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AN INVESTIGATION OF SAFETY PROBLEMS AT SKEWED RAIL-HIGHWAY GRADE CROSSINGS

by

Eric Paltell
Graduate Research Author

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

Skewed rail-highway grade crossings can be a safety problem because of the restrictions which the angle of crossing may place upon a motorist's ability to detect an oncoming train and because of the potential roadway hazard which the use of flangeways in crossing surfaces poses for cyclists. This study has found that at skewed grade crossings in Virginia where design sight distance requirements cannot be met restrictions have usually been imposed by vegetation, buildings, or embankments and not by the angle of crossing. The investigation of cyclist accidents has shown that these accidents appear to be limited to crossings that intersect the centerline of the highway at an angle of 30° or less. To improve safety at these crossings, it is suggested that cyclist warning signs be installed, a section on skewed crossings hazards be added to the _Virginia Motorcycle Operator's Manual_, instruction on skewed crossing safety be included in the Department of Education's bicycle safety program, and, at those crossings where cyclist accidents are a frequent occurrence, engineering feasibility studies be conducted on the use of a rubber crossing surface with filler strips in the flangeways.

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INTRODUCTION

Safety problems at rail-highway grade crossings can be traced back to the development of the railroad industry in the United States in the 19th century. Because trains proved to be a reliable, economical, and rapid form of transportation, railroads were often allowed to build tracks down existing streets and roads of many cities and towns. As time progressed and the United States began to build a national highway system, rights-of-way adjacent to railroad rights-of-way were often acquired for road construction. As a result of these developments, many of America's streets and highways are now located near railroad tracks, and a multitude of rail-highway grade crossings have been created throughout the nation.(1) The _1981 National Rail-Highway Crossing Inventory Bulletin_ listed nearly 214,000 such crossings in use.(2)

Although engineers usually try to design grade crossings so that the highway centerline is as close to perpendicular to the railroad tracks as possible, restrictions caused by rights-of-way or the topography sometimes require that the roadway intersect the tracks at less than a 90° angle. In these circumstances, two problems may develop: a reduction in sight distance which restricts a motorist's ability to detect an oncoming train and a potential roadway hazard for cyclists. The latter problem is the main concern of this report.

Objectives

The purpose of the study was to investigate the extent to which skewed rail-highway grade crossings affect the safety of vehicles traversing them. The principal objective was to define the nature and scope of cyclist hazards at skewed crossings; however, it also explored the limitations which the angle of skew places upon sight distances at grade crossings.

Where safety problems were found, an attempt was made to determine the angular limits within which the hazard exists. Potential countermeasures to these hazards were identified and recommendations for their use have been suggested where warranted.

Definition of Skewed Crossings

For the purposes of this report, a "skewed crossing" is defined as any rail-highway grade crossing which intersects the roadway centerline at an angle of 70° or less. This determination was made on the basis of previous studies which identified such crossings as locations where sight distance is more likely to be restricted and the potential for both vehicle-train and non-train involved accidents may be greater than it is at crossings which intersect the roadway at angle between 70° and 90°.(3,4)

RESEARCH PROCEDURES

Literature Survey

As a preliminary step, information on grade crossing safety and motorcycle usage was gathered and reviewed. Literature searches were conducted by the Transportation Research Information Service and the Motorcycle Safety Foundation. Additionally, participants in the 1980 National Rail-Highway Crossing Safety Conference and other railroad, transportation, and motorcycle industry officials were contacted for information on hazards at skewed crossings.

Inventory of Skewed Crossings

As a participant in the National Rail-Highway Grade Crossing Inventory, the Virginia Department of Highways and Transportation maintains an inventory of all public grade crossings within the Commonwealth. The inventory is organized according to the eight construction districts of the Department. The crossings are further divided into urban and rural crossings within each district. Because the information available on rural crossings is more accessible and up-to-date than that on urban crossings, the former was taken as the primary data base.

Given the amount of time and resources available for this research, it was impossible to identify all rural skewed crossings in Virginia. Consequently, the study was limited to crossings in the Bristol, Staunton, Culpeper, Richmond, and Salem districts, where 70% of the state's rural crossings are located. An inventory of all public grade crossings in these five districts produced a total of 558 skewed crossings. For each crossing, information was assembled on the angle of crossing, traffic volume, vehicle-train accidents occurring during the past 5 years, crossing surface, maximum train and vehicle speeds, sight distance, and warning devices. A distribution of the inventoried crossings by smallest crossing angle is given in Table 1.

Table 1

Inventoried Crossings by Smallest Crossing Angle

District	Number of Crossings by Indicated Angle							
	0°-20°	21°-30°	31°-40°	41°-50°	51°-60°	61°-70°	71°-90°	Total
Culpeper	4	5	14	14	10	8	75	130
Richmond	1	13	16	33	44	19	126	252
Staunton	3	19	29	31	23	21	143	269
Salem	2	12	23	15	18	9	70	149
Bristol	8	38	45	39	34	8	119	291
Total	18	87	127	132	129	65	533	1091

Accident Analysis

Using the information gathered in the inventory of skewed crossings, accident records were reviewed for those crossings where the average daily traffic volume (ADT) exceeded 1,000 vehicles or where at least one vehicle-train collision had been reported. Using these criteria, records of accidents occurring within 150 ft. (45.6 m.) of a crossing during a 5-year period (January 1, 1978 to December 31, 1982) were obtained for 178 crossings. A distribution of these crossings by smallest crossing angle is given in Table 2.

The accident reports were reviewed to determine whether the skew of the crossing had caused or contributed to any accidents in which a cyclist had lost control of his vehicle. The reports were also reviewed to determine whether a skew-imposed reduction of sight distance was a factor in any of the reported vehicle-train collisions.

On-Site Surveys

On the basis of the inventory of skewed crossings and accident analyses, 67 crossings were chosen for use in the on-site surveys. In these surveys, information was compiled on crossing conditions, flangeways,* sight distance, roadway geometrics, and surrounding topography. In an effort to determine whether unreported cyclist accidents had occurred at a crossing, employees of nearby businesses and local residents were questioned. A distribution of the crossings visited is given in Table 3.

Table 2

Crossings Used in Accident Analyses
by
Smallest Crossing Angle

District	Number of Crossings by Indicated Angle						
	0°-20°	21°-30°	31°-40°	41°-50°	51°-60°	61°-70°	Total
Culpeper	2	2	8	4	5	2	23
Richmond	1	5	4	9	11	7	37
Staunton	2	11	9	4	5	6	37
Salem	0	4	6	6	4	1	21
Bristol	4	13	13	15	9	6	60
Total	9	35	40	38	34	22	178

*A flangeway is a 2 to 3½ in. (5.1 cm. to 8.9 cm.) wide groove located on either side of the running rails which accommodates the flange of the train wheels and prevents the rails from coming in contact with the crossing surface.

Table 3

Crossings Used in On-Site Surveys
by
Smallest Crossing Angle

District	0°-20°	21°-30°	31°-40°	41°-50°	51°-60°	61°-70°	Total
	Numbers of Crossings by Indicated Angle						
Culpeper	2	2	3	1	2	0	10
Richmond	1	4	4	1	0	0	10
Staunton	3	11	7	4	0	0	25
Bristol	3	5	4	5	4	1	22
Total	9	22	18	11	6	1	67

Data Synthesis

Once the literature survey, inventory, accident analyses, and on-site surveys were completed, the accumulated information was reviewed and a decision was made on where to focus the remainder of the research. Because reduced sight distance at skewed crossings did not prove to be a problem in Virginia, it was decided that there would be no need to investigate countermeasures. However, cyclist hazards which warranted the use of countermeasures were found at some skewed crossings. Therefore, the remaining research was centered on possible solutions to cyclist problems at these crossings.

