MINNESOTA DEPARTMENT OF TRANSPORTATION

RESEARCH

2008-07

Effects of Center-Line Rumble Strips on Non-Conventional Vehicles

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Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2008-07		

4. Title and Subtitle	5. Report Date
Effects of Center-Line Rumble Strips on Non-Conventional Vehicles	January 2008
	6.
7. Author(s) Kenneth W. Miller	8. Performing Organization Report No.
9. Performing Organization Name and Address St. Cloud State University 720 Fourth Avenue South St. Cloud, MN 56301-4498	10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (c) 89424
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul, Minnesota 55155	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
http://www.lrrb.org/PDF/200807.pdf

16. Abstract (Limit: 200 words)

Centerline rumble strips are being installed on rural Minnesota Highways in an effort to reduce crossover accidents. This study looks for possible detrimental effects on 2 and 3 wheeled cycles.

Motorcycle accidents reports since centerline rumble strips first appeared on rural highways in 1999 revealed only 29 accidents on roads with the rumble strips. None of these reports implicated the rumble strips as a factor in the accident. There were also no visible indications of rider correction or overcorrection in 40 hours of roadside observations. Controlled conditions on a closed circuit supported this observation through 32 riders in all types of cycles and experience levels from 0 to 41 years of street riding. Interviews confirmed that the riders had no difficulty or concern with the rumble strips.

The recommendation from this study is that cyclist should become familiar with the rumble strips in rider safety courses and driving examinations. There were no indications to impede the installation of rumble strips and no indication that signage is justified.

17. Document Analysis/Descriptors		18. Availability Statement
Centerline Rumble Strip Rumble Strip	Motorcycle Three-wheel vehicle	No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	29	

Effects of Center-Line Rumble Strips on Non-Conventional Vehicles

Final Report

Prepared by:

Kenneth W. Miller

College of Science and Engineering
St. Cloud State University

January 2008

Published by:

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

Acknowledgements

The author would like to thank Bill Ruhr and the staff of the Minnesota Highway Safety and Research Center. This research would not have been possible without the help and expertise of Bill Ruhr. The safety center was irreplaceable as a location where rumble strips can be added and the tests safely run.

Thanks also go to Njeh Smith, a student at St. Cloud State University for his help in the research for this document. His assistance and patience through some long afternoons of observations were valuable in completing this work.

Tom Dumont of Mn/DOT was also a valuable contributor to this project.

Last, but not least, the author would also like to thank the members of the Technical Advisory Committee. Their help and guidance helped greatly in completing this work.

- Gary Dirlam
- David Engstrom
- Dan Warzala
- Matt Gjersvik
- Cassandra Isackson
- Rob Ege
- Randy Reznicek

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Executive Summary

The state of Minnesota has been installing centerline rumble strips on rural highways since 1999. Studies in Minnesota and several other states have shown them to be an effective means of reducing crossover crashes. While the general benefits have been measured, research into the effects of centerline rumble strips on non-conventional vehicles has been limited. (This research project is a review of motorcycle rider behavior on roads with centerline rumble strips. The most significant finding is that centerline rumble strips have added no measurable risk to motorcycles or three wheel cycles.)

About one half of all motorcycle crashes nationally and in Minnesota are single vehicle incidents. Of particular concern are those incidents caused by overcorrection, 2.5% of crashes in Minnesota and 4.4% nationally. Rumble strips have not been shown to cause stability concerns for motorcycles, so problems will be a result of rider behavior. This is a particular concern with new drivers where NHTSA estimates lack of experience to be the second leading cause of these single vehicle motorcycle crashes, behind chemical impairment. Finally, these concerns are compounded by the statistic that about half of the motorcycle fatalities in Minnesota (30 of 61 for 2001) were in rural areas where most rumble strips are being added.

