R. L. Carstens   R. Y. Woo   June 1982

# Warrants for Rumble Strips on Rural Highways

Iowa Highway Research Board   HR-235

ISU-ERI-Ames-83002
ERI Project 1524

In Cooperation with the Highway Division,
Iowa Department of Transportation

report

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Final Report

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Department of Civil Engineering
Engineering Research Institute
Iowa State University; Ames, Iowa 50011

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# EXECUTIVE SUMMARY

Research was undertaken, sponsored by the Iowa Department of Transportation, to identify specific locations where rumble strips could be expected to improve highway safety. The objective of the research was to recommend warrants for their use on rural highways.

An inventory of rumble strip installations on the rural highway systems in the state was conducted in 1981. A total of 685 installations was reported on secondary roads and 147 on primary highways. Over 97 percent of these were in advance of stop signs at intersections. Most of the other installations were in advance of railroad grade crossings.

The accident experience with and without rumble strips was compared in two ways. A before-and-after comparison was made for the same location if accident records were available for at least one full year both preceding and following the installation of rumble strips. Accident records for this purpose were available from a statewide computerized record system covering the period from 1977 through 1980. The accident experience at locations having rumble strips installed before 1978 was compared with a sample of comparable locations not having rumble strips.

The secondary road sample used for the before-and-after comparison included 88 locations. There were also 119 locations having rumble strips in the sample for which the accident experience was compared with 119 comparable locations that did not have rumble strips. Some of these were deleted from the sample for analysis since they were unique types of installations where no accidents were experienced during the

period for which records were available. The primary highway sample included 21 locations with before-and-after accident experience and 28 locations having rumble strips that were matched with 28 comparable locations without rumble strips. Comparisons were made on the basis of both the total number of accidents and the number of accidents attributed to running a stop sign.

There was no difference in the accident experience of secondary road locations between the periods before and after the installation of rumble strips. Secondary road locations having rumble strips for longer periods experienced slightly more accidents than comparable control locations without rumble strips.

At primary highway locations in the before-and-after sample, the accident experience following the installation of rumble strips was significantly lower than it had been before their installation. There was little difference in accident rates between the control locations and primary highway locations with rumble strips installed before 1978.

However, no correlation could be demonstrated between the occurrence of accidents at the locations in the sample and factors including traffic volume, sight distance, and distance from the last stop. Analysis of the before-and-after samples indicated that the accident rate could be expected to improve following installation of rumble strips only if it were fairly high preceding their installation, above 2.5 accidents/MEV at secondary locations and above 2.0 accidents/MEV at primary locations.

These conclusions led to a recommendation that the installation of rumble strips should be considered at intersections experiencing accident rates in excess of those stated above if the results of an engineering study indicate that their installation will exert a beneficial effect on highway safety. It was also recommended that rumble strip installations should conform with the standard design prepared by the Iowa Department of Transportation.

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## ACKNOWLEDGMENTS

The research reported here was carried out by the Engineering Research Institute, Iowa State University. It was sponsored by the Highway Division, Iowa Department of Transportation, through the Iowa Highway Research Board.

Undergraduate Research Assistants who conducted the field inventories and provided other invaluable assistance included Randy Ruchotzke, Dan Carlson, Nasser Nikpour, George Reyher, and Janelle Ohms.

Research personnel wish to extend their appreciation to each County Engineer in Iowa. All responded to the questionnaire which provided some of the factual input to this research. Special thanks are directed to the following persons who participated as an advisory panel and made helpful suggestions for increasing the value of the research:

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Craig Gregersen, Assistant Attorney General, General Counsel Division, Iowa Department of Transportation.

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Richard Mull, Assistant Attorney General, General Counsel Division, Iowa Department of Transportation.

Stanley L. Ring, Professor of Civil Engineering, Iowa State University.

Dwight L. Stevens, Traffic Engineer, Highway Division, Iowa Department of Transportation.

Rodney D. Vlotho, Hardin County Engineer.

The authors, however, retain responsibility for the interpretations of factual input to the research and for its findings and conclusions.

# CHAPTER I. INTRODUCTION

## Background for the Study

The use of rumble strips on paved rural highways is often suggested as a means of enhancing safety. Rumble strips are widely used in some jurisdictions in advance of intersections controlled by stop signs. A few jurisdictions also make use of rumble strips in advance of railroad grade crossings or at other locations perceived as requiring supplemental warning devices.

The use of rumble strips has become sufficiently widespread that some drivers appear to expect them at every location where a stop may be required. As a result, the absence of a rumble strip is frequently cited as evidence of negligence in support of a tort claim resulting from an accident at a location where rumble strips could have been installed but were not.

No definitive guidelines or warrants have been developed to suggest locations at which rumble strips should be installed. Some of the research reported in the literature indicates that they can be highly effective in reducing accidents at some locations. On the other hand, the saturation use of rumble strips in Iowa was shown to be ineffective in reducing accidents under some circumstances. In fact, the use of rumble strips is believed to lead to an increase in accidents at some locations, particularly where bicycles or mopeds are present in significant numbers.

Research was undertaken in an effort to identify specific locations where rumble strips could be expected to improve highway safety.

Factors that were considered include intersection sight distances, approach gradients, accident experience, and distance from the last previous stop. These factors were quantified through a field inventory of selected locations where rumble strips had been installed. Analysis of the correlation of these factors with safety could make use of the accident records available through the Accident Location and Analysis System (ALAS).

## Project Overview

### Research Goal and Objectives

The goal of the research was to improve safety on rural highways by recommending guidelines or warrants for the use of rumble strips. To accomplish this goal, those factors were to be identified and quantified that could be used to distinguish between locations where rumble strips can be shown to be effective in reducing accidents and those locations where no beneficial effect on accident frequency may be expected. The effect of each factor was to be quantified so that numerical warrants could be developed. An additional objective was to reassess the conclusions regarding rumble strip installations in Black Hawk, Bremer, and Chickasaw Counties that were studied in the Iowa Highway Research Board research project HR-184, "Determination of Rumble Strip Effectiveness."

### Research Approach

The technical literature was reviewed for publications that reported the results of research relating to the use of rumble strips or other articles about their use. A summary of the information obtained from these reports and articles is included in Chapter II.

Chapter III describes the sample of locations used to analyze the effectiveness of rumble strips in reducing the frequency of accidents. The purpose of this sampling was to develop two subsets of rumble strip installations in Iowa. Since accident data were available through ALAS only for the period 1977 through 1980, before-and-after accident comparisons were possible only for locations at which rumble strips were installed in 1978 or 1979. These locations constituted the first subset of rumble strip installations. The second subset consisted of a representative sample of locations at which rumble strips were installed prior to 1978. Accident comparisons for this subset were made with a sample of comparable locations at which no rumble strips had been installed. Other information needed to complete an analysis of the factors affecting accident experience was obtained from a field inventory of the locations having rumble strips and the associated control locations.

The results of statistical analyses of the safety effects following rumble strip installation are reported in Chapter IV. The purpose of these analyses was to identify any variables that characterized locations where installation of rumble strips had exerted a beneficial effect on the frequency of accidents and to quantify the relationships involved.

Conclusions and recommendations resulting from this research are presented in Chapter V. The recommendations were formulated following a meeting with an advisory panel that assisted the research team.

Further analyses were undertaken at the suggestion of the advisory panel, and the results of these analyses are reported in Chapter IV and have been reflected in the recommendations.

# CHAPTER II. REPORTED RESULTS OF PREVIOUS RESEARCH

The earliest significant use of rumble strips in the United States apparently occurred in the Chicago area in 1954 [1,2]. Cook County installed approximately 212 "rumble areas" in advance of stop signs. At one such installation, the percentage of vehicles making complete stops increased from 46 percent before the rumble area was installed to 76 percent after its installation.

Since this earliest reported use, rumble areas or rumble strips have been used quite extensively to augment and reinforce a warning message. A number of reports have been published which summarize the results of research associated with the use of these devices; some significant details of this research are summarized in this chapter.

## Statewide Study in Illinois

The State of Illinois has studied a number of rumble strips installed in 1962 [3,4]. These were of three different designs. Of these, only one type was of a sufficiently large sample size to develop significant accident statistics and also was deemed adequate as a warning device. This type was installed at five intersections on the state highway system.

Before-and-after comparisons of total accidents were made at these locations. Of the five intersections, the accident rate declined at two intersections and increased at two others. At the fifth location, the one with the highest accident rate, the accident rate increased about 40 percent during the next three years after rumble strips were installed, then declined following installation of flashing beacons. A total of 93 accidents occurred at the five intersections during the three-year period preceding the installation of rumble strips, and 98 accidents occurred during the three years following rumble strip installation. Apparently rumble strips were considerably more effective at reducing accidents at four-way and one-way stops than at two-way stops.