Investigation of Countermeasures

The final phase of this study was focused upon methods by which cyclist safety at skewed crossings could be improved. Transportation officials and representatives of the motorcycle and grade crossing industries were contacted for their opinions. Additionally, the Manual on Uniform Traffic Control Devices (MUTCD) and other pertinent information on grade crossing safety procedures were reviewed. These countermeasures are discussed in detail in a later section of this report.

SIGHT DISTANCE

Statement of Problem

One of the most important factors in vehicle-train collisions is the inability of an approaching motorist to detect an oncoming train. Section 5.2 of the Railroad-Highway Grade Crossing Handbook states: "The primary requirement for the geometric design of a grade crossing is that it provides adequate sight distance for the motor vehicle operator to make an appropriate decision as to whether to stop or to proceed." (1) Failure to provide adequate sight distance increases the potential for vehicle-train accidents.

Sight distance can be measured through the use of a minimum sight triangle determined by the maximum vehicle and train speeds. Distances based upon these speeds are measured along the roadway and the track and a line is drawn between them to define the area of the triangle as shown in Figure 1.

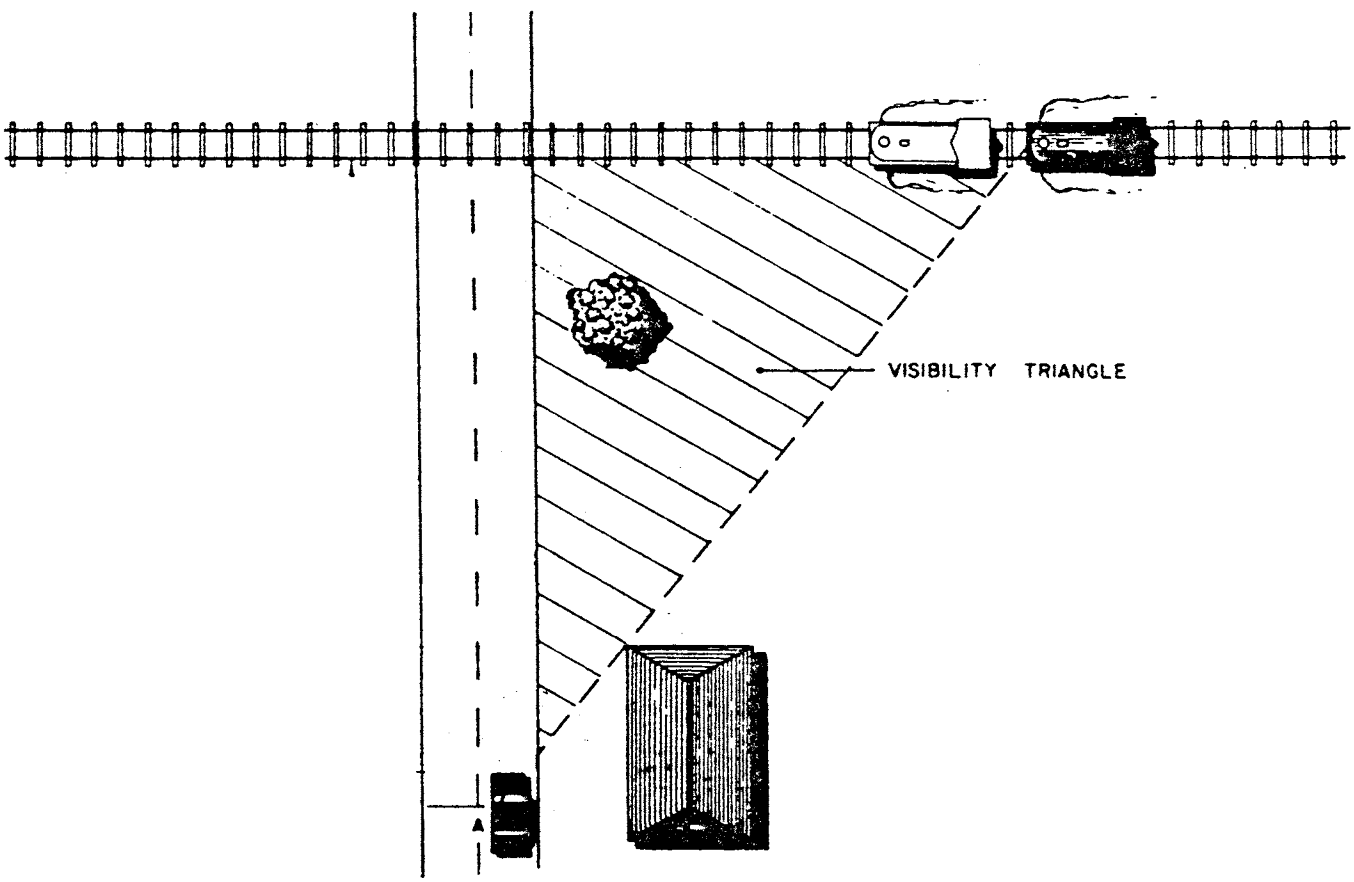

Figure 1. Minimum sight triangle. (From reference 1)

The distance along the highway must, as a minimum, be the safe stopping distance for a vehicle travelling at a given approach speed. The distance along the railroad tracks is that which would result in a train travelling at its maximum timetable speed arriving at the crossing at the same time that the approaching motor vehicle comes to a stop. (1) Table 4 lists the required design sight distances for various combinations of motor vehicle and train speeds. (5)

At many crossings, vegetation, topography, buildings, or the geometric design of the crossing make it difficult to achieve the minimum sight triangle. For the purposes of this study, the most important restriction on sight distance was the one imposed by the angle of crossing. According to the Grade Crossing Handbook, the crossing angle "has a significant effect on the motorist's field of view, and the amount of skew from the ideal of 90° should be minimized." (1)

Table 4

Required Design Sight Distances in Feet for Combinations of Motor Vehicle and Train Speeds

TRAIN SPEED (MPH)	DESIGN SIGHT DISTANCE FOR HIGHWAY SPEED OF 0 MPH	10 MPH	15 MPH	20 MPH	25 MPH	30 MPH	35 MPH	40 MPH	45 MPH	50 MPH	55 MPH	60 MPH	65 MPH	70 MPH	75 MPH
10	162	126	104	94	91	94	96	99	101	107	113	118	125	129	138
15	242	189	156	141	137	141	143	147	152	161	169	176	187	194	207
20	323	252	208	188	182	188	191	197	203	214	226	235	250	258	276
25	404	315	260	235	227	235	238	246	253	267	282	293	312	322	344
30	484	378	312	281	273	281	286	295	303	321	339	352	374	387	414
35	565	441	364	328	318	328	333	342	354	375	395	411	436	452	483
40	645	504	416	376	364	376	382	394	406	428	452	470	500	516	552
45	725	567	468	422	409	422	429	442	455	482	508	528	561	580	620
50	807	630	520	470	454	470	476	492	506	534	564	586	624	644	688
55	886	694	573	516	500	516	524	540	556	588	621	645	685	710	758
60	967	756	624	562	546	562	572	590	606	642	678	704	748	774	828
65	1049	819	676	610	591	610	619	638	657	695	734	762	810	837	895
70	1129	882	728	656	636	656	666	684	708	750	790	822	872	904	986
75	1210	945	780	704	681	704	714	737	758	803	847	879	935	967	1035
80	1290	1008	832	752	728	752	764	788	812	856	904	940	1000	1032	1104
85	1370	1070	885	799	774	779	812	835	861	910	960	998	1059	1097	1172
90	1450	1134	936	844	818	844	858	884	910	964	1016	1056	1122	1160	1240
95	1533	1200	990	890	865	890	910	935	960	1020	1070	1115	1190	1225	1310
DISTANCE ON HIGHWAY FROM CROSSING (FT)	20	65	95	125	165	215	270	330	395	470	560	640	745	840	965

Note: 1 mph = 1.61 kph; 1 ft. = 304 m.