The first phase of this study was a review of motorcycle crashes in Minnesota. A summary of 9,845 motorcycle crashes since the first rumble strips were installed in 1999 were matched with rumble strip locations. Rumble strips inside the metro area were not considered because it was felt there are too many factors to isolate any by rumble strips. It was found that 29 of these incidents occurred in sections of road with centerline rumble strips. One of the 29 was a fatality.

Reports on 26 of those 29 crashes were reviewed to determine if rumble strips were a primary or contributing factor. None of the reports mentioned rumble strips or showed them in the diagrams. All but two of them had clear causes unrelated to rumble strips. The riders in five of those incidents crossed the centerline during or immediately prior to the accident. There were no indications that rumble strips contributed to the crash. In three of them, there was enough ambiguity in the cause that road surface is a possible factor.

The second phase of the study was 44 hours of roadside observation. Both direct observation and video recordings were used on rural highways to monitor for centerline crossing and rider behavior. These observations revealed a limited number of rumble strip crossings and no unusual behavior or directional changes during the crossing. The rumble strips did not appear to deter any passing opportunities.

The final phase of the study was more controlled observation of rider behavior on a closed circuit. Riders went through a one-mile course that included two lane changes over centerline rumble strips. There were 32 participants in this study on a full range of cycles including touring, cruising, and sport bikes. Included with those vehicles were two three-wheeled cycles and a scooter. Experience ranged from two new riders with learner’s permits through 41 years.

Close observation of the riders showed no adjustments to steering, brakes, or throttle while crossing the rumble strips. Post ride interviews confirmed the observations. None of the riders expressed any difficulty or concern when crossing the rumble strips. About half (14) did not

notice the rumble strips before crossing them but still expressed no concern while crossing. All of them said they did notice the presence of rumble strips when encountering them on public roads. None of the riders considered the rumble strips to be a hazard, although eight considered them to be a nuisance when passing.

A review of the information found in this study reveals no indications that centerline rumble strips pose a hazard to motorcycles or three-wheel motorcycles. The awareness of the riders can be seen as an indication that there is no justification for warning signs. The only concern is how new riders will behave when encountering rumble strips for the first time. Exposing riders to the rumble strips in controlled situations should resolve this concern. Adding rumble strips to motorcycle safety courses and driving examinations will reduce this concern.

Chapter 1: Introduction

Project Proposal

The objective of this project is to find any adverse effects of centerline rumble strips on drivers of non-conventional vehicles and propose remedial action if needed. Vehicles specifically targeted are motorcycles and three-wheeled motorcycles. This study will look for dangerous or inappropriate responses by the driver on encountering the rumble strips.

Background

Extensive research has been done in the area of in-lane rumble strips on driver behavior. In studies by Kathleen Harder [1] [2], there were limited effects seen on attentive drivers, but significant improvements for sleep deprived drivers. She has an ongoing project (CTS 2003032) to establish guidelines for rumble strip use. Guidelines are already established in other locations in the US and Canada, and are similar in most cases [3] [4].

Studies of potential adverse effects have been more limited. In the report by Griffith [5], the possibility of crashes by driver “overreaction” was presented in a study of shoulder rumble strips. The emphasis of this study was overreaction by impaired (drowsy or alcohol influence) drivers overcorrecting what could have been an off-road crash into a collision with oncoming traffic or moving the incident downstream to a possibly more dangerous location. The research used crash data from California and Illinois to look for changes associated with the rumble strips. No significant relationship between the rumble strips and crashes due to overcorrection was found. This is a primary concern with motorcycles where overcorrecting with steering or braking is likely to end in a fall. According to The National Highway Traffic Safety Administration (NHTSA), 49% of all motorcycle crashes are single vehicle crashes [6]. According to the Minnesota Office of Transportation Safety figures for 2004, 2.5% of motorcycle crashes list overcorrection as the cause. It is likely a contributing factor in a much larger portion of the crashes. Overcorrection is the primary concern with centerline rumble strips and is associated with inexperience, inattentiveness, and impairment.