A comparison of accident types and severity before and after rumble strip installation indicated a substantial reduction in the proportion of injury accidents during the "after" period. Control locations selected for comparison experienced a slight increase in injury accidents during the same period. The only consequential change in the type of accident following rumble strip installation was a 50 percent reduction in "Ran Stop" accidents. This study excluded all accidents "that were in no way influenced by the presence or lack of rumble strips."

As part of the same study, the number of vehicles that stopped or practically stopped following passage over rumble strips was found to be 94.5 percent. This compares with 91.4 percent of vehicles that exhibited the same behavior at four comparable locations.

Driver reactions to rumble strips were also assessed. When the persons surveyed were advised that the rumble strips served to alert a driver to the presence of a stop sign, 76 percent considered them a good idea and only 18 percent considered them a bad idea. The other 6 percent were categorized as indifferent. It was also noted that state police issued 30 arrest tickets at one rumble strip installation to drivers who crossed the center line to avoid rumble strips.

Conclusions from this study are as follows [4]:

> "We can only conclude that rumble strips, like many other nonstandard traffic control devices, are effective only as long as they are startlingly different from the normal device confronting the average driver. As the motorist becomes acquainted with these nonstandard devices, his reaction to them becomes less pronounced. This same conclusion has been reached in many instances by traffic engineers studying various types of nonstandard traffic control devices. Increasing evidence continues to grow to substantiate the thesis that the long-range overall reduction of the highway accident toll depends to a large extent upon teaching the motorist the value of heeding and respecting uniform traffic control devices. He must have confidence that the same device means the same action is required, regardless of where that device is encountered."
>
> "Rumble strips can be used as a temporary method of alerting traffic to an unusual condition for an interim period of time required to complete a more permanent correction of an existing hazard. They are of little or no value as a permanent installation. They should never be considered as a part of normal highway design for a permanent installation."

The author of this report suggested use of rumble strips only under the following circumstances:

1. When the intersection is hidden from view by either a horizontal or vertical curve.
2. When the intersection has a history of accidents caused by failure to observe the traffic control device.
3. When the traffic control device follows a long tangent.

## Statewide Study in Minnesota

Rumble strip installations in Minnesota have been the subject of at least two reports available in the literature. The first of these covered 7 rumble strip installations at 6 rural stop locations [2]. No significant conclusions regarding accident experience resulted from this study. However, the report did note that the percentage of full stops increased from 37.2 percent to 63.3 percent following the installation of rumble strips. The average speed of approaching traffic was reduced by 2.76 mph throughout the zone of influence of the rumble strips.

A more extensive study covered 28 rumble strip installations for which at least two years of accident data were available before the installation, after the installation, or both [5]. After adjusting for the differences in before and after time periods, a reduction of 11 percent in accidents at the rumble strip locations was noted. Since the locations used for control experienced a 16 percent reduction in accidents, it was concluded that no reduction in accidents could be attributed to the installation of rumble strips at these 28 locations. However, a reduction of 36 percent in the number of accidents that were attributed to failure to stop for a stop sign was noted. It follows that accidents resulting from all other causes increased considerably.

## Other Studies Relating Experience with Rumble Strips

Experience with rumble strips in Contra Costa County, California, has been the subject of two reports [1,6]. The earlier report describes four locations where rumble strips were installed: two T intersections, a Y intersection, and a four-way stop. A reduction of about 78 percent in the accident rate at these locations followed the installation of rumble strips. Other studies indicated a reduction in speeds on the approach with rumble strips and improvements in lane placement. The later report covers one of the T intersections only and indicates a continuing low number of accidents followed by a sharp increase when the rumble strip was obliterated during resurfacing.

In a recent report, a Swedish researcher reports that reductions in speed from 5 to 18 km/hr were noted at two rumble strip installations in Sweden [7]. A study of traffic characteristics at a freeway lane closure work zone in Texas also noted significant speed reductions that were primarily attributable to rumble strips [8].

## Report on HR-184 by Iowa Department of Transportation

This report summarizes the findings from a study conducted in three contiguous counties in northeast Iowa: Black Hawk, Bremer, and Chickasaw Counties [9]. These were classified as urban, intermediate, and rural, respectively, for analysis purposes. The three study counties were "saturated" with rumble strips. That is, rumble strips were installed at all paved approaches to stop signs where the pavement condition permitted.

A before-and-after comparison at selected locations indicated some reduction in total accidents in Black Hawk County, a slight increase in Bremer County, and a significant reduction in Chickasaw

County. Accidents that were categorized as "rumble strip related" decreased in all three counties. This comparison was used to assess the benefits of rumble strips at specific locations.

A comparison of intersection accidents throughout a county before and after rumble strip installation was used as a basis for evaluating the saturation treatment. In this comparison, accidents increased in both Black Hawk and Bremer Counties but decreased in Chickasaw County. The total for the three counties combined increased from 219 to 248, a 13 percent increase. The number of "stop sign related" accidents was unchanged in the three counties combined at 58 during each period. This includes an increase in Black Hawk County and a decrease in the other two counties. It should be noted that traffic volume was assumed to be consistent during the "before" and "after" periods.

The proportion of night accidents was also noted for each of the saturated conditions. No significant correlation was noted between the existence of rumble strips and the proportion of accidents occurring at night.

One conclusion from this study was that rumble strips are beneficial at locations which experience "ran stop sign" accidents. It was also concluded that saturation use of rumble strips is beneficial in rural areas with low traffic volumes and relatively long distances between intersecting roads, but not in intermediate and urban counties.

## Summary Comments

Reports available from the literature consistently demonstrate an increased proportion of vehicles stopping when rumble strips precede a stop sign. They also consistently demonstrate changes in the pattern of deceleration so that the speed is reduced through the latter stages of an approach to a stop sign or other condition for which warning has been afforded.

However, results of accident studies relating to the use of rumble strips are less consistent. Of those summarized here, only the Contra Costa County locations experienced substantial reductions in accident totals. It may be noted that three of the four reductions cited therein are not statistically significant at a 95 percent level of confidence, the level generally accepted for such analyses. In all but one of the other analyses presented, only certain types of accidents were shown to be beneficially affected by the presence of rumble strips. The one exception was from the Iowa HR-184 study dealing with Chickasaw County. Further discussion of this conclusion will follow in Chapter IV.

Considerable attention was devoted to the design of rumble strips as part of the statewide studies in Illinois and Minnesota. In addition, a number of other reports dealing with rumble strip design were reviewed as part of this research. These are not considered directly relevant to the goal and objectives of this research and consequently are not summarized here.

## References

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6. Kermit, Mark L. "Rumble Strips Revisited," Traffic Engineering, 38, No. 5 (Feb. 1968), pp. 26-30.

7. Pettersson, Hans-Erik. "The Effects of Rumble Strips at Two Installations" (in Swedish), National Road and Traffic Research Institute, Linköping, Sweden, Rapport No. 213, 1981.

8. Levine, Steven Z. and Kenneth W. Crowley. "The Effect of Rumble Strips on Speeds Through a Freeway Lane Closure Work Zone," paper presented at the 61st Annual Meeting, Transportation Research Board, Washington, D.C., January 18-22, 1982.

9. Iowa Department of Transportation, Highway Division, Office of Road Design, Design Safety Section. "Determination of Rumble Strip Effectiveness," HR-184 Report, Jan. 1979.

# CHAPTER III. SURVEY OF RUMBLE STRIPS IN IOWA

In establishing a sample size for the study of rumble strips in Iowa, the objective was to obtain as large a sample as practicable in order to increase the statistical validity of the data derived from this sample. Since each increment to the sample necessitated one or two additional field inventories, the project budget constituted the principal constraint on sample size.

An accident record was obtained for each rumble strip location included in the sample and for associated control locations. This information was available only for calendar years 1977 through 1980 from the ALAS, a computer-accessed accident record storage system maintained by the Office of Safety Programs, Iowa Department of Transportation.

The purpose in obtaining accident records was to permit comparison of the accident experience at locations having rumble strips with comparable locations not having rumble strips. One possible basis for comparison is the before-and-after experience at one location. Such a sample could be obtained for this research if rumble strips had been installed in 1978 or 1979. In such a case, either one or two years of accident data were available for the period preceding installation of rumble strips, and either two years or one year of accident data were available following their installation.

If rumble strips had been installed in either 1980 or 1981, there was no suitable basis for comparing accident experience; as a result, such installations could not be included in the sample. On the other hand, if rumble strips had been installed in 1977 or earlier, a comparison of accident experience could be made with a location that was similar in all essential respects except for the absence of rumble strips. In these cases, accident experience was compared for the three-year period 1978 through 1980 for installations made in 1977, or for a four-year period 1977 through 1980 for earlier installations. The year during which rumble strips were installed was always excluded from a comparison.

