and accident rates. The conflict rate was never found to be attributable to any single intersection characteristic but was probably the result of the combination of several. Some evidence suggests that modification of existing signals may result in a slightly higher conflict rate than will the installation of a new signal, but the supporting data are sketchy at best. The same is true for accident rates. At best, all that can be said about accidents based on the data gathered in this study is that, in general, the ratio of accidents involving left-turning vehicles to all accidents that occur at the intersections increases after E/P signals are installed.

This study has made some determinations, but more work is still to be done. A study is under way at the research council to determine what types of intersections lend themselves to E/P signal treatment. To establish guidelines for the installation of E/P left-turn phasing at new locations and for modifying existing locations, a comparison is being made of existing E/P intersections and non-E/P intersections on the basis of such characteristics as approach and left-turn traffic volumes, traffic mix, speed limit, geometrics, sight distance, accident and conflict rates, intersection configuration, and commercial development.

ACKNOWLEDGMENT

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Notice: The opinions, findings, and conclusions expressed in this paper are those of the author and not necessarily those of the sponsoring agencies.

Safety Effects of Rumble Strips on Secondary Roads

R.L. CARSTENS

Research was undertaken to identify specific locations where rumble strips could improve safety on rural secondary roads. Of the 685 rumble-strip installations on secondary roads in Iowa, 207 were selected for detailed study. At 88 locations a before-and-after comparison of the accident experience was made because accident records were available for at least one full year both preceding and following the installation of rumble strips. (Accident records were available only for 1977-1980.) The accident experience at the 119 locations that have rumble strips installed before 1978 was compared with a sample of comparable locations that do not have rumble strips. No difference was found in the accident experience at secondary road locations between the periods before and after the installation of rumble strips. Secondary road locations that have rumble strips for longer periods experienced slightly more accidents than did comparable control locations that did not have 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. Furthermore, no correlation could be demonstrated between the occurrence of accidents at the locations in the sample and factors such as traffic volume, sight distance, and distance from the last stop.

The use of rumble strips on paved rural secondary roads has often been suggested as a means of enhancing safety. Rumble strips are used widely 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 thought to require supplemental warning devices.

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 effective in reducing accidents at some locations. On the other hand, several studies of rumble-strip use have shown that the number of accidents does not change following the installation of rumble strips, although the number of certain types of accidents may be reduced.

BACKGROUND

Research was undertaken 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 stop. These factors were quantified through a field inventory of selected locations in Iowa where rumble strips had been installed. Analysis of the correlation of these factors with safety made use of the accident records available in Iowa through the accident location and analysis system (ALAS).

The goal of the research was to improve safety on rural secondary roads 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 could 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.

SURVEY OF RUMBLE STRIPS ON SECONDARY ROADS IN IOWA

Sample

The sample was developed by means of a mailed survey sent to each of the 99 county engineers in Iowa. Information was requested on all rumble strip locations on the secondary road system in the state.

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, for a total of 685 rumble strip installations. Of these 661 were at stop sign locations and 24 were at other locations, primarily at railroad crossings.

The sample for the field study was selected as follows:

1. Rumble strip installed in 1978 or 1979--a 100-percent sample;
2. Rumble strip installed in 1977 or earlier--a 50-percent sample with a maximum of six from any one county.

Locations to be inventoried for the sample of locations that have had rumble strips since at least 1977 were selected by 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 1977-1980 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:

1. Before-and-after comparison of locations with rumble strips installed in 1978 or 1979, 88;
2. Locations with rumble strips installed in 1977 or earlier, 119; and
3. Locations without rumble strips for control purposes, 119.

The types of locations at which these rumble strip installations were located are shown in Figure 1. The number of locations of each type is given in Table 1.

Inventories and Analyses

An inventory of field conditions was performed at each of the 207 locations with rumble strips that were included in the data sample as well as at the 119 locations without rumble strips that were used for control purposes. Information was recorded in the field for all of the independent variables listed in Table 2 except those related to traffic volumes.