Much of the increase in motorcycle crashes can be attributed to the large number of new cyclists on the road. Nationally (NHTSA), the number of registered motorcycles has increased from 3,826,373 in 1997 when motorcycle fatalities were at a low point. By 2003, the number of registered motorcycles has increased to 5,370,035. At the same time the fatalities has increased from 2,116 to 3,714. All of the difference cannot be attributed to the number of vehicles. The fatality rate over the same period has increased from 55.30 to 69.16 fatalities per 100,000 vehicles, or from 20.99 to 38.93 fatalities per 100 million miles traveled. Injury rates have followed a similar trend dropping from 1,374 to 1,250 per 100,000 vehicles, but increasing from 522 to 703 injuries per 100 million miles traveled.

Minnesota followed this trend. There were 1,431 motorcycle crashes in 2005, which was the highest in ten years. More significant is the severity. Nearly 20 of every 100 crashes in 2005 resulted in significant injury with 4.3 of them resulting in a fatality [7]. Close to national trends, 58% of these were single vehicle incidents. Factors most frequently cited by officers in single vehicle incidents are unsafe speed (21%), driver inexperience (10%), inattention or distraction

(10%), overcorrecting (4.4%), and improper or unsafe lane use (3.0%). Since the centerline rumble strips primarily target rural highways, another key concern from the same report is that 30 of the 61 fatalities in 2001 were in or around cities or townships with populations under 1,000.

Information is lacking on how drivers of non-conventional vehicles react to centerline rumble strips. Motorcycles and three-wheel motorcycles pose the difficulty of having more hand-based controls which are more sensitive to vibration from the road. Motorcycles are a particular concern because such a significant proportion was single vehicle crashes. NHTSA attributes lack of experience to be the second leading cause of single vehicle motorcycle crashes (first is chemical impairment)[6]. This is reinforced by past studies have found up to 85% of crashes occur within the motorcyclist’s first year of driving regardless of past experience in other vehicles.

A related effect of the rumble strips in the centerline is that vehicles travel farther the centerline, keeping them farther from oncoming traffic. Studies in Minnesota by Harder [8] and Pennsylvania by Porter [9] both confirm this trend. Lane width is a factor, where this change in location is 3 inches for an 11 foot lane and 5.5 inches for a 12 foot lane. Neither study broke this trend down by vehicle type.

Risk Factors

No evidence has been found to indicate the rumble strips pose a stability problem for motorcycles. As a prelude to this study, the author drove over the rumble strips installed at the Minnesota Highway Safety and Research Center (MHSRC) using a 600cc sport bike and 800cc cruiser. The drives included crossings similar to a passing maneuver at 55 MPH, hard acceleration, and hard braking on the strips. There was no effect on vehicle stability and the only hard braking on the sport bike gave noticeable discomfort in the rider’s arms.

Any adverse responses to the rumble strips are most likely related to rider response since stability is not a known issue. Factors in the response include; rider experience, inattention or drowsiness, vehicle type, and rider impairment. Rider experience and awareness of rumble strips in particular should greatly mitigate any sudden response by the rider. Vehicle type may also have a large effect. In one extreme, touring and three-wheeled motorcycles are heavier, have larger wheels, have relatively soft suspension, and most of the rider’s weight is on a well padded seat. This greatly reduces the amount of vibration transmitted to the rider. On the other extreme is sport bikes, which are manufactured to be light, have smaller tires, stiffer suspension, and place more of the rider’s weight on the handlebars. Sport bikes also have a larger portion of the younger and less experiences riders.

Chapter 2: Research Procedure

Two approaches were taken in this research; a study of the effects from existing rumble strip installations and a controlled study of rider behavior. Existing rumble strips will be evaluated from a review of motorcycle crash data and an observational study. The rider behavior study was done on a closed circuit with a sample covering a variety of motorcycle types and ruder experience levels.

The approach used for this study is to look for effects through three methods; look for evidence of causal relationship between centerline rumble strips and existing crash reports, direct observation on public roads, and observation of riders in a controlled circuit.