## Secondary Road Sample

The secondary road sample was developed by means of a mailed survey. This survey was sent to each County Engineer in Iowa and requested information on all rumble strip locations on the secondary highway system in the state. Copies of the survey form and its accompanying letter are included in Appendix A. This form was developed following a pretest of a slightly different form sent to six County Engineers in central Iowa. The form used in the pretest was first evaluated for its ability to transmit the required information, and then revised accordingly.

Mailed returns were received from 93 counties, and the necessary information was obtained from the other six counties by telephone. Twenty-four counties reported that no rumble strips had been installed on secondary roads. Other counties reported from 1 to 41 locations at which rumble strips had been installed. The total number of installations reported was as follows:

| | |
|---|---|
| Installed before 1977 | 230 |
| Installed in 1977 | 130 |
| Installed in 1978 or 1979 | 146 |
| Installed in 1980 or 1981 | 179 |
| Total | 685 |

Of the 685 installations reported, 661 are at stop sign locations and 24 at other locations, primarily at railroad crossings.

The sample for the field study was selected as follows:

- Rumble strip installed in 1978 or 1970; a 100 percent sample.
- Rumble strip installed in 1977 or earlier; a sample was selected from each county, nominally a 50-percent sample with a maximum of six in any one county. The locations to be inventoried were selected using random numbers as grid coordinates to avoid a bias in designating the sample locations. Control locations for a comparison of accident experience were in the same county or a contiguous county in Iowa, and were located and selected by the field crew to be comparable in terms of geometrics and traffic control.

A location was excluded if there had been a significant change during the period 1977 through 1980 in traffic control, surface type, or any other characteristic that would invalidate a before-and-after comparison of accident experience at the location.

The number of locations included in the secondary road sample was as follows:

- 88 locations with rumble strips installed in 1978 or 1979, for before-and-after comparison.

- 119 locations with rumble strips installed 1977 or earlier.
- 119 locations without rumble strips for control purposes.

The types of locations at which these rumble strip installations were located are shown in Figure 1. The number of secondary locations of each type is given in Table 1. A breakdown by the jurisdictional classification of the highways involved is displayed in Table 2. In this connection it should be noted that a number of routes recently have been reclassified so that some routes that formerly were primary highways are now secondary highways and vice versa. The classification shown in Table 2 is that with which the highways were marked during a field inventory in 1981. This classification may differ from the one in effect at the time rumble strips had been installed.

## Primary Highway Sample

An inventory of primary locations with rumble strips was obtained from the Traffic Engineer, Iowa Department of Transportation. This inventory included 147 locations. Urban locations were deleted as well as those for which the date of installation was 1980, 1981, or indeterminate. The resulting usable sample included 91 rumble strip installations made in 1977 or earlier and 21 installations effected in 1978 or 1979.

A field inventory was made of all locations at which rumble strips had been installed in 1978 or 1979. Accident data were obtained for a before-and-after comparison at these locations.

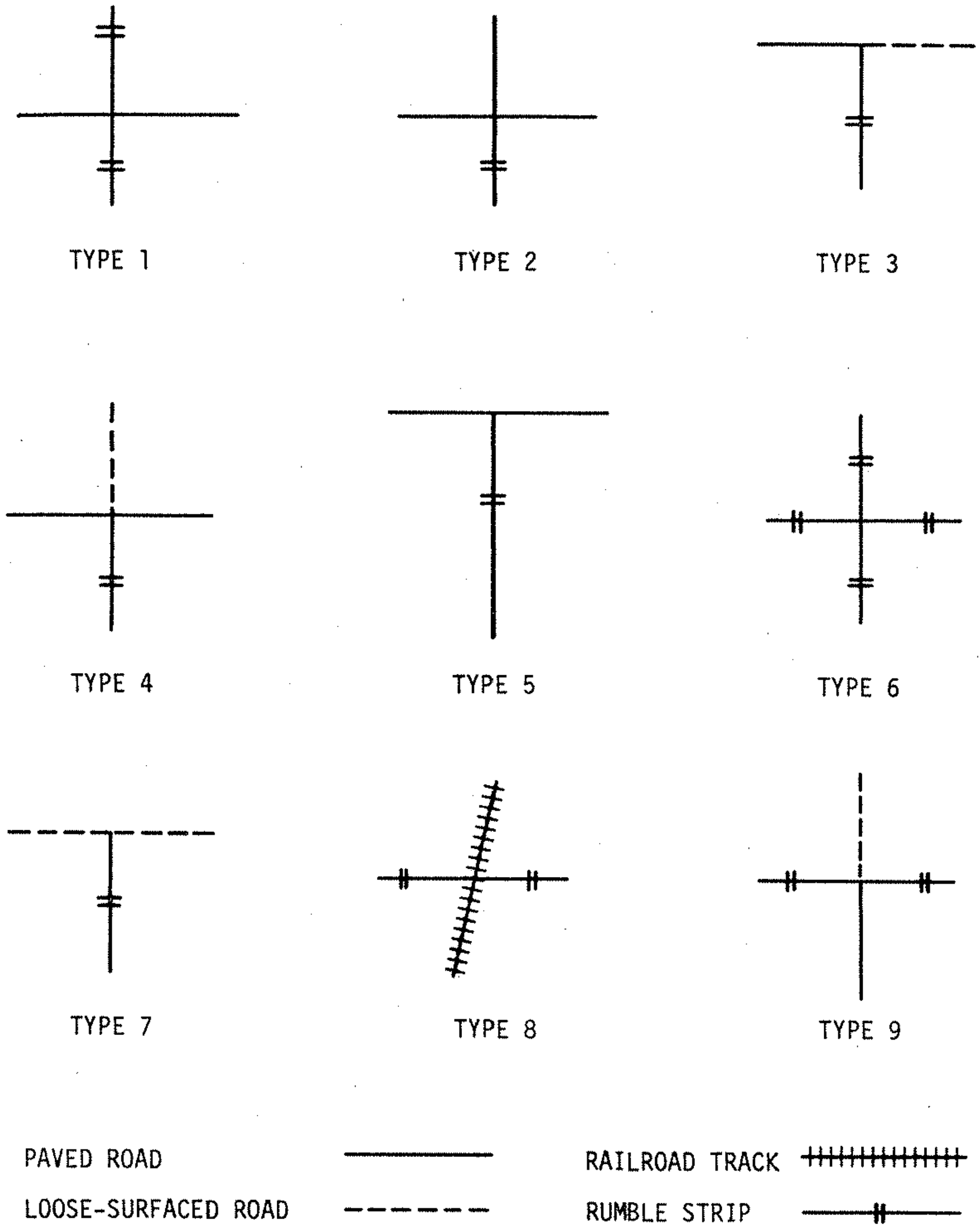



Figure 1. Types of locations included in rumble strip sample.

Table 1. Summary of secondary road sample by type of location.

| Location type | Number of Locations | |
|---|---|---|
| | Without Control | With Control (Pairs) |
| 1 | 10 | 16 |
| 2 | 8 | 4 |
| 3 | 5 | 1 |
| 4 | 27 | 49 |
| 5 | 33 | 41 |
| 6 | 0 | 0 |
| 7 | 2 | 0 |
| 8 | 2 | 8 |
| 9 | 1 | 0 |
| Total | 88 | 119 |

Table 2. Jurisdictional classification of highways in secondary sample.

| Jurisdiction | Number of Locations: Without Control | With Control | Control Locations |
|---|---|---|---|
| Intersection of secondary with primary | 45 | 51 | 46 |
| Intersection of secondary with secondary | 41 | 60 | 61 |
| Intersection of secondary with railroad | 2 | 8 | 8 |
| Intersection of primary with primary | 0 | 0 | 4 |
| Total | 88 | 119 | 119 |

All of the primary locations with rumble strips installed before 1978 were surveyed. A location from this group was included in the data sample only if an essentially similar primary location could be identified for control purposes, regardless of its location within the state. Because so many primary intersections tended to be "one of a kind" in terms of geometric layout or the use of traffic control devices, suitable control locations were identified for only 28 locations with rumble strips installed before 1978.

The number of primary locations of each type included in the sample is given in Table 3. A breakdown by the jurisdictional classification of the highways involved is displayed in Table 4.

## Field Inventories

An inventory of field conditions was carried out at each of the 256 locations with rumble strips installed that were included in the data sample as well as at the 147 locations without rumble strips that were used for control purposes. A copy of the field inventory form is included in Appendix B.

It should be noted that two sight triangle lengths were recorded if the field inventory was conducted at a time when crops were immature. The actual distance measured was recorded and, where pertinent, an estimate was recorded of the length of the sight triangle that would exist with mature crop growth.

