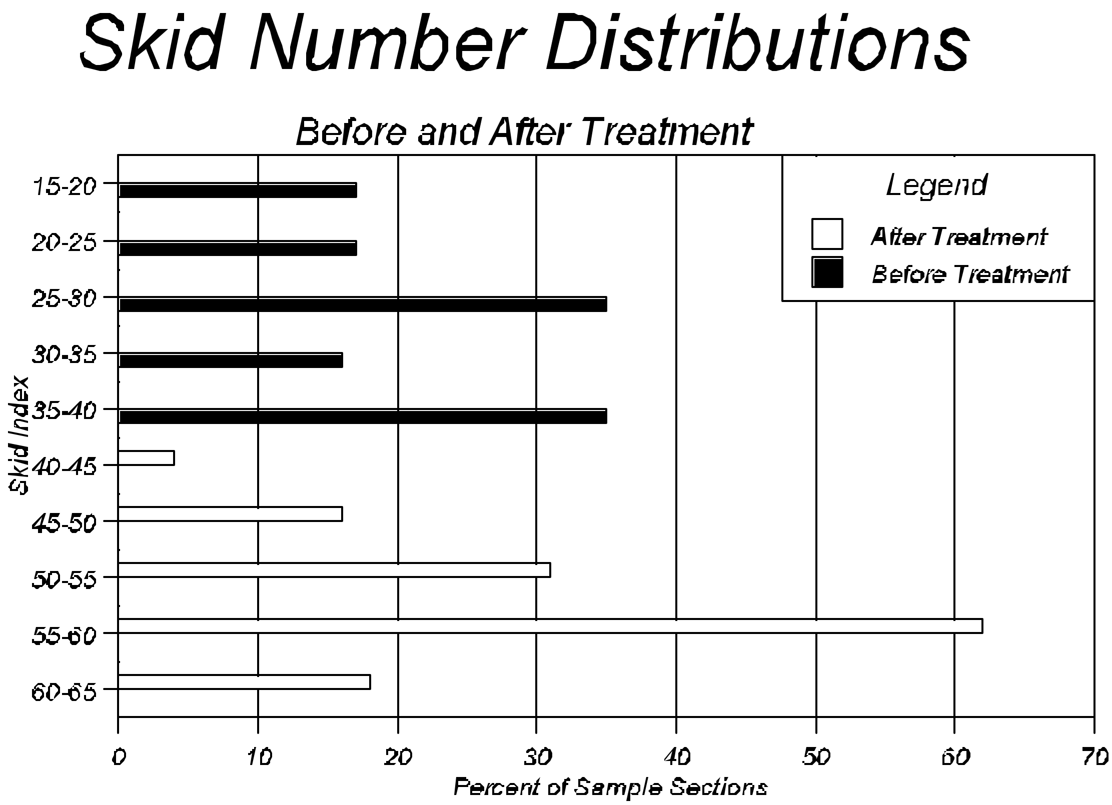

FIGURE 2. ACCIDENT RATE DISTRIBUTION BEFORE CHIP SEAL APPLICATION

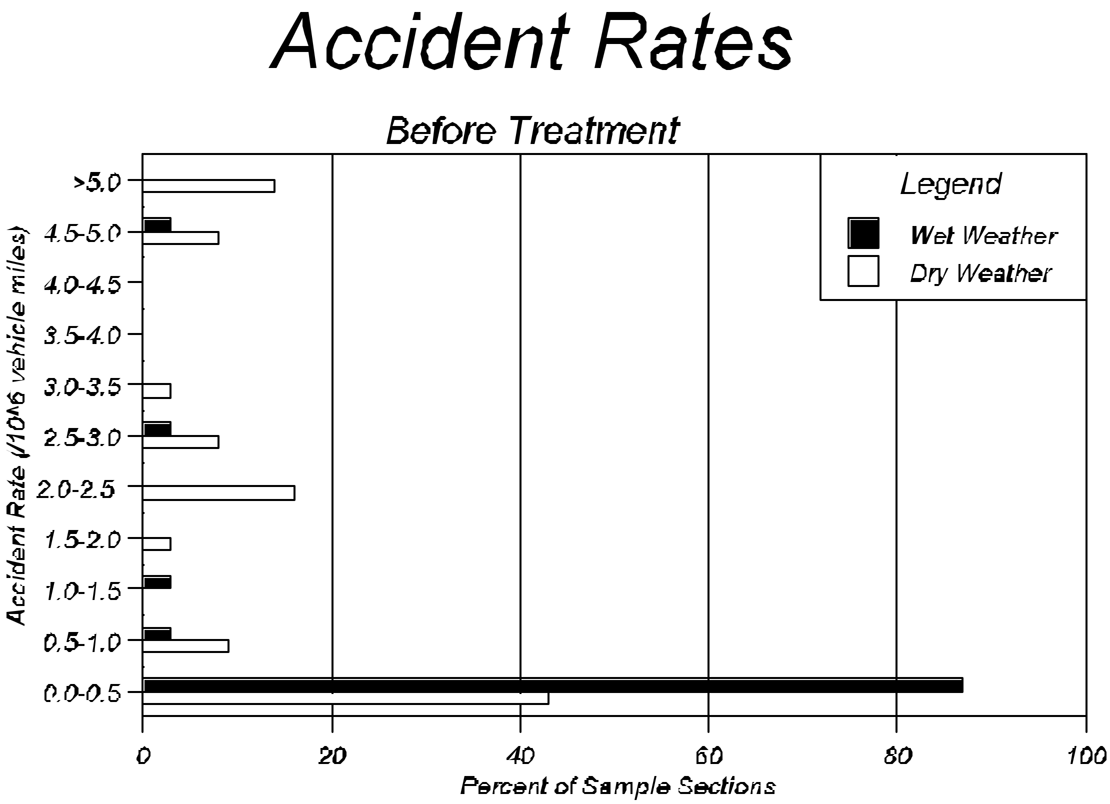