Source: Reference 5

A skewed angle of crossing may make it difficult to obtain the minimum sight triangle by limiting the distance a motorist can see down the tracks. As a result, a motorist approaching a skewed crossing may not recognize a train approaching from the acute angle in sufficient time to make an appropriate decision as to whether to stop or to proceed. Even if the motorist does recognize the approaching train, he may not be able to accurately judge its rate of closure upon the crossing.(3)

A second type of sight distance often restricted at skewed crossings is the stopped vehicle sight distance. Many vehicles, such as school buses and carriers of hazardous materials, are required by law to stop at most railroad crossings. Other vehicles may have to stop because of the presence of a stop sign or train-activated flashing lights. In all of these circumstances, the stopped motorist must be able to see far enough down the tracks to accurately judge whether he will be able to safely cross the tracks before the train reaches the crossing.(3) The required design sight distances for vehicles stopped 20 ft. (6.1 m.) from a crossing are given in Table 4 where highway speed = 0.

At skewed grade crossings, an adequate stopped vehicle sight distance is most difficult to achieve along the portion of the tracks which forms the acute angle of crossing. A stopped motorist may be required to look over his shoulder and out the rear window of his vehicle to obtain the required design sight distance. This problem is especially severe with respect to trucks, which usually have limited rear window sight distance because of the configuration of the cab or truck bed . Because warning devices which require a vehicle to stop can be effective only when reinforced by a driver's visual confirmation of an approaching train, efforts should be made to ensure adequate stopped vehicle sight distances.(3)

Countermeasures

The most effective countermeasure in situations where the minimum sight triangle or the required stopped vehicle sight distance cannot be achieved is the installation of train-activated warning devices. If roadside vegetation, nearby buildings, or the angle of crossing make it difficult to achieve the minimum sight triangle, consideration must be given to the installation of flashing lights. For further protection, these lights may be supplemented with warning bells. Such measures provide an approaching motorist with enough advance notice of an oncoming train to allow him to stop safely.

If the stopped vehicle sight distance does not allow for the visual confirmation of an approaching train, crossing gates may be necessary to deter a vehicle from crossing into the path of a train. Although section 11-701 of the Uniform Vehicle Code requires vehicles to stop when "a clearly visible electric or mechanical signal device gives warning of the immediate approach of a railroad train," many motorists will still attempt to cross the tracks if they cannot actually see the approaching train. (6, 3) For this reason, gates are recommended if the stopped vehicle sight distance is inadequate. (3)

Research Objectives

In light of the sight distance problems discussed in the preceding section, it was decided that a portion of this study would attempt to determine whether insufficient sight distance is a problem at skewed crossings in Virginia. Accident records were examined for evidence which would identify a skew-imposed reduction of sight distance as a possible cause of a vehicle-train collision. Additionally, the sight distances available at the crossings studied in the on-site surveys were compared to the requirements established in Table 4. If the angle of skew made it difficult to obtain the required minimum sight triangle or stopped vehicle sight distance, an investigation was made to determine whether appropriate warning devices had been installed. For example, if the maximum timetable train speed at a crossing with flashing lights only is 20 mph (32.2 kph), a motorist stopped 20 ft. (6.1 m.) from the crossing must be able to see 323 ft. (98.2 m.) down the tracks in order to make a proper decision as to whether to attempt to cross. If, because of a 35° angle of crossing, the stopped motorist can see only 150 ft. (45.6 m.) down the tracks, the sight distance would be deemed to be inadequate. In this situation, the use of additional warning devices may be warranted.

Research Results

Accident Analyses

A review of the accident reports obtained for 178 crossings identified 55 vehicle-train collisions that had occurred within the last 5 years. In 4 of these accidents, a skewed angle of crossing may have contributed to the motorists' failure to detect an oncoming train in time to stop safely. However, a skew-imposed reduction of sight distance could not be clearly identified as a cause of these accidents.

Skewed Crossing Inventory

An analysis of the sight distance information in the grade crossing inventory indicated that the angle of skew placed some restriction upon the sight distance measured 10 ft. (3.05 m.) from the crossing at 162 of the 558 crossings inventoried. However, this information was not sufficient for determining whether the design requirements in Table 4 could be met. The sight distance data in the inventory did indicate that the skew of the crossing was more often identified as a restriction on sight distance when the angle of crossing was less than 45°.

On-Site Surveys

In an effort to compare the design requirements in Table 4 with the sight distances available at skewed crossings in Virginia, sight distance measurements were made at 36 of the crossings visited in the on-site surveys. Maximum timetable train speeds and vehicle approach speeds were obtained from the grade crossing inventory and used to calculate the required minimum sight triangle and stopped vehicle sight distance at each crossing. Corresponding sight distance measurements were made at the crossings on the basis of the types of warning devices present. The criteria used are given below.

Crossbucks Only. Since no train-activated warning devices are present at this type of crossing, both the minimum sight triangle and stopped vehicle sight distance were measured. The sight distance was measured from the safe stopping distance for a vehicle approaching at the recorded approach speed for the crossing and from a distance of 20 ft. (6.1 m.) from the crossing. The measured distances were then compared to those in Table 4.

Flashing Lights With No Gates. Because the train-activated flashing lights would alert an approaching motorist to the presence of an oncoming train, only the stopped vehicle sight distance was measured at this type crossing. The results were compared to the design distances in Table 4.

Flashing Lights With Gates. The combined use of lights and gates serves to both alert the approaching motorist to the presence of an oncoming train and prevents him from crossing into the path of the train. As a result, the sight distances were not measured at these crossings.

Results of the measurements indicated that design sight requirements for the minimum sight triangle could not be met at 8 of the 12 crossings with crossbuck protection only. However, the restrictions at each of the 8 crossings were caused by the presence of vegetation, roadside buildings, embankments, or railroad equipment -- not by the angle of skew.

Design requirements for the stopped vehicle sight distance could not be met at 8 of the 24 crossings with flashing light protection. At 6 of the 8 crossings, restrictions were imposed by brush, topography, buildings, or equipment, -- not by the angle of crossing. At the two crossings where the angle of crossing did restrict sight distance, the measured distance was within 35 ft. (10.6 m.) of that required in Table 4.

Observations made at the crossings where accident reports suggested that the angle of crossing may have contributed to a vehicle-train collision did not produce evidence that would confirm the skew as being a causal factor.

Summary and Analysis

On the basis of research done in the skewed crossing inventory, accident analyses, and on-site surveys, skew-imposed restrictions on sight distance at grade crossings in Virginia do not not appear to be a problem. Although evidence indicates that a skewed angle of crossing does limit both the stopped vehicle sight distance and the minimum sight triangle, the use of flashing lights and crossing gates appears to have effectively countered this problem. At crossings where sight distance problems have been found, they stem from roadside obstacles such as buildings and vegetation -- not from the angle of skew.

CYCLIST HAZARDS

Statement of Problem

The hazards which cyclists face at skewed rail-highway grade crossings stem from the design of most crossing surfaces. Railroads require the use of a 2 in. to 3¼ in. (5.1 cm. to 8.3 cm.) wide groove on the inside of each running rail to accommodate the flange of a train wheel. At many crossings, a similar groove is used on the outside of the running rails to prevent the rail from coming in contact with the surface of the crossing. These grooves are known as "flangeways" and are shown in Figure 2. Crossings which incorporate the use of both inside and outside flangeways are known as double flangeway crossings.