Table 3. Summary of primary highway sample by type of location.

| Location Type | Number of Locations | |
|---|---|---|
| | Without Control | With Control (Pairs) |
| 1 | 7 | 2 |
| 2 | 0 | 0 |
| 3 | 0 | 0 |
| 4 | 2 | 13 |
| 5 | 11 | 13 |
| 6 | 1 | 0 |
| 7 | 0 | 0 |
| 8 | 0 | 0 |
| 9 | 0 | 0 |
| Total | 21 | 28 |

Table 4. Jurisdictional classification of highways in primary sample.

| Jurisdiction | Number of Locations: Without Control | Number of Locations: With Control | Number of Locations: Control Locations |
|---|---|---|---|
| Intersection of primary with primary | 17 | 23 | 22 |
| Intersection of primary with secondary | 4 | 4 | 5 |
| Intersection of secondary with secondary | 0 | 1 | 1 |
| Total | 21 | 28 | 28 |

# CHAPTER IV. FINDINGS

One of the purposes of the accident data analyses was to quantify the reduction in accidents at locations where rumble strips had been installed. A further purpose, assuming a safety benefit from installing rumble strips, was to identify the factors which distinguished locations that experienced a reduction in accidents following rumble strip installation from those where no such reduction had occurred.

To accomplish this analysis, the factors displayed in Table 5 were quantified. It may be noted that two different dependent variables were used, NTA, the total accident rate at a location, and NRA, the rate for accidents involving a "ran stop sign" notation by the investigating officer. In both cases, accident rates were expressed in the number of accidents per million entering vehicles (MEV).

Aside from NTA and NRA, no effort was made to segregate accidents by type. There was no indication from available data that the frequency of any particular type of accident was influenced by the presence or absence of rumble strips.

Nor was accident severity considered as a variable in this research. The results of the HR-184 study showed an almost perfect correlation between accident severity and the total number of accidents. The average severity was the same both before and after the installation of rumble strips. Furthermore, since the number of accidents typically occurring at the rural locations included in the samples for this study was so small, the random occurrence of a single fatal accident could have seriously distorted comparisons based on accident severity.

Table 5. Variables in the models.

| Code | Variables |
| --- | --- |
| | **Dependent variables** |
| NTA | Total accident rate (accident/MEV) at node |
| NRA | 'Run Stop Sign' accident rate at node |
| | **Independent variables** |
| INTER | Intersection type (Secondary/Primary) |
| HWY | Highway type (T-type, RR Xing or others) |
| CONTROL | Type of control (one way stop or others) |
| IANGLE | Intersection angle, degrees |
| DUMMY | Presence or absence of rumble strip |
| MEV | Million entering vehicles per year |
| APPROACH | Approach volume for the link with rumble strip |
| INTERVOL | Intersecting volume |
| VISIBLE | Distance stop sign is visible, ft |
| SIDE | Number of driveways, field entrances, and gravel roads within 0.5 mile |
| RIGHT | Right sight triangle length, ft |
| LEFT | Left sight triangle length, ft |
| MILE | Miles of travel from last stop sign, reduction in speed to 30 mph or less, freeway entrance, beginning of pavement, or travel through incorporated city |
| EL | Difference in elevation, point 200 ft from intersecting road relative to center of intersection, in. |
| WIDTH | Pavement width, ft |
| FILLET | Length of intersecting fillet, ft |

Comparability of data for this research was assured by expressing the variables MEV, APPROACH, and INTERVOL in terms of 1976 traffic volumes. Volume data available for other years were converted to 1976 volumes using factors based on statewide totals for travel volumes on secondary roads in Iowa.

It should be noted that a maximum value of 1,000 ft was recorded for the variables VISIBLE, RIGHT, and LEFT. Average characteristics of the rumble strip installations included in the analyzed sample analyzed are displayed in Table 6. Distances to the rumble strips in this table are measured from the center of the intersection.

## Secondary Road Sample

Before undertaking an analysis of the data, the ten Type-8 locations (railroad crossings) and the one Type-9 location were deleted from the secondary road sample. No accidents were recorded at any of these 11 locations during the period 1977 through 1980. As a consequence, the inclusion of these unique installations in a larger sample could not contribute meaningfully to a data analysis. The remaining secondary road sample included 85 intersections with rumble strips installed in 1978 or 1979, 111 intersections with rumble strips installed before 1978, and 111 intersections without rumble strips.

Average values for the independent variables for analysis of the secondary road sample are displayed in Table 7. It may be noted that the average values for all variables are very consistent among the three subsamples. In particular, the control locations exhibit characteristics virtually identical to the locations with rumble strips installed before 1978.

Average values for the dependent variables are shown in Table 8. As indicated in the table, there are no significant differences in accident experience between comparable samples. For example, the average rates for total accidents are the same before and after rumble strip installation at the locations with rumble strips installed in 1978 or 1979. The average rate for the "run stop sign" type of accident is 3 percent higher following the installation of rumble strips.

In a comparison of 111 intersections with rumble strips installed before 1978 with 111 comparable intersections without rumble strips, the control locations show lower accident rates. The difference is 21 percent in the case of total accidents and 14 percent in the case of "run stop sign" accidents. These differences are not statistically significant.

In view of the fact that no safety benefit is apparent from the installation of rumble strips on secondary roads, it is not surprising that analysis of these data failed to identify any variables that were significantly associated with a favorable effect on accident experience. Regression analyses were undertaken using several different subsamples based upon the type of location. None was successful in demonstrating that rumble strips could be expected to improve accident experience in association with any particular characteristics of an intersection. Cross-classification analyses and discriminant analyses were equally unsuccessful.

Table 6. Characteristics of rumble strip installations.

| Characteristic | Average values: Primary highways | Average values: Secondary roads |
|---|---|---|
| Number of installations (approaches) | 61 | 222 |
| Number with 1 strip | 0 | 1 |
| Number with 2 strips | 2 | 20 |
| Number with 3 strips | 59 | 201 |
| Length of strip parallel with centerline, ft | 25.2 | 25.4 |
| Distance, end of strip to pavement edge, in | 13.4 | 10.1 |
| Distance, end of strip to centerline, in | 1.9 | 3.1 |
| Angle of strip with centerline, degrees | 75.7 | 75.8 |
| Distance, intersection to 1st strip, ft | 345.4 | 375.5 |
| Distance, intersection to 2nd strip, ft | 944.1 | 755.0 |
| Distance, intersection to 3rd strip, ft | 1,572.4 | 1,060.2 |

Table 7. Mean values and standard deviations of independent variables, secondary highways.

| Variable | Installed 1978-1979 μ | Installed 1978-1979 σ | Installed before 1978 μ | Installed before 1978 σ | No Rumble Strip μ | No Rumble Strip σ | Total Secondary μ | Total Secondary σ |
|---|---|---|---|---|---|---|---|---|
| | | | | Associated with intersection | | | | |
| | (N = 85) | | (N = 111) | | (N = 111) | | (N = 307) | |
| IANGLE | 83.588 | 14.092 | 86.396 | 9.491 | 87.928 | 7.022 | 86.173 | 10.373 |
| MEV | 0.528 | 0.437 | 0.550 | 0.461 | 0.485 | 0.380 | 0.520 | 0.426 |
| INTERVOL | 1,158.6 | 1,019.6 | 1,236.9 | 1,188.0 | 1,107.8 | 978.2 | 1,168.5 | 1,067.6 |
| | | | | Associated with approach | | | | |
| | (N = 95) | | (N = 127) | | (N = 127) | | (N = 349) | |
| APPROACH | 432.126 | 439.865 | 430.701 | 313.498 | 352.740 | 294.039 | 402.719 | 347.252 |
| VISIBLE | 966.463 | 111.060 | 945.370 | 129.623 | 947.559 | 120.277 | 951.908 | 121.382 |
| SIDE | 4.221 | 1.846 | 4.362 | 2.359 | 4.354 | 2.328 | 4.321 | 2.214 |
| RIGHT | 266.000 | 221.350 | 225.827 | 158.673 | 261.197 | 192.812 | 249.633 | 190.104 |
| LEFT | 283.095 | 213.098 | 247.528 | 181.547 | 246.496 | 179.693 | 256.834 | 190.130 |
| MILE | 5.442 | 3.642 | 5.472 | 3.214 | 5.309 | 2.825 | 5.405 | 3.197 |
| EL | 6.063 | 27.465 | 9,094 | 29.714 | 5.795 | 33.235 | 7.069 | 30.426 |
| WIDTH | 22.189 | 0.689 | 22.071 | 0.692 | 22.465 | 0.974 | 22.246 | 0.821 |
| FILLET | 77.863 | 25.316 | 81.244 | 21.579 | 76.118 | 22.546 | 78.458 | 23.037 |

Table 8. Mean values and standard deviations of dependent variables, secondary highways.

| | Accident rate, accidents/MEV $\mu$ | $\sigma$ |
|---|---|---|
| Rumble strips installed 1978-1979 (N = 85) | | |
| Total accidents, before | 1.244 | 2.335 |
| Total accidents, after | 1.236 | 1.887 |
| Run-stop-sign accidents, before | 0.588 | 1.674 |
| Run-stop-sign accidents, after | 0.608 | 1.439 |
| Rumble strips installed before 1978 (N = 111) | | |
| Total accidents | 1.000 | 1.283 |
| Run-stop-sign accidents | 0.352 | 0.614 |
| Control intersections, no rumble strips (N = 111) | | |
| Total accidents | 0.793 | 1.207 |
| Run-stop-sign accidents | 0.304 | 0.647 |

Further evaluations were carried out using only the before-and-after sample. A plot of the accident experience at these intersections is displayed in Figure 2. Of the 85 locations, no accidents were recorded at 28 locations during both periods, before and after the installation of rumble strips. Accident experience improved following installation of rumble strips at 27 of the other 57 locations, worsened at 26 locations, and was unchanged at 4 locations.