FIGURE 3. ACCIDENT RATE DISTRIBUTION AFTER CHIP SEAL APPLICATION

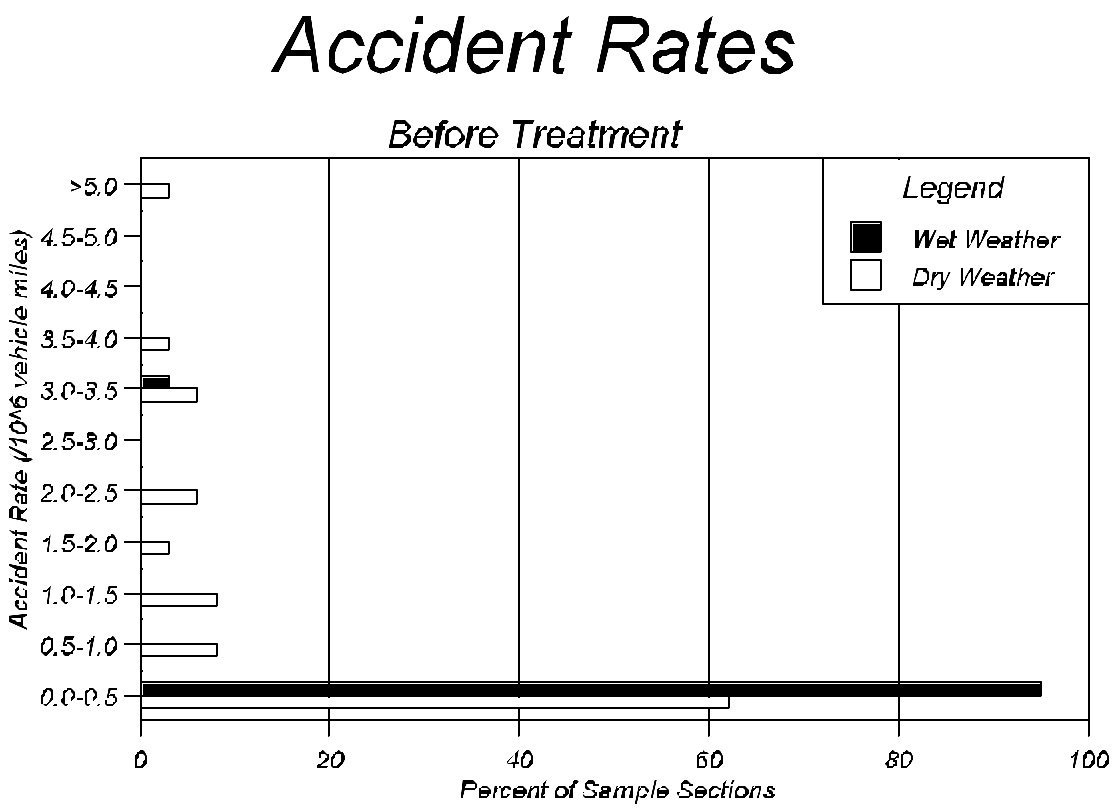

FIGURE 4. EXPECTED ACCIDENT