An accident record was obtained for each rumble strip location included in the sample and for asso-

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

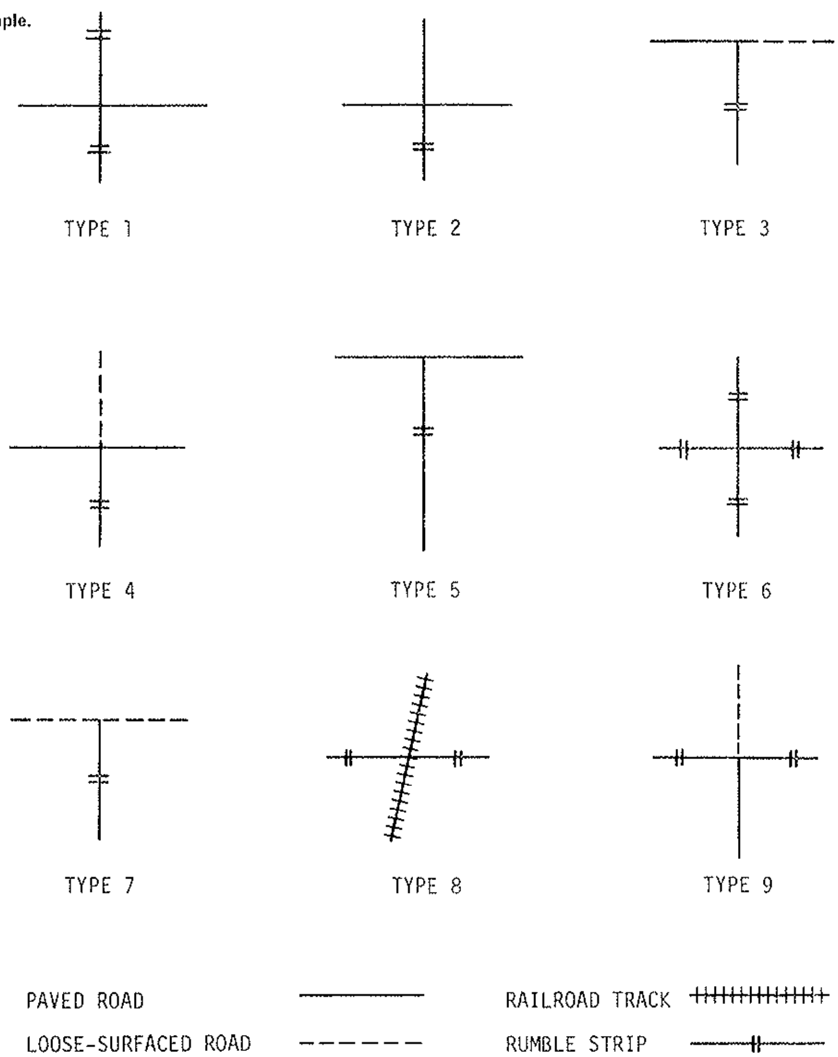

Table 1. Summary of secondary road sample by type of location.

Type of Installation	Number of Locations: Without Control	Pairs with Control
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. Variables used in models.

Code	Variable
Dependent	
NTA	Total accident rate at node (accident/million entering vehicles per year)
NRA	Run stop sign accident rate at node
Independent	
INTER	Intersection type (secondary or primary)
HWY	Highway type (T-type, RR-Xing, or other)
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 link with rumble strip
INTERVOL	Intersecting volume
VISIBLE	Distance stop sign is visible (ft; maximum of 1,000 ft)
SIDE	Number of driveways, field entrances, and gravel roads within 0.5 mile
RIGHT	Right sight triangle length (ft; maximum of 1,000 ft)
LEFT	Left sight triangle length (ft; maximum of 1,000 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)

Table 3. Mean values and standard deviations of dependent variables used in models.

Dependent Variable	Accident Rate (Accidents/MEV): Mean	SD
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

ciated control locations. This information was available only for calendar years 1977-1980 from ALAS, a computer-accessed accident record storage system maintained by the Office of Safety Programs, Iowa Department of Transportation.

Accident records were obtained to compare the accident experience at locations that have rumble strips with comparable locations that do not have 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 these cases either one or two years of accident data were available for the period preceding installation of rumble strips, and either one or two years of accident data were available following their installation.

Rumble strips installed in either 1980 or 1981 did not have a sufficient amount of accident experience on which to base a comparison; therefore, 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 1978-1980 for installations made in 1977, or for 1977-1980 for earlier installations. The year during which rumble strips were installed was always excluded from a comparison.

The 10 type-8 locations (railroad crossings) and the 1 type-9 location were deleted from the secondary road sample. No accidents were recorded at any of these locations during 1977-1980. Therefore, 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.

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 that distinguished locations that experienced a reduction in accidents following installation of rumble strips from those where no such reduction had occurred.