As may be seen in Figure 2, there was an improvement in accident experience at all of the 14 locations that had an accident rate in excess of 2.5 accidents/MEV before rumble strips were installed. None of these changes was statistically significant with 95 percent confidence. Nor were there any common factors characterizing these 14 intersections.

Logic would suggest that the single-vehicle run-off-the-road accident at a T intersection would be more susceptible to improvement by the installation of rumble strips than most other types of accidents. Consequently, eight Type-5 (T intersection) locations were identified from the before-and-after sample at which accident experience had improved following the installation of rumble strips. The eight locations experienced a total of 31 accidents in the period 1977 through 1980, 22 of which were single-vehicle accidents. Of the single-vehicle accidents, 17 occurred at night. This type of accident declined from 1.0 per intersection-year of exposure in the period before rumble strips were installed to only 0.25 per intersection-year following their installation. According to this subsample, the installation of rumble strips appears to exert a favorable effect at T

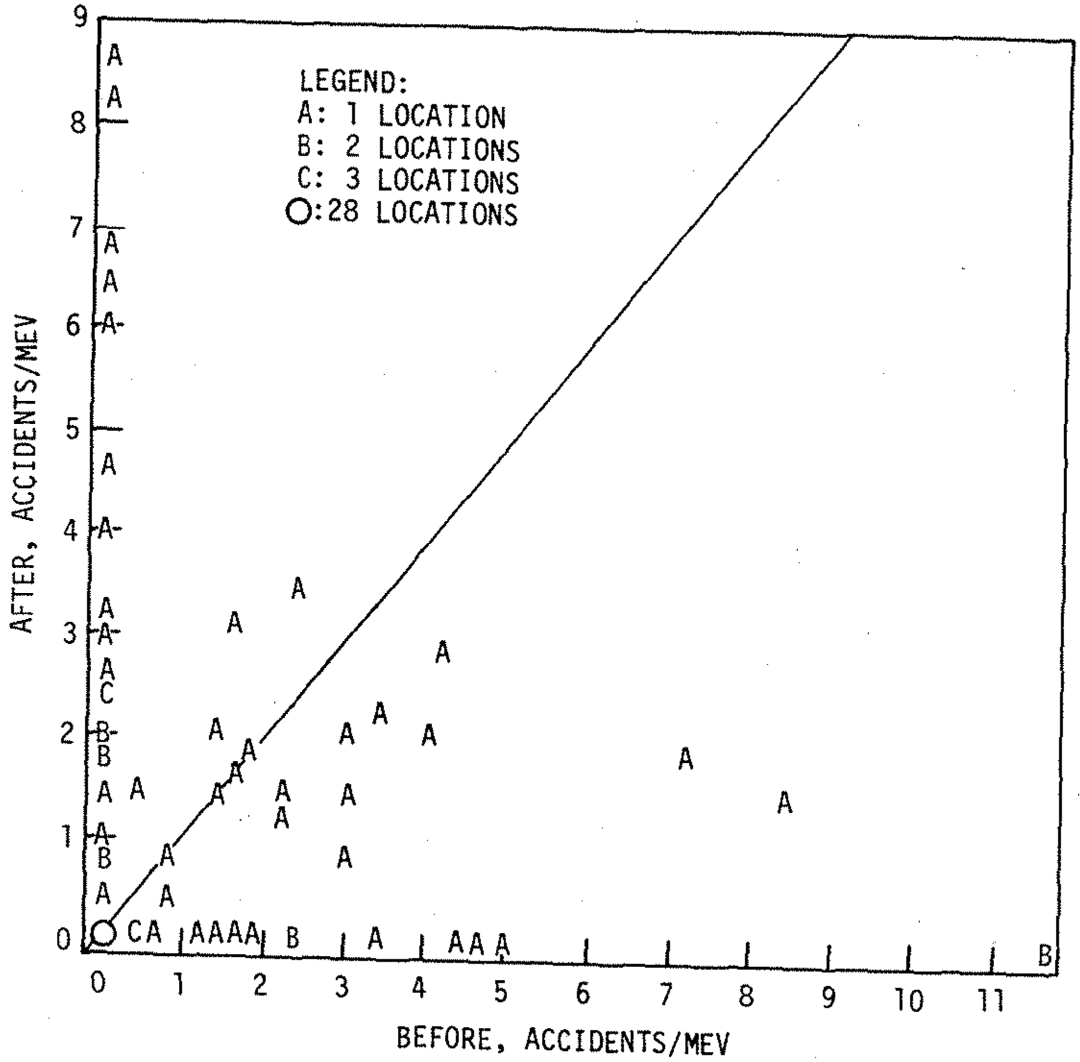



Figure 2. Before-and-after comparison of total accident rate, secondary roads.

intersections with a high proportion of single-vehicle accidents occurring at night.

However, 14 intersections of this type in the before-and-after sample experienced an increase in total accidents following installation of rumble strips. The total number of accidents at these locations was 42 in the period 1977 through 1980. Twenty-one of these involved only a single vehicle; 16 of them occurred at night. An average of 0.10 single-vehicle accidents per intersection-year of exposure occurred before rumble strip installation. This increased to 0.60 per intersection-year after their installation. A hypothesis that rumble strips might be effective in reducing single-vehicle run-off-the-road accidents at T intersections could not be confirmed by this analysis.

## Primary Highway Sample

Average values for the independent variables from the primary road sample are displayed in Table 9. As was the case for secondary roads, average values for the three subsamples are very comparable. In comparison with the secondary road sample, traffic volumes were about twice as high at primary locations. Intersection sight distances are greater at primary intersections, and the average distance from the last stop is longer than at secondary locations.

Average values for the dependent variables are shown in Table 10. In the case of primary highway rumble strips installed in 1978 or 1979, a reduction of 51 percent in the average total accident rate followed the installation of rumble strips. The number of "run stop

Table 9. Mean values and standard deviations of independent variables, primary highways.

| Variable | Installed 1978-1979 μ | Installed 1978-1979 σ | Installed before 1978 μ | Installed before 1978 σ | No Rumble Strip μ | No Rumble Strip σ | Total Secondary μ | Total Secondary σ |
|---|---|---|---|---|---|---|---|---|
| Associated with intersection | | | | | | | | |
| | (N = 21) | | (N = 28) | | (N = 28) | | (N = 77) | |
| IANGLE | 80.714 | 14.772 | 89.821 | 0.945 | 86.786 | 7.603 | 86.234 | 9.568 |
| MEV | 1.229 | 0.650 | 1.068 | 0.565 | 1.001 | 0.484 | 1.088 | 0.562 |
| INTERVOL | 2,246.5 | 1,139.5 | 2,277.3 | 1,507.2 | 2,276.7 | 1,184.9 | 2,268.7 | 1,283.6 |
| Associated with approach | | | | | | | | |
| | (N= 31) | | (N = 30) | | (N = 30) | | (N = 91) | |
| APPROACH | 1,634.903 | 1,196.407 | 1,162.200 | 503.665 | 816.733 | 540.183 | 1,209.341 | 876.011 |
| VISIBLE | 979.355 | 81.166 | 994.400 | 23.106 | 954.267 | 101.350 | 976.044 | 77.149 |
| SIDE | 4.194 | 3.563 | 4.367 | 2.977 | 4.567 | 2.700 | 4.374 | 3.076 |
| RIGHT | 443.645 | 243.776 | 362.833 | 236.190 | 329.500 | 156.400 | 379.374 | 219.110 |
| LEFT | 377.548 | 224.537 | 292.167 | 147.816 | 338.333 | 176.681 | 336.473 | 187.460 |
| MILE | 9.906 | 7.183 | 10.357 | 8.282 | 6.737 | 6.052 | 9.010 | 7.328 |
| EL | 22.097 | 37.627 | 12.133 | 27.928 | 8.467 | 20.867 | 14.319 | 29.957 |
| WIDTH | 24.806 | 4.915 | 22.800 | 1.864 | 23.333 | 0.922 | 23.659 | 3.191 |
| FILLET | 122.593 | 54.444 | 114.967 | 41.499 | 112.667 | 34.016 | 116.540 | 43.412 |

Table 10. Mean values and standard deviations of dependent variables, primary highways.

| | Accident rate, accidents/MEV | |
|---|---|---|
| | $\mu$ | $\sigma$ |
| Rumble strips installed 1978-1979 (N = 21) | | |
| Total accidents, before | 1.473 | 1.400 |
| Total accidents, after | 0.723 | 0.839 |
| Run-stop-sign accidents, before | 0.529 | 0.956 |
| Run-stop-sign accidents, after | 0.329 | 0.672 |
| Rumble strips installed before 1978 (N = 28) | | |
| Total accidents | 0.792 | 0.653 |
| Run-stop-sign accidents | 0.291 | 0.422 |
| Control intersections, no rumble strips (N = 28) | | |
| Total accidents | 0.838 | 0.566 |
| Run-stop-sign accidents | 0.266 | 0.228 |

sign" accidents declined by 38 percent. Only the reduction in the total accident rate was statistically significant with 95 percent confidence.