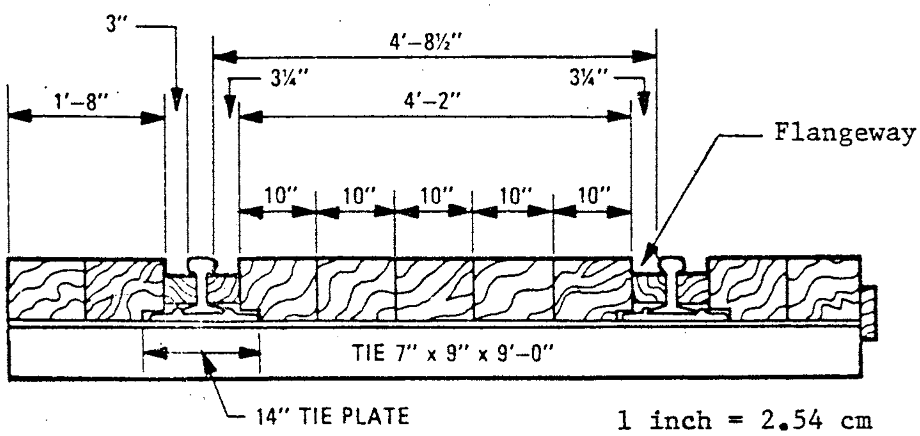

Figure 2. Typical flangeways (double flangeway crossing). (From reference 1)

Although flangeways are usually not a problem for motor vehicles, they may be a hazard for bicyclists and motorcyclists traversing a skewed grade crossing. Because current street-legal motorcycles have tires from 2 in. (5.1 cm.) to 6 in. (15.2 cm.) in width, it is sometimes possible for these wheels to catch in the flangeway and cause the rider to lose control of the motorcycle and fall. (7) The small width of bicycle tires (average design tire width of 1½ in. (3.8 cm.) makes the flangeway a hazard for bicyclists as well. (9)

When a railroad intersects the highway at an angle approximating 90°, there is little chance that a cyclist will catch a tire in a flangeway. But, as the angle of intersection decreases and the path of the railroad more closely parallels that of the highway, the potential for cyclist accidents increases. (8) For this reason, skewed grade crossings present bicyclists and motorcyclists with a special problem.

Crossing Surfaces

The width and number of flangeways at a crossing are usually determined by the type of surface used. Whereas at some crossings only a 2½ in. (6.4 cm.) inside flangeway is used, at others double flangeways up to 3¼ in. (8.3 cm.) wide are installed. At still other crossings, an outer flangeway is used, but its design allows for the insertion of some type of filler material. This section of the report discusses the design of the most commonly used crossings as listed in the Railroad-Highway Grade Crossing Handbook.(1) Data on the number of crossings currently in use has been obtained from the Department of Transportation's Rail-Highway Crossing Accident/Incident and Inventory Bulletin for 1981,(2).

Asphalt Crossings

Asphalt crossings are of two types: plain and modified. The plain asphalt crossings consist of a bituminous surface over the entire crossing area, while modified asphalt crossings use wooden planks (known as timber headers) or flange rails to separate the asphalt from the running rails and form flangeways. Outer flangeways are not required, but they effectively protect the asphalt from damage caused by movement of the rail. A maximum inside flangeway width of 2½ in. (6.4 cm.) is specified. Observations have indicated that outer flangeways are usually between 2½ in. and 3½ in. (6.4 cm. and 8.9 cm.) wide. Asphalt crossings account for 55% of all crossings currently in use.

Full Wood Plank (Full-Depth Timber) Crossings

Wooden planks or timbers are placed over the cross ties to form a crossing surface. Specifications require a 3¼ in. (8.3 cm.) inside flangeway and a 3 in. (7.6 cm.) outer flangeway. Full wood plank crossings account for 15% of the crossings currently in use.

Sectional Timber Crossings

Prefabricated panels composed of 8 ft. to 9 ft. (2.4 m. to 2.7 m.) long timbers are placed over the cross ties to form a crossing surface. The panels are of such width that two panels usually form the surface between the inner flangeways and one is used to cover the cross ties on the outside of each rail. Specifications require the use of a 2¼ in. (5.7 cm.) inside flangeway and a 2½ in. (6.4 cm.) outer flangeway. Sectional timber crossings account for 14% of those currently in use.

Research Objectives

The purpose of the research for this portion of the study was to investigate the extent to which flangeways contribute to cyclist accidents at skewed grade crossings in Virginia. Through the review of accident records and the use of on-site surveys, this research attempted to determine how often and under what circumstances these accidents are occurring.

Research Results

Accident Analyses

Accident records were obtained for the 178 crossings identified in the skewed crossing inventory as having an ADT greater than 1,000 vehicles or as having been the site of a vehicle-train collision during the past 5 years. These records revealed that 180 non-train-involved accidents were reported at or near these crossings between January 1, 1978, and December 31, 1982. Eight of these involved motorcycles, and in 5 of the 8, the crossing flangeway was identified as the primary cause of the accident. These accident reports are summarized in Table 5.

Table 5

Summary of Motorcycle Accident Reports

Location	Angle of Crossing	Date of Accident	Cause of Accident	Surface Condition	Cyclist Injured
Rte. 974 Harrisonburg (DOT #842230B)	10°	6/5/80	front tire caught in flangeway	wet	yes
Rte. 974 Harrisonburg (DOT #842230B)	10°	9/6/81	front tire caught in flangeway	dry	yes
Rte. 974 Harrisonburg (DOT #842230B)	10°	9/18/81	rear tire caught in flangeway	dry	yes
Rte. 974 Harrisonburg (DOT #842230B)	10°	5/20/82	front tire caught in flangeway	dry	yes
Rte. 29 Prince William Co. (DOT #714363S)	20°	8/18/79	rear tire caught in flangeway	wet	yes

On-Site Surveys

On-site surveys were conducted to get information on both crossing conditions and cyclist accidents. Because accident reports are not filed unless serious personal injury or property damage results, cyclist accidents at skewed crossings often are not reported to the police. For this reason, persons living or working within sight of a crossing were asked whether they knew of any accidents in which the tires of a bicycle, moped, or motorcycle had caught in a flangeway and resulted in a spill. If they responded positively, interviewees were asked to estimate how often these accidents occurred. When possible, several persons were questioned in an effort to corroborate information. Interviews were conducted at 31 of the 67 crossings visited. At the remaining crossings, there were no businesses or homes nearby from which accidents may have been observed.

The survey of the crossings showed that 40 had a modified asphalt surface, 15 had a plain asphalt surface, and 12 had a sectional timber surface. Thirty-five of the crossings used both an inside and outside flangeway, while 27 used an inside flangeway only. At 5 crossings, no flangeway was visible.

The interviews with persons near the crossings revealed that at 8 crossings, flangeway conditions had been the cause of at least 1 cyclist accident during the past 5 years. Two of these crossings were identified as accident locations in the accident analyses (Table 5), while 6 were identified through the interviews. All 8 of these crossings intersect the highway centerline at an angle of 30° or less. A summary of the survey results for the 8 crossings where accidents were reported is given in Table 6. Pictures and descriptions of some of these crossings are given in Figures 3 through 7.

Persons questioned at the 23 other grade crossings did not report any motorcycle, moped, or bicycle accidents as having occurred during the past 5 years. These crossings were, therefore, considered not to have been the site of cyclist accidents during that period.