Crash data was supplied by Minnesota Department of Transportation (Mn/DOT). The database included dates and locations of crashes going back to 1999. Those occurring on sections of roads with rumble strips were evaluated to see if the rumble strips were primary or contributing factors.

The observational study used several different roads, particularly between St. Cloud and Brainerd. Vehicles were watch for the number of times they crossed the rumble strips and for any unusual behavior. The nature of this study kept observation distances between 1/8 and 1 mile, so only large corrections were visible.

The last study was a more controlled observational study. Riders drove a circuit at MHSRC that included two rumble strip sections. This allowed close observation of the riders' controls during the maneuvers. It also allowed time for rider discussion on the study and rumble strips in general. Riders were chosen to cover a range of experience from learner's permit to 41 years. Sport bikes, touring bikes, cruisers, and three-wheel motorcycles were all included.

Chapter 3: Review of Crash Data

This phase of the study was a review of motorcycle crash data to find cases where the rumble strips were a cause or contributing factor in any motorcycle crashes. This study did not include the metro area. It was felt that the amount of traffic and large number of other factors would make it impossible to determine where rumble strips may have been a contributing factor.

Since the first rumble strip outside the metro area was installed in November 1999, reports from 1999 to 2006 were studied. The summary listed data for 9,845 crashes, including the location and date of the incident. Table 3.1 lists the locations of centerline rumble strips in Minnesota. This was compared to the crash summary and there were 29 crashes found that occurred on roads with rumble strips.

We did not anticipate that rumble strips would be specifically cited in most cases, so a rating system was devised to consider the likelihood that they were a factor in the crash. The rating system is summarized in Table 3.2. Accident reports were requested for these 29 crashes plus an additional 33 chosen at random to see if the method would falsely indicate a causal relationship. Mn/DOT was able to supply 58 of the 62 accident reports, including 26 of the 29 at locations with rumble strips. The accident reports were rated on the scale from Table 3.2 after being randomized and without knowledge of which ones were in locations with centerline rumble strips.

Table 3.1 - Current non-Metro Centerline Rumble Strip Locations

Location	Date Installed	Miles			Notes
T.H.		**Start**	**End**	**Total**	
District 1					
None					
District 2					
None					
District 3					
55 - Buffalo to Rockford	19 June 2000	156.845	164.430	7.6	
23 – Paynsville to Richmond	11 Aug 2000	168.354	180.617	12.3	See note
169 – Wigwam Bay, Mille Lacs Lake	28 Sep 2000	224.472	225.594	1.1	SP 4814-46
169 – St. Albans Bay, Mille Lacs Lake	28 Sep 2000	228.059	229.919	1.9	SP 1804-48
15 – Kimball to I-94	1 Sep 2003	132.290	141.370	9.1	
23 – St. Cloud to Milaca	1 Sep 2003	209.084	216.833	7.7	Under SP 8823-38
		218.435	219.844	1.4	
		220.008	222.195	2.2	
		222.625	227.836	5.2	
		228.507	230.288	1.8	
25 – T.H. 95 to Brainerd		93.435	97.247	3.8	Under SP 8823-38
		98.774	103.835	5.1	