Control locations experienced a 6 percent higher average rate of total accidents than comparable primary locations with rumble strips installed before 1978. However, the rate of "run stop sign" accidents was 9 percent lower at the locations without rumble strips than at the comparable locations having rumble strips. Neither of these differences was statistically significant.

As was the case with secondary road intersections, analyses of these data did not identify any characteristics of primary road intersections that were consistently associated with a reduction in accident rates. Consequently, additional analyses were undertaken of the 21 intersections for which before-and-after accident data were available. A plot of this comparison appears in Figure 3.

Of the 21 intersections in this sample, 5 had no accidents both before and after rumble strip installation, 13 experienced a reduction in the total accident rate, and 3 that had no accidents before rumble strip installation experienced some accidents following their installation. It should be noted, however, that because of the limited period of exposure and relatively low traffic volumes, only one of the decreases in accident experience was significant with 95 percent confidence that the change did not occur by chance.

As shown in Figure 3, each of the 8 intersections that had accident rates of 2.0 accidents/MEV or higher before rumble strips were installed experienced a marked reduction in accident rates following

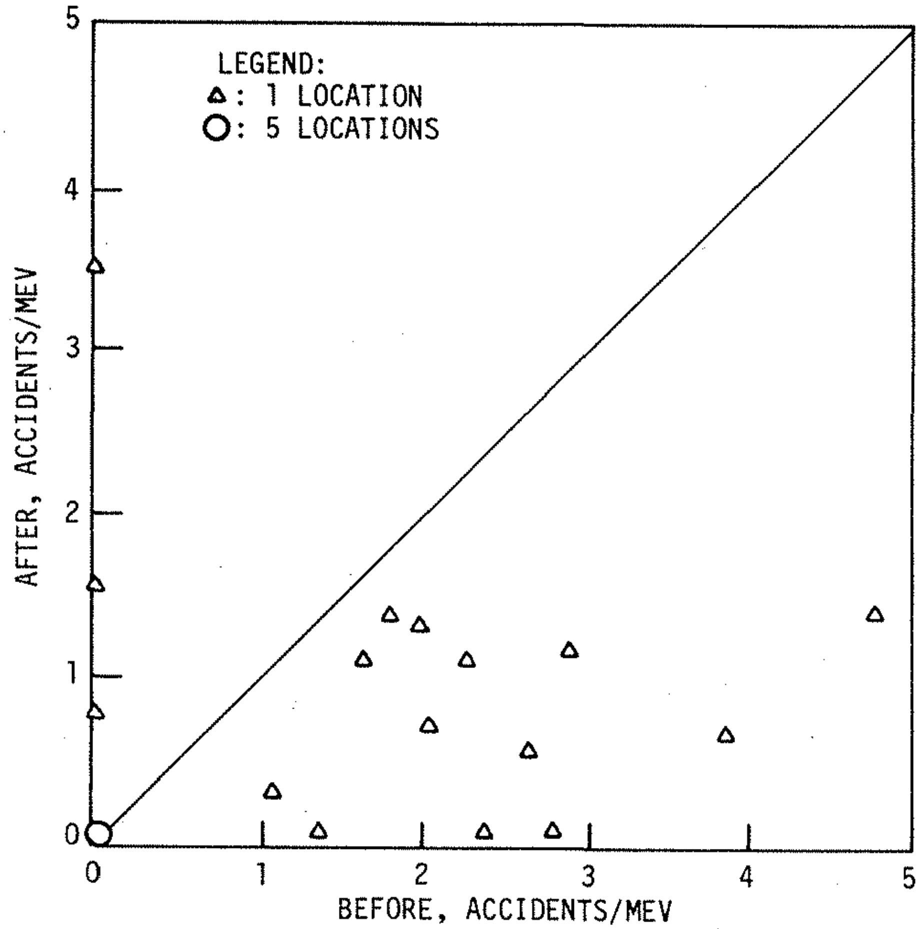



Figure 3. Before-and-after comparison of total accident rate, primary roads.

their installation. The 13 intersections with lower accident rates in the before period experienced little or no improvement or a worsening in their accident rate after rumble strips were installed.

A further analysis of 20 of the intersections in this sample was undertaken in order to distinguish between accidents occurring during daylight hours and those occurring at night. (The other intersection in the before-and-after sample was unique in that it was located in an area that was lighted for some distance on either side of the intersection.) Of these, 14 were lighted and 6 were not. The daytime accident rate declined by 51 percent at the lighted locations and 83 percent at the locations without lights between the "before" and "after" periods. In constrast, the nighttime rate declined by 67 percent at the unlighted locations but only 6 percent at the lighted locations. Although the sample size was quite small, these data suggest that rumble strips may be more effective in reducing nighttime accidents at unlighted intersections than at lighted intersections.

## Other Analyses

Most of the reports on rumble strip use in Iowa have been anecdotal rather than definitive descriptions of research results. During the course of this research, two County Engineers described to research personnel their experiences with two particularly troublesome intersections. In each instance, rumble strips had been installed in response to an accident rate that was considered excessive. The description of these experiences concluded with the comment that "there hasn't been an accident since the rumble strips were installed." Both of the intersections in question were included in the sample of secondary installations made before 1978. Both had accident rates higher than the average for that group of intersections, an indication of the incorrect impressions that can result from incomplete reporting of accidents to the authorities responsible for operating and maintaining highways.

When this research was undertaken, it was intended that a comparison would be made of the current accident experience with the earlier experience at the intersections included in the HR-184 study reported in 1979. The rumble strips for that study were installed in 1976. Accident records in 1975 and 1977 afforded the basis for the before-and-after comparison.

So many changes in the rumble strip installations had occurred in Black Hawk and Bremer Counties that a comparison in these two counties was not practicable. However, the rumble strips included in the earlier study remained with only minor changes in Chickasaw County. Thirty-two intersections that had rumble strips for most or all of the period 1977 through 1980 were included in the HR-184 study. There were 34 accidents at these locations during the 4-year period, 5 in 1977, 12 in 1978, 10 in 1979, and 7 in 1980. Fourteen intersections had no accidents during that period.

The before-and-after comparison made in the HR-184 report focused on "selected locations," only those having one or more accidents in the "before" period. A similar comparison made for years 1977 through

1980 would show a reduction each year. For example, a total of 5 accidents occurred at 5 of the 32 intersections in 1977. The same 5 intersections experienced only 4 accidents in 1978, an apparent reduction of 20 percent. However, the total number of accidents at all 32 locations increased from 5 to 12, an increase of 140 percent. It is believed that the method of analysis used in the earlier study could not properly support a conclusion as to the safety benefits from rumble strips installed at individual intersections in a rural county. No long-range trend is evident in the occurrence of accidents at intersections in Chickasaw County with rumble strips.

As a part of this research, a limited study of the obedience to stop signs was undertaken. Traffic behavior at stop signs was observed at several locations in central Iowa. Vehicles that did not encounter a conflict with intersecting traffic were categorized according to whether a vehicle stopped, nearly stopped, perceptibly slowed, or did not slow. Only two locations, one with rumble strips and one without, were sufficiently similar in terms of geometry, sight distance, and the proportion of traffic approaching a stop sign that did not encounter a conflict to afford an entirely valid comparison. This comparison is displayed in Table 11. It may be noted that about 77 percent of the approach traffic that did not encounter a conflict stopped or nearly stopped where rumble strips were present compared with about 66 percent where there were no rumble strips.