Table 6

Cyclist Accidents Reported in On-Site Surveys

Location	Crossing Angle	Type of Surface	Condition of Surface	Type of Accident	Frequency of Accidents	Special Circumstances
Rte. 974 City of Harrisonburg (DOT #842230B)	10°	1,5	very poor	motorcycle and bicycle	2-3 per month	4" to 5" wide ruts have developed along flangeways. Heavy cyclist traffic due to nearby university. See Figure 3
Rte. 655 Rockingham Co. (DOT #842198K)	20°	1,4	poor	bicycle	3 per year	Asphalt cracked and broken. Ruts developing. See Figure 4
Rte. 67 Tazewell Co. (DOT #468893D)	20°	1,5	very poor*	motorcycle	2 per month	No accidents observed in 5 months since resurfacing.
Rte. 29 Prince William Co. (DOT #714363S)	20°	1,5	good	motorcycle	1 per year	High ADT (17,000) See Figure 5
Rte. 11 City of Harrisonburg (DOT #859981U)	25°	2,4	good	motorcycle and bicycle	2-4 per month	Heavy cyclist traffic due to nearby university. See Figure 6
Rte. 147 Chesterfield Co. (DOT #715248N)	30°	1,5	good	moped and bicycle	2-3 per year	High ADT (18,500) See Figure 7
Rte. 11 Frederick Co. (DOT #517961N)	30°	1,4	poor*	motorcycle	6 per year	No accidents observed in 7 months since resurfacing. Wooden inserts in outer flangeways.
Rte. 669 Louisa Co. (DOT #225072C)	30°	3,5	fair	motorcycle	1 per year	Hazard exists from east approach only.

*prior to resurfacing

1 inch = 2.54 cm

Notes on Type of Crossing Surfaces

1. asphalt with timber headers
2. asphalt with flange rails
3. sectional timber
4. inside flangeways only
5. double flangeways

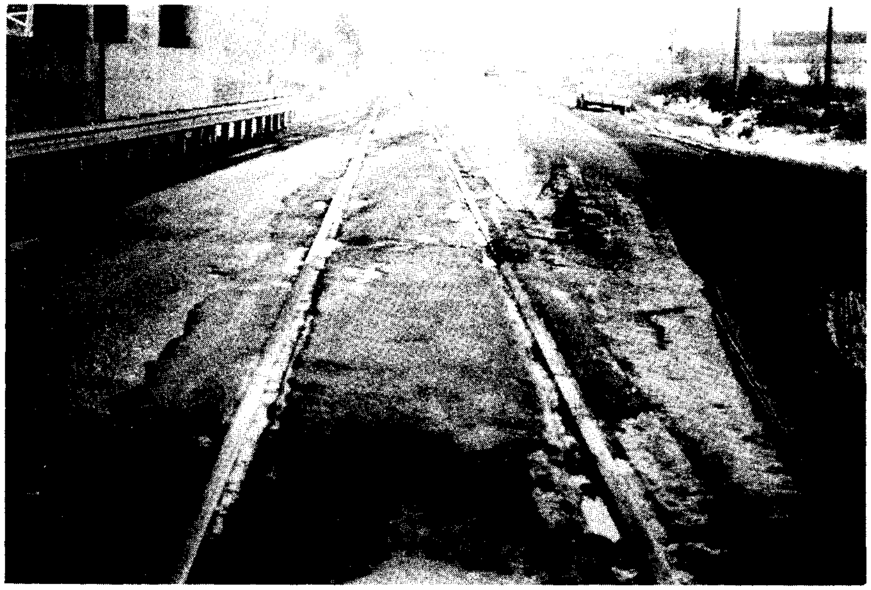

Figure 3. Rte. 974 city of Harrisonburg (DOT #842230B): 10° angle of intersection, asphalt surface with timber headers, 3 in. (7.6 cm.) double flangeways. 4 in. to 5 in. (10.1 cm. to 12.7 cm.) wide ruts along flangeways.

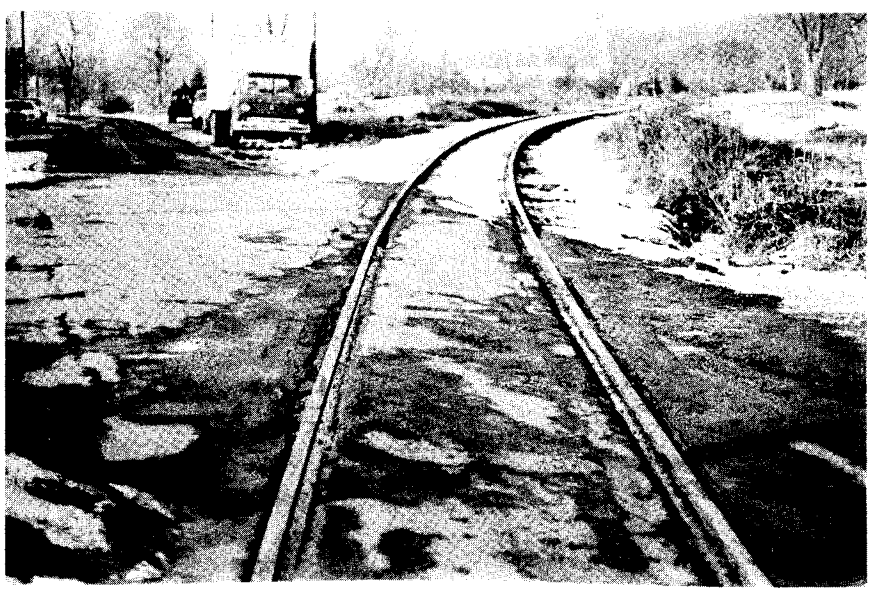

Figure 4. Rte. 655 Rockingham Co. (DOT #842198K): 20° angle of intersection, asphalt surface with timber headers, 3½ in. to 4 in. (8.9 cm. to 10.1 cm.) inside flangeway only. Note broken asphalt along flangeways.

Figure 5. Rte. 29 Prince William Co. (DOT #714363S): 20° angle of intersection, asphalt surface with timber headers, 3 in. (7.6 cm.) double flangeways. Crossing in good condition.

Figure 6. Rte. 11 city of Harrisonburg (DOT #859981U): 25° angle of intersection; asphalt surface with flange rails; 2 3/4" (7.0 cm) inside flangeway only. Crossing in good condition.

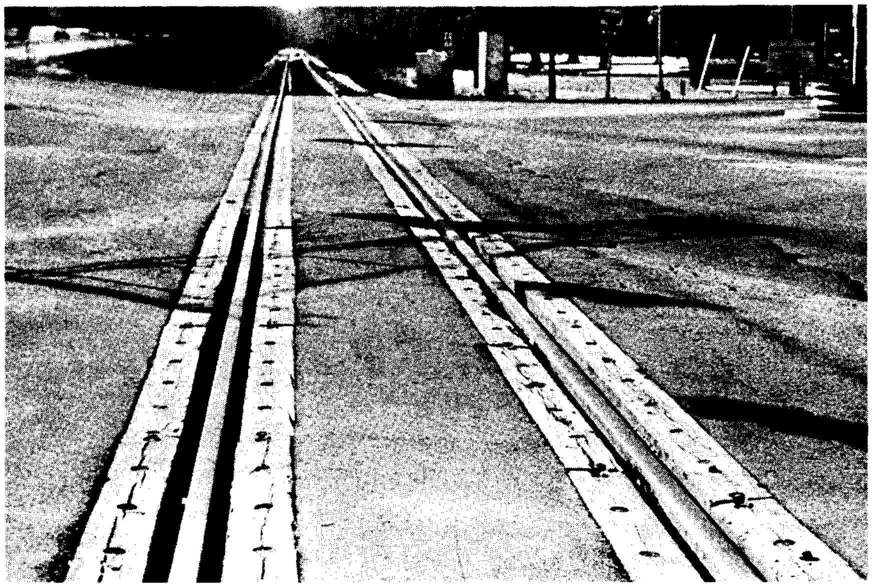

Figure 7. Rte. 147 Chesterfield Co. (DOT #715248N): 30° angle of intersection, asphalt surface with timber headers, 2½ in. (6.3 cm.) inside flangeway, 3 in. (7.6 cm.) outer flangeway. Crossing in good condition.