RATES IF NO CHIP SEAL IS APPLIED

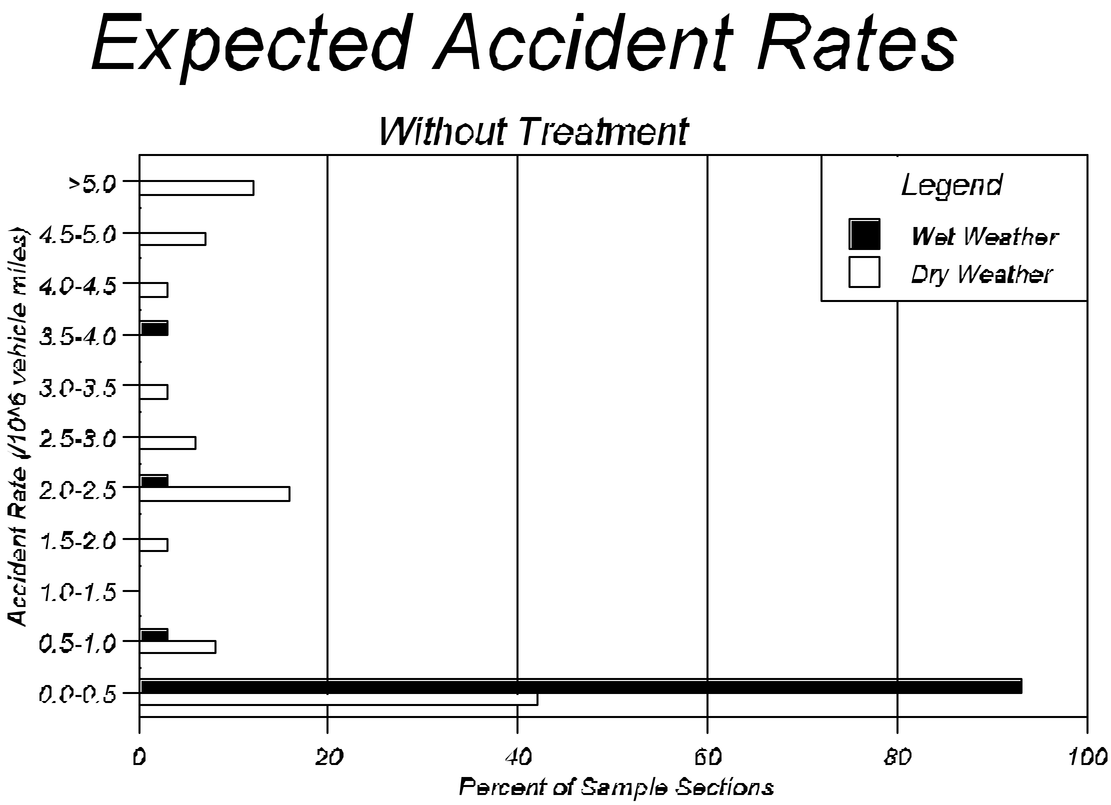

FIGURE 5. EXPECTED ACCIDENT RATES AFTER CHIP SEAL APPLICATION