Table 11. Comparison of stop sign obedience with and without rumble strips.

| Location | Vehicles not encountering conflict: Full stop | Nearly stopped | Perceptibly slowed | Did not slow | Vehicles encountering conflict |
|---|---|---|---|---|---|
| Iowa 210 at US 69 (rumble strips) | 97 (9.8%) | 666 (67.1%) | 230 (23.2%) | 0 (0.0%) | 360 |
| Story Co. E23 at US 69 (no rumble strips) | 43 (5.1%) | 509 (61.0%) | 283 (33.9%) | 0 (0.0%) | 339 |

# CHAPTER V. CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

As is the case with any traffic control device, the final authority for the installation of rumble strips lies with the elected or appointed officials responsible for a particular system of highways. Installation of these devices has often been a reaction to a serious motor vehicle accident with the expectation that similar accidents would be prevented in the future. The results of this research strongly suggest that in many instances the installation of rumble strips will have no effect on the occurrence of accidents, even though the level of stop sign obedience may be expected to increase.

In particular, it is concluded that the frequency of accidents at rural locations on secondary roads was independent of the presence or absence of rumble strips. Nor were any factors identified that characterize locations where a reduction in accident frequency could be expected to result from the installation of rumble strips. It was noted, however, that secondary road intersections with accident rates higher than 2.5 accidents/MEV always showed a reduction in accident rate following the installation of rumble strips, although this reduction in accident rate would be expected by chance, given the low traffic volumes and infrequent occurrence of accidents at these locations.

On the other hand, primary highway intersections where rumble strips had been installed experienced a significant reduction in accident rate in the first year or two following their installation.

As was the case with secondary road intersections, no specific characteristics could be identified that were unique to primary intersections that experienced a reduction in accident rate following the installation of rumble strips. However, all of the primary highway intersections that had accident rates of 2.0 accidents/MEV or higher experienced a marked reduction in accident rate in the one or two years after rumble strips were installed. It is hypothesized that rumble strips are more helpful in primary highway intersections than at secondary road intersections for some or all of the following reasons:

1. Primary highways serve a higher proportion of drivers who are unfamiliar with the highway.
2. Trips tend to be longer on primary highways so that fatigue and the monotony of driving may play a more significant role than on secondary roads.
3. Traffic volumes are higher on primary highways, so the number of potential conflicts is greater.
4. The geometric layout of primary highway intersections often is more complex than that of secondary road intersections.

The Illinois study discussed in Chapter II indicated that the beneficial effect of rumble strips on safety was most pronounced immediately following their installation and tended to diminish with the passage of time. The results of this study tended to confirm this conclusion. Before-and-after accident rates provide a measure of the short-run effects of rumble strips on safety, since the "after" period was limited to one or two years. A comparison of accident rates at locations with rumble strips installed for longer periods with the accident rates at comparable control locations affords a measure of the long-run effect of rumble strips on safety. For both primary and secondary locations, the long-run effect of rumble strips was less favorable than the short-run effect.

Nothing in the findings from this research suggests that rumble strips will cause an increase in accidents. However, there is at least one accident of record in Iowa that occurred when evasive maneuvers by a bicyclist to avoid a rumble strip resulted in a headon collision with an automobile. An appropriate design of rumble strips should preclude the occurrence of accidents of this nature.

## Recommendations

In view of the rather limited safety benefits that may be anticipated from rumble strips, their use should conform with the following recommendations:

1. The installation of rumble strips on secondary roads should be considered at locations having an accident rate higher than 2.5 accidents/MEV where the results of an engineering study indicate that their installation will exert a beneficial effect on highway safety.
2. The installation of rumble strips on primary highways should be considered at locations having an accident rate higher than 2.0 accidents/MEV where the results of an engineering study indicate that their installation will exert a beneficial effect on highway safety.

3. Rumble strips, where installed, should conform with the Iowa Department of Transportation standard design (see Appendix C), to the extent practicable. It is important that the following aspects of the design are observed:

   a. Individual grooves should be cut at an angle with the roadway centerline to reduce the tendency for passage over the rumble strip to induce a harmonic vibration of a motor vehicle.

   b. The depth of individual grooves should not exceed 0.5 inch to avoid the possibility of damaging a vehicle while still providing the desired audible and tactile warning to drivers.

   c. A strip at the pavement edge at least 18 inches wide should be left without grooves to provide a safe path for travel by bicycles, mopeds, and light motorcycles.

# APPENDIX A

# SECONDARY ROAD RUMBLE STRIP

# SURVEY FORM

Iowa State University of Science and Technology Ames, Iowa 50010

Engineering Research Institute
College of Engineering
104 Marston Hall
Telephone: 515-294-2336

June 22, 1981

The Iowa Highway Research Board recently approved the award of a research contract to the Engineering Research Institute, Iowa State University, to study rumble strips. The objective of this research is to develop warrants for the use of these devices on primary or secondary highways.

In this connection, we need to establish a complete inventory of rumble strip installations on secondary highways. The enclosed survey form is directed to that end. Please indicate on the form the few items of information requested for each such installation in your county. Also please send me a county highway map on which the location of each installation is circled and numbered so that the numbers correspond with those on the rumble strip survey form. If you have no rumble strips on your secondary system, please write "None" across the survey form and return it to us.

We shall be using the ALAS computerized record for accident data that will be correlated with the characteristics of rumble strip locations. Since the ALAS file includes accident records for the period 1977 through 1980, the year that rumble strips were installed is important to us if this occurred after 1976.

A sample of rumble strip locations will be selected randomly from throughout the state. This will be followed by a field study of those locations, and some number of control locations not having rumble strips, to include measurements of sight distances and other physical characteristics.

Please contact me (phone 515-294-6777) if you have any question about the survey or just wish to chat about rumble strips. Thank you for your assistance in completing and returning the survey form.

Sincerely yours,

R. L. Carstens
Professor of Civil Engineering
Principal Investigator

RLC/ch

Enclosure a/s

County ________________

## RUMBLE STRIP SURVEY

| Number (use on County map) | Approaches with rumble strips: East | South | West | North | Type of control: Stop signs | RR Xing | Other (explain) | Year installed: Before 1977 | Other (specify) | Significant change since 1976 (see reverse): No | Yes | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 2 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 3 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 4 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 5 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 6 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 7 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 8 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 9 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 10 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 11 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 12 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |
| 13 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | | ☐ | ☐ | |

(Use additional sheet if necessary)

In general; are rumble strips well received in your county? Please explain. ________________

Return to: R. L. Carstens, Department of Civil Engineering, Iowa State University, Ames, Iowa 50011

Accident data are available to us (using the ALAS record) only for the period 1977 through 1980. We can draw valid conclusions from these data only if no significant change has occurred at a rumble strip location during that period. Answer "Yes" in the column regarding significant changes and indicate the year of the change if any of the following has occurred since December 31, 1976, relating to an approach having rumble strips:

1. The approach, or an intersecting approach, was paved for the first time.
2. The type of control was changed (2-way stop to 4-way stop, uncontrolled to 2-way stop, or a similar change).
3. The nature of the traffic control devices was materially changed, such as would occur if beacons had been added.
4. The applicable speed limit was changed.
5. There was a change in alinement.
6. The sight distance in at least one quadrant has either increased or decreased significantly.
7. The level of nighttime illumination has changed materially.
8. Traffic volumes have changed substantially, such as would occur if a nearby road were permanently closed.
9. Some other change was made that would tend to invalidate before-and-after comparisons of accident experience at this location.

Please answer "No" if none of the above changes occurred since December 31, 1976. (A change in functional classification would not be significant for our purposes.)