Summary and Analysis

A review of the information compiled in the accident analyses and on-site surveys indicates that cyclist accidents have been known to occur at 8 grade crossings in Virginia. The following characteristics have been associated with these crossings:

- All 8 crossings intersect the centerline of the highway at an angle of 30° or less. One of these crosses at an angle of 10°, 3 cross at an angle of 20°, 1 crosses at an angle of 25°, and 3 cross at an angle of 30°.

- At 4 crossings, broken asphalt, deteriorated headers, and/or ruts along the flangeway have created a rough crossing surface. At 2 of these crossings, accidents had not been observed in the 5 to 7 months since improvements had been made to the surface.

- Two crossings are located on routes used by cyclists travelling to and from James Madison University in Harrisonburg. As a result, there is an unusually high volume of cyclist traffic.

- Seven of the 8 crossings had a modified asphalt crossing surface; the other had a sectional timber surface.

- Five of the 8 crossings have an outer flangeway in addition to an inside flangeway.

- At 2 crossings, wet road surfaces contributed to at least 1 motorcycle accident.

An analysis of the accumulated data failed to produce conclusive trends with respect to the frequency of accidents at skewed crossings. However, evidence does indicate that the angle of crossing, the volume of cyclist traffic, and the condition of the crossing surface have some effect upon the number of accidents occurring at a crossing.

Overall, cyclist accidents do not appear to be a major problem at skewed grade crossings in Virginia. Accident reports and on-site interviews produced evidence of motorcycle, moped, or bicycle accidents at only 7 of the 178 crossings for which records were obtained.* However, all of the crossings where accidents were reported intersect the centerline of the highway at an angle of 30° or less. No accidents were reported at any of the crossings with a skew greater than 30°. Thus, the results of this research reveal that cyclist accidents have occurred at 16% (7 of 44) of those crossings which meet the roadway at an angle of 30° or less. At some of these crossings, the condition of the crossing surface, the volume of cyclist traffic, and the use of outer flangeways appear to have contributed to the accidents.

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*The accidents reported at the Rte. 11 crossing in Harrisonburg (DOT #859981U) are not included here because it is an urban crossing and was not part of the accident analyses. Although the Rte. 974 crossing (DOT #842230B) is now in the city of Harrisonburg, it is classified as a rural crossing in the Grade Crossing Inventory, and, therefore, was included in the accident analyses.

COUNTERMEASURES

Introduction

The preceding section of this report described the circumstances under which cyclists have been known to get the tires of a motorcycle, moped, or bicycle caught in a skewed crossing flangeway. In this section, methods through which safety at skewed crossings can be improved will be identified and discussed.

It should be noted that this investigation of countermeasures was based primarily upon literature reviews and discussions with transportation officials and representatives of the motorcycle and grade crossing industries. Because of the time constraint on this research, it was not possible to field test these countermeasures.

Crossing Repairs

Since the condition of the crossing appears to have been a contributing factor in some of the cyclist accidents identified in this study, repairs to the crossing surface may be one way to improve safety at skewed crossings. Surface improvements at skewed crossings where cyclist accidents are known to be a problem should be designed to eliminate ruts along the flangeways through the repair or replacement of deteriorated asphalt, timbers, and headers. Repairs could also include the elimination of outer flangeways when conditions permit. Canadian rail lines try to reduce the number of ruts to be traversed at sharply skewed crossings by paving in the outer flangeway whenever crossing design incorporates the use of an outside flange rail.(10) Several crossings identified in the on-site surveys used wooden inserts of the type shown in Figure 8 to fill the outer flangeway.

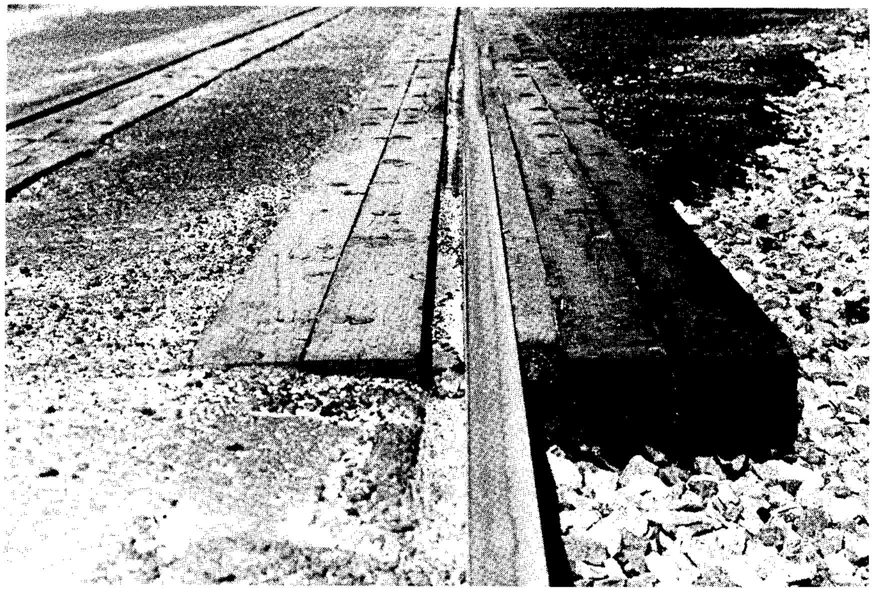


Figure 8. Outer flangeway with wooden insert.

Rubber Grade Crossings

The most effective way to improve cyclist safety at skewed crossings would be to eliminate the flangeways.(12) But, because the design of a train wheel requires the use of flangeways at grade crossings, it would be impractical to simply fill in the inner flangeways at crossings where cyclist accidents are known to be a problem. However, rubber grade crossing surfaces allow for the use of a "filler strip" which can be placed in the inner flangeway (no outside flangeway is used with rubber crossings). This filler strip compresses under train loads to accommodate the flange of a train wheel, but springs back up to rail height under normal vehicular traffic. A rubber crossing with filler strips is shown in Figure 9.

According to representatives of both the Goodyear Tire and Rubber Company and the Park Rubber Company, filler strips are intended primarily for use at industrial in-plant crossings with "normal train-switching speeds."(11) Normal train switching speeds have been defined by both companies to be no more than 10 mph (16.1 kph). If