To accomplish this analysis the factors displayed in Table 2 were quantified. Two different dependent variables were used, the total accident rate at a location (NTA) and the rate for accidents involving a ran-stop-sign notation by the investigating officer (NRA). 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. The available data did not indicate that the frequency of any particular type of accident was influenced by the presence or absence of rumble strips.

Accident severity was not considered as a variable in this research. The results of an earlier study of experience in Iowa with rumble strips on county roads 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, because 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.

Average values for the dependent variables are given in Table 3. As indicated in the table, the differences in accident experience between comparable samples are not significant. For example, the average rates for total accidents are the same before and after rumble strip installation at the locations where rumble strips were 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.

Because no safety benefit is apparent from the installation of rumble strips on secondary roads, analysis of these data failed to identify any variables that were significantly associated with a favorable effect on accident experience. Regression analyses were undertaken by using several different subsamples based on 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.

Further evaluation were carried out by using only the before-and-after sample. No accidents were recorded at 28 of the 85 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. Analyses of single-vehicle run-off-the-road accidents at T-intersections showed no differences between the before and after experience. The proportions of accidents that occur at night also exhibited no change following the installation of rumble strips.

CONCLUSIONS

The frequency of accidents at rural locations on secondary roads was independent of the presence or absence of rumble strips. No factors were identified that characterize locations where a reduction in accident frequency could be expected to result from the installation of rumble strips. Although secondary road intersections that have accident rates higher than 2.5 accidents/MEV always showed a reduction in accident rate following the installation of rumble strips, this reduction would be expected by chance given the low traffic volumes and infrequent occurrence of accidents at these locations.

Notice: 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. The author, however, retains responsibility for the interpretations of factual input to the research and for its findings and conclusions, which are not necessarily those of the Highway Division of the Iowa Department of Transportation.

Sign Vandalism—Costly and Dangerous National Problem

HIMMAT S. CHADDA AND EVERETT C. CARTER

Sign vandalism has become a costly and often deadly national problem. In addition to the millions of dollars in cost to replace vandalized signs, this situation denies motorists the critical information necessary for safe driving and increases the potential for severe traffic accidents. Nationally, the replacement costs for vandalized signs are startling—about $50 million annually in direct costs and indirect costs for injuries and tort liability claims of about the same magnitude. The accident statistics on fatalities, property damages, and personal injuries that result from vandalized or missing signs are frightening and point out the magnitude of the problem. Some jurisdictions have become alarmed at the increasing rate of sign vandalism and its adverse economic, social, and safety impacts. The nature, magnitude, and criticality of the sign vandalism problem requires a strong concerted effort at both the national and local levels to combat this costly and dangerous traffic safety problem. A grass roots approach is suggested for a full understanding of who vandalizes signs, why they do so, when and where sign vandalism is more pronounced, and the true consequences of this prankishness. Positive and problem-specific countermeasures (physical, legal, judicial and enforcement, and educational) that should be pursued at the national, state, and local levels are discussed in this paper. A systems approach framework for selecting countermeasures for local and problem-specific sign vandalism was developed and partly tested. This approach should be fully implemented.

Sign vandalism has become a costly and often deadly national problem. In addition to the millions of dollars taxpayers spend to replace vandalized signs, vandalism denies the motorists the critical information necessary for safe driving and increases the potential for severe and often tragic traffic accidents. Nationally, the replacement costs for vandalized sign are startling. According to FHWA estimates, total annual direct costs to the states, counties, and cities are $50 million (1). Indirect costs for injuries and tort liability claims are estimated to be the same. Accident statistics on fatalities, property damages, and personal injuries from vandalized or missing signs (especially intersection-control signs and STOP signs in particular) are rather frightening and are indicative of the magnitude of the problem.

State and local jurisdictions and the federal government have become alarmed at the increasing rate of sign vandalism and its adverse impact on local agency budgets and the safety of highway users. The nature, magnitude, and criticality of the sign vandalism problem requires a strong concerted effort at both the national and local levels to combat this costly and dangerous traffic safety problem.

SCOPE OF SIGN VANDALISM PROBLEM

Vandalism as defined in the Webster's Dictionary means "willful or malicious destruction or defacement of public or private property." In the area of traffic engineering, vandalism has affected different types of traffic control devices. Traffic control devices and equipment that are routinely vandalized include signals (especially lenses for pedestrian indications and pedestrian push buttons), signs (all types of regulatory, warning, informational, and directional), traffic cones, delineators, traffic counters, reflectorized pavement markers and buttons, and occasionally pavement markings.

In the past few years sign vandalism has created