# APPENDIX B

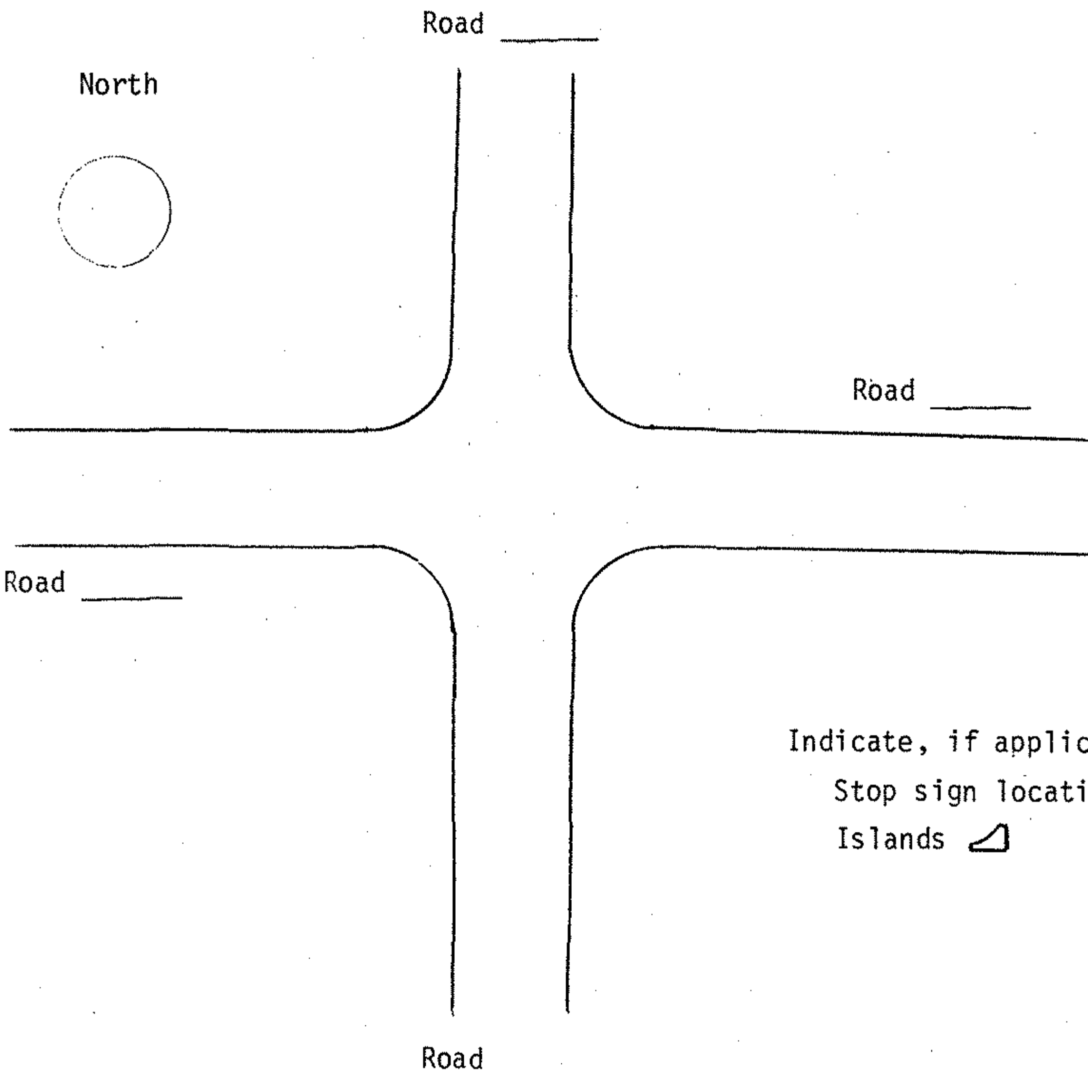
## FIELD INVENTORY FORM

# Rumble Strip Survey

Location: Date of survey: ________________

County: ________________________ Time start: ________________

Intersection of ______ with ______ Survey by: ________________




Indicate, if applicable:

Stop sign locations

Islands

Intersection angle ________ degrees.

Rumble strips are raised ____ or grooved ___.

| | Approach East | South | West | North |
| --- | --- | --- | --- | --- |
| Number of strips | ______ | ______ | ______ | ______ |
| Length each strip, ft | ______ | ______ | ______ | ______ |
| Average distance, strip to pavement edge, in | ______ | ______ | ______ | ______ |
| Average distance, strip to roadway center, in | ______ | ______ | ______ | ______ |

Angle of strip with roadway ______ degrees.

| Distance from intersecting road, ft | Approach East | South | West | North |
|---|---|---|---|---|
| First rumble strip | _____ | _____ | _____ | _____ |
| Second rumble strip | _____ | _____ | _____ | _____ |
| Third rumble strip | _____ | _____ | _____ | _____ |
| Distance stop sign is visible, ft (or other sign if appropriate) | _____ | _____ | _____ | _____ |
| Number within 0.5 mile | | | | |
| Driveways | _____ | _____ | _____ | _____ |
| Field entrances | _____ | _____ | _____ | _____ |
| Sight triangle, length in ft | | | | |
| Right | _____ | _____ | _____ | _____ |
| | _____ | _____ | _____ | _____ |
| Left | _____ | _____ | _____ | _____ |
| | _____ | _____ | _____ | _____ |
| Distance, mi (indicate only shortest one) | | | | |
| Previous stop sign | _____ | _____ | _____ | _____ |
| Turn, posted 30 mph or slower | _____ | _____ | _____ | _____ |
| Beginning of pavement | _____ | _____ | _____ | _____ |
| Freeway entrance | _____ | _____ | _____ | _____ |
| Difference in elevation, in (point 200 ft from intersecting road relative to center of intersection) | _____ | _____ | _____ | _____ |
| Pavement width, ft | _____ | _____ | _____ | _____ |
| Length of intersection fillet, ft | _____ | _____ | _____ | _____ |

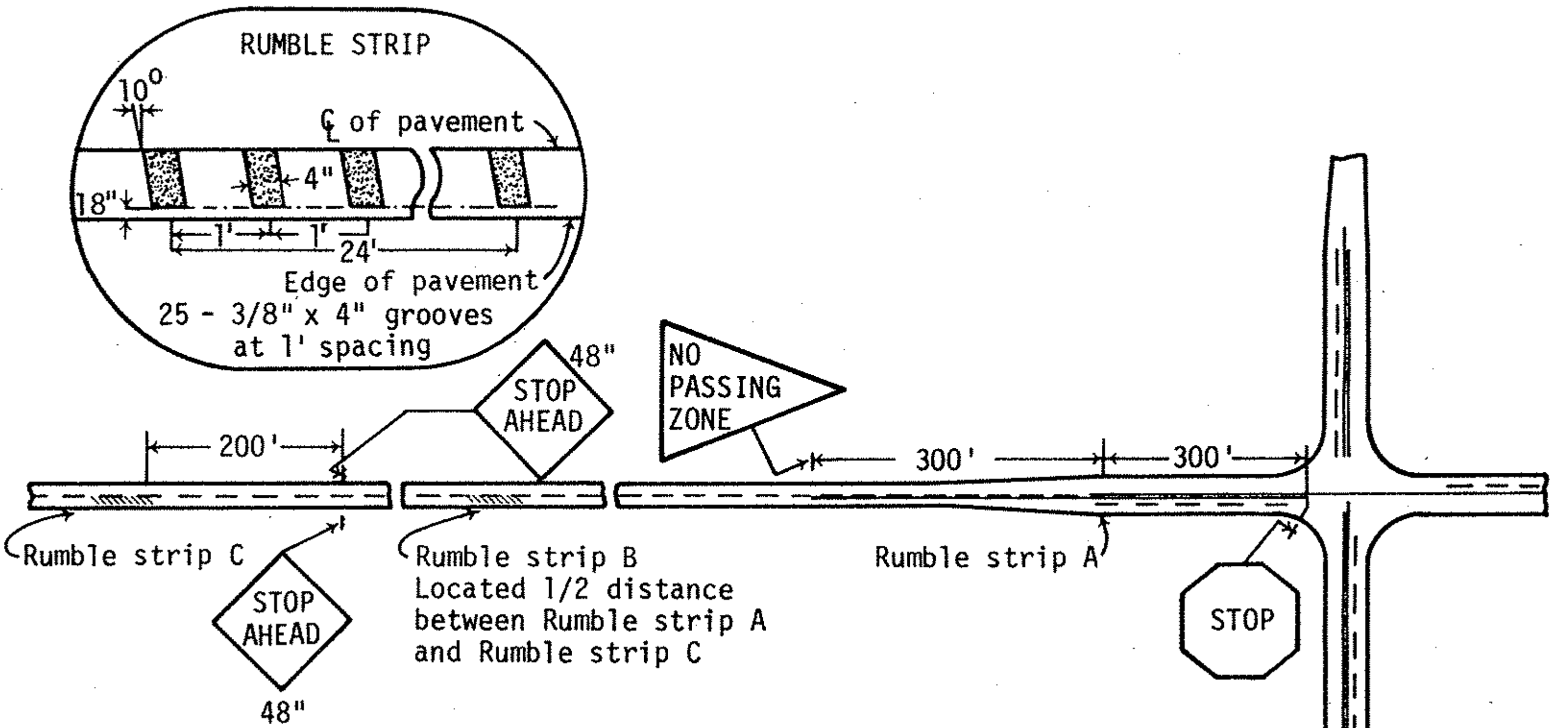
(Office use only)

| | East | South | West | North |
|---|---|---|---|---|
| Approach volume | _____ | _____ | _____ | _____ |
| Intersecting volume | _____ | _____ | _____ | _____ |
| MEV/yr | _____ | _____ | _____ | _____ |
| Accidents from _____ to _____ | _____ | _____ | _____ | _____ |

# APPENDIX C

## IOWA DEPARTMENT OF TRANSPORTATION

## STANDARD DESIGN FOR RUMBLE STRIPS




RUMBLE STRIP STANDARD
TRAFFIC ENGINEERING
9-6-67