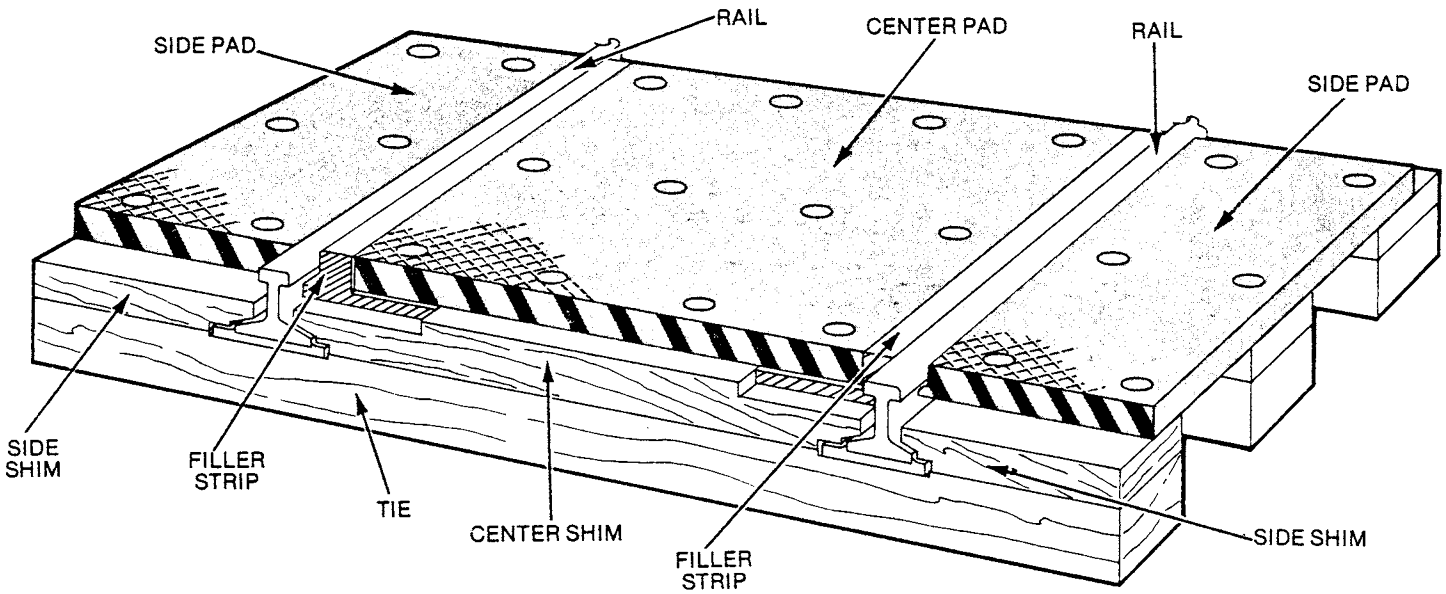


Figure 9. Rubber crossing with filler strips.

filler strips are used at crossings where train speeds exceed 10 mph (16.1 kph), they deteriorate rapidly and require frequent replacement.(12)

At highway crossings where maximum train speeds do not exceed 10 mph (16.1 kph), it is possible that rubber crossings with filler strips can be accommodated. Park Rubber has installed specially designed rubber crossings with filler strips at two highway locations in Florida where moped tires were known to have gotten caught in the inner flangeway. Since their installation, the filler strips have proved to be wear-resistant and no cyclist accidents are known to have occurred.(12)

A decision to install rubber crossings with filler strips must not only take into account maximum train speeds, but must also consider the relatively high cost of installation. Rubber crossings cost approximately three times as much to install as do asphalt or timber crossings.(1,13) This cost may be offset by the longer service life of rubber crossings, which has been estimated to be three times that of a plain asphalt crossing and twice that of modified asphalt or sectional timber crossings. (1) However, the filler strips will probably deteriorate more quickly than the remainder of the rubber crossing surface.(12)

Although a rubber crossing surface with filler strips in the inner flangeway may greatly improve cyclist safety at skewed crossings, the feasibility of using filler strips depends upon train speeds and crossing conditions, thereby requiring evaluation by crossing and track engineers before a decision to use them can be made. The ultimate decision must weigh the benefits to be gained in cyclist safety against the costs for installing the crossing and the possible replacement of deteriorated filler strips.

Warning Signs

Section 2C-1 of the MUTCD states that the use of warning signs is warranted "when it is deemed necessary to warn traffic of existing or potentially hazardous conditions on or adjacent to a highway or street." Additionally, section 9B-15 recommends the use of hazardous condition warning signs "where roadway or bicycle trail conditions are likely to cause a bicyclist to lose control of his bicycle."(14) Because cyclist accidents are known to occur at some grade crossings which intersect the highway at an angle of 30° or less, the use of warning signs at these crossings may be warranted.

Section 9A-1 of the MUTCD lists five basic requirements a warning sign must fulfill to be able to perform its intended function. These are:

1. Fulfill a need
2. Command attention
3. Convey a clear, simple meaning
4. Command the respect of road users
5. Give adequate time for a proper response

Like other warning signs, any cyclist warning sign designed for use at skewed crossings would have to meet these criteria.

Research done for this study indicates that there are two types of cyclist warning signs in use at some skewed crossings. Both signs use either symbols or word messages to warn cyclists that they are approaching a potentially hazardous grade crossings. These signs are described below.

Harrisonburg Sign

The Harrisonburg sign bears the message "Cyclist Cross With Caution" and is shown in Figure 10. It has been mounted beneath the railroad advance warning sign (W10-1) at several sharply skewed crossings in or near Harrisonburg, Virginia.

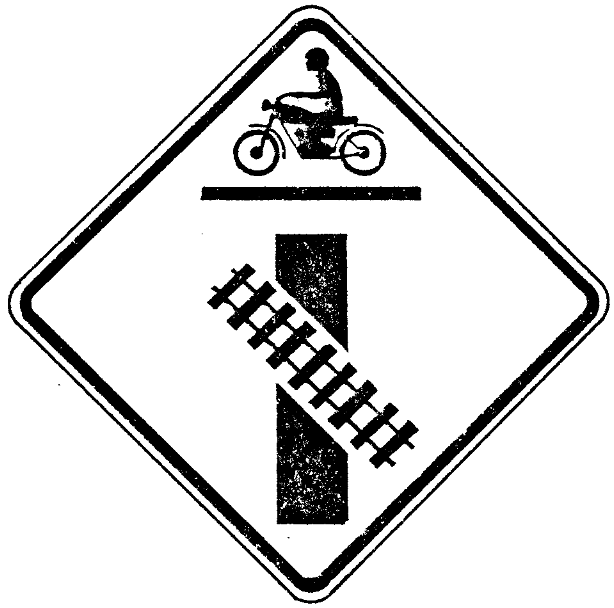
Colors	Dimensions
Legend: Black	Minimum: 30" x 30"
Border: Black	Standard: 36" x 36"
Background: Yellow	Note: 1 inch = 2.54 cm

Figure 10. Harrisonburg sign.

Interviews with students at James Madison University in Harrisonburg indicated that some students who rode bicycles or motorcycles across the Rte. 11 crossing (DOT #859981U) were not aware of the sign and that others who had noticed the sign did not believe that it effectively identified the nature of the hazard. Although the railroad advance warning sign identifies an upcoming grade crossing and the cyclist warning sign advises the cyclist to use caution, neither sign conveys the message that the crossing is a skewed one.

California Sign

The California Department of Transportation (Caltrans) has installed the symbolic sign shown in Figure 11 at grade crossings which intersect a state highway at an angle of 30° or less. Department specifications require that the sign be erected midway between the crossing and the railroad advance warning sign. The railroad tracks



Colors

Legend: Black
Border: Black
Background: Yellow

Dimensions

Minimum: 30" x 30"
Standard: 36" x 36"
Special: 48" x 48"
Note: 1 inch = 2.54 cm

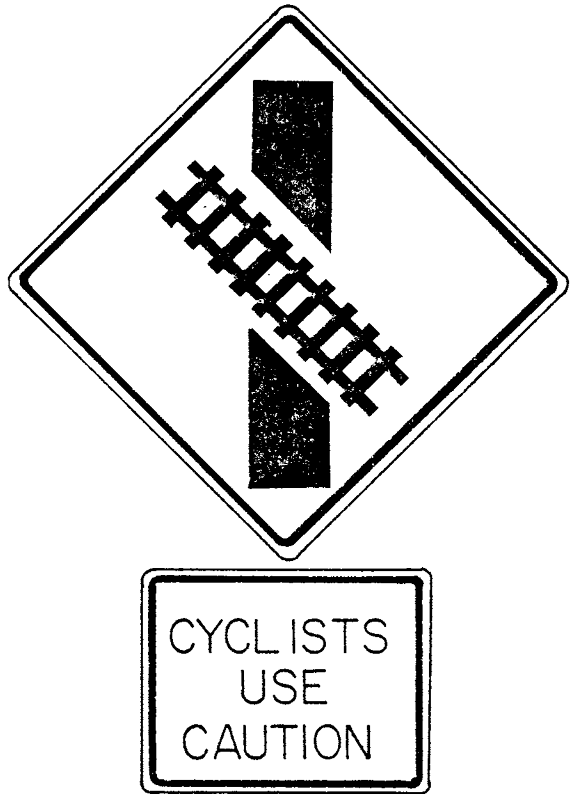
Figure 11. California sign.

symbol may be shown with the tracks crossing either to the left or to the right. Use of the motorcyclist symbol is optional.

Caltrans officials report that California motorcyclists have responded favorably to this sign. Although no formal research has been done, the general feeling is that the sign has reduced the number of accidents occurring at sharply skewed crossings.(15)

Combination Sign

The author has used the designs of the Harrisonburg and California signs to develop a sign which combines a symbolic skewed crossing with the message "Cyclists Use Caution" to both convey the nature of the roadway hazard and warn the cyclist to exercise caution. Because the meaning of the symbolic warning sign may not be immediately clear to the public, use of the supplemental plaque is recommended. In accordance with section 2A-13 of the MUTCD, the supplemental plaque may be removed 3 years after the initial installation. The combination sign and supplemental plaque are shown in Figure 12.



<u>Colors</u>

Legend: Black
Border: Black
Background: Yellow

<u>Dimensions</u>

Minimum: 30" x 30"
Standard: 36" x 36"
Special: 48" x 48"
Plaque: 24" x 18"
<u>Note</u>: 1 inch = 2.54 cm

Figure 12. Combination sign.

It is suggested that the sign be erected on a separate post by itself, midway between the crossing and the railroad advance warning sign. This location would both allow the sign to command the cyclist's attention and provide the cyclist with adequate time to respond.

Cyclist Education

Motorcyclists

According to the Motorcycle Safety Foundation, the number of motorcycle accidents caused by a particular roadway hazard can be reduced if riders are made aware of both the existence of this hazard and the safety precautions necessary to decrease the chances that an accident will occur.(8) Ideally, this would be done through rider participation in programs such as the MSF's motorcycle rider course, which teaches riders the skills they need for safe motorcycling. However, since most motorcyclists do not participate in such programs, other methods of educating them must be used. Because the Virginia Motorcycle Operator's Manual (VMOM) is provided to motorcyclists preparing for a license examination, inclusion of a passage on skewed crossings in this manual would be an effective way to both inform riders of the hazards present at skewed crossings and advise them of the proper safety precautions to take as they approach these crossings.

The current VMOM (January 1984) includes the following paragraph on railroad tracks under the heading, "Handling Dangerous Surfaces:"

> You don't have to cross railroad tracks head-on (at a 90 degree angle). Usually, it is safer to take the tracks as they come, riding straight within your lane. A motorcycle can cross tracks at an angle as sharp as 45° without difficulty. Changing your course to take tracks head-on can be more dangerous than crossing at an angle--it may carry you into another lane of traffic.(18)

However, cyclists are advised to change directions when crossing "trolley tracks, ruts in the middle of the road, or pavement seams that run parallel to your course." Crossing at an angle of at least 45° is recommended because "the tracks or seam could catch your tires and throw you off balance."(18)

Because the results of this research show that the tires of motorcycles have also been known to get caught in flangeways at crossings which intersect the roadway at an angle of 30° or less, inclusion of an additional passage on skewed crossings may be warranted. This passage should both inform motorcyclists of the hazards present at sharply skewed crossings and advise them to decrease the chances of an accident by crossing at an angle between 45° and 90°.(8) This passage might be worded as follows:

> When railroad tracks intersect the road at a very sharp angle (30° or less), it is possible that the tires of your motorcycle will catch in the crossing, causing you to lose control and fall. Try to approach sharply skewed crossings at an angle of at least 45°, but be careful not to stray into another lane of traffic when changing directions.

Bicyclists

The Virginia Department of Education includes a bicycle safety program in the health education curriculum required for elementary and 8th grade students. (17) This program is designed to make school-age children aware of the hazards associated with riding a bicycle and teach them the skills they need for safe cycling. Because the findings of this study have shown that it is possible for bicyclists as well as motorcyclists to get their tires caught in a flangeway at sharply skewed crossings, informing students of the hazards present at these crossings and instructing them in the proper way to approach them (as in the case of motorcyclists, at an angle between 45° and 90°) could be an effective way to improve bicyclist safety at skewed crossings. Inclusion of a section on skewed crossing hazards in the bicycle safety program would be especially useful to children who later go on to ride mopeds or motorcycles.

DISCUSSION OF FINDINGS

The results of the sight distance portion of this research indicate that skew-imposed restrictions on a motorist's ability to see an oncoming train do not appear to be a problem at grade crossings in Virginia. Where design sight distance requirements for a grade crossing have not been met, restrictions have usually been imposed by vegetation, buildings, or embankments and not by the angle of skew.

The investigation of cyclist accidents at skewed crossings did not produce evidence of a major safety problem in Virginia. Only 8 crossings were identified as having been the site of bicycle, moped, or motorcycle accidents during the past 5 years, and at most of the crossings, accidents were a relatively infrequent occurrence. Additionally, because only five cyclist accidents were reported to the Virginia State Police, it appears that most accidents of this type do not usually result in serious personal injury or property damage.

However, all 8 of the crossings at which accidents are known to have occurred intersect the centerline of the highway at an angle of 30° or less. Accidents at these crossings have occurred when a cyclist got the tires of his moped, motorcycle, or bicycle caught in a flangeway and lost control. In some cases, ruts along the flangeways and a high volume of cyclist traffic have contributed to accidents occurring at a particular crossing. At other accident locations, however, the crossing surface has been in good condition and the volume of cyclist traffic has not been unusually high. Thus, the data accumulated in this research show that rail-highway grade crossings which intersect the centerline of the highway at an angle of 30° or less can be a hazard to cyclists.

As with any safety program, a decision on the type of countermeasures to be used at sharply skewed grade crossings should be made on the basis of the severity of the problem. Since cyclist accidents are known to have occurred at only 16% of the sampled crossings with a skew of 30° or less, it would be difficult to justify crossing repairs or feasibility studies on the use of rubber crossings with filler strips at all crossings with a skew of 30° or less. However, measures such as the inclusion of a section on skewed crossing hazards in the VMOM and in the Department of Education's bicycle safety program may be appropriate. In accordance with section 2C-1 of the MUTCD, which states that warning signs be used "to warn traffic of existing or potentially hazardous conditions on or adjacent to a highway or street," the use of cyclist warning signs at those crossings which intersect the roadway at an angle 30° or less appears warranted.

RECOMMENDATIONS

In light of the finding that motorcycle, moped, and bicycle accidents have been known to occur at 16% of the grade crossings studied which intersect the centerline of the highway at an angle of 30° or less, the following recommendations are made:

1. Cyclist warning signs should be installed at crossings which intersect the highway at an angle of 30° or less. The sign used should be designed to both make the cyclist aware of the skewed angle of crossing and to advise him to cross with caution. The combination sign shown in Figure 12, erected on a separate post midway between the crossing and the railroad advance warning sign (W10-1), is suggested for use. However, a final decision on the type of sign to use should be based on the results of field tests.

2. The <u>Virginia Motorcycle Operator's Manual</u> should include a section which will both inform motorcyclists of the hazards present at crossings with a skew of 30° or less and advise them to cross at an angle of at least 45°.

3. The Virginia Department of Education should include instruction on bicyclist safety at sharply skewed grade crossings in the bicycle safety program offered to elementary and 8th grade students.

4. At sharply skewed crossings where motorcycle, moped, or bicycle accidents are a frequent occurrence, an engineering feasibility study should be conducted to determine whether a rubber crossing surface with filler strips in the flangeways can be installed.

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