Location	Date Installed	Miles			Notes
T.H.		**Start**	**End**	**Total**	
		104.293	116.689	12.4	
		117.196	120.862	3.7	
		122.041	125.787	3.7	
		129.029	154.413	25.4	
55 – Annandale to T.H. 25	1 Sep 2003	142.222	143.986	1.8	Under SP 8823-38
		144.507	146.695	2.2	
		147.215	147.319	0.1	
		148.769	155.025	6.3	
65 – T.H. 107 to T.H. 23	1 Sep 2003	53.647	64.929	11.3	Under SP 8823-38
95 – 2 miles East of T.H. 25 to Mille Lac / Isanti	1 Sep 2003	9.164	21.902	12.7	Under SP 8823-38
		23.900	26.854	3.0	
18 – Brainerd to Garrison	1 Sep 2003	3.163	19.570	16.4	Under SP 8823-38
169 – T.H. 27 to Mille Lac / Crow Wing line	1 Sep 2003	214.105	221.303	7.2	Under SP 8823-38
		223.352	224.472	1.1	
		225.594	227.519	1.9	
210 – T.H. 169 to McGregor	1 Sep 2003	160.668	174.373	13.7	Under SP 8823-38
371 – Nisswa to 0.5 mi South Pine River	1 Sep 2003	41.338	49.603	8.3	Under SP 8823-38
		51.013	55.036	4.0	
95 – W Isanti Co. Line to Cambridge	2004	29.000	40.000	11.0	3005 – 11
District 4					
None					
District 6					
63 – Racine to 2 miles S of Stewartville	29 Nov 1999	23.420	27.490	4.1	
District 7					
14 – E Jct T.H. 15 (New Ulm) to T.H. 99 (Nicollet)	2004?	104.300	117.800	13.5	
District 8					
23 – N Jct T.H. 71 to Paynesville	11 Aug 2000	147.087	168.354	21.3	
71 – N Jct 23 to Co Rd 27	11 Aug 2000	129.204	130.164	1.0	

Note - Used to go Paynesville to I-94. Much of this portion of TH 23 is being reconstructed to 4-lane divided. Paynesville to Richmond was resurfaced. Shoulder rumble strip put in, centerline rumble strip left out July 2005.

Table 3.2 - Incident Rating Scale

Rating	Significance of centerline rumble strips
1	Definitely not a significant factor. Vehicle did not cross the rumble strip or another cause precluded their significance.
2	The primary cause was something other than the rumble strip, but it may have been a contributing factor.
3	The primary cause was something other than the rumble strip, but it was crossed and may have been a contributing factor.
4	Some ambiguity in the cause of the crash and the vehicle crossed the rumble strip during or immediately prior to the incident.
5	Rumble strips were specifically mentioned or directly implied as a factor in the crash.

Most of the reports were rated at one. None of the accident reports specifically mentioned rumble strips or showed them in the sketches. Most crashes followed the common patterns of vehicles turning in front of the motorcycle, excessive speed causing the vehicle to fall in a turn, and falling on road hazards such as gravel. The only Driving Under the Influence (DUI) incident in the sample was on a section without rumble strips. Only ten of the reports had a rating greater than one with five of them occurring on roads with rumble strips.

The narratives from those five accident reports are in appendix A. Only one rated a 4, two rated at 3, and two rated at 2. One of those rated 2 was a fatal. In the first narrative, the only one rated 4, the cited cause was leaning incorrectly into a turn. As a result the driver crossed the opposite lane and fell in the opposite shoulder. This was rated highly because the precise cause of the rider losing control is unknown and the centerline was crossed. It appears from the narrative that the loss of control was prior to crossing the centerline rumble strip, but is not explicitly stated.

There were two incidents that rated a 2. In the first one, narrative number 2, the cause was unknown. The vehicle was on the right side of the road after the crash, but what happened before is unknown. In narrative number 3, the motorcycle attempted to pass a tractor, which made turn into a field with no signal. The motorcycle did cross the rumble strip during or immediately prior to the incident.

That last two described rated a 2. In narrative 4, one motorcycle rear-ended the other after passing a car. There was a rumble strip crossing immediately prior to the incident. The last narrative was a fatal crash where the rider lost control and ran under the wheels of an oncoming truck. The investigation of this incident found that the rider lost control of the motorcycle before the incident and crossed the centerline prior to the crash and had clipped another vehicle before encountering the truck.

After reviewing the accident reports, it can be safely concluded that the rumble strips were not a primary factor in any of the crashes. In five cases, it is a possible but unlikely contributing factor.

Chapter 4: Observational Study

This phase of the study was a study of vehicle behavior on public roads. An observer was watching traffic to see the frequency of vehicles crossing the centerline and look for behavior when crossing the rumble strip. Three methods were used in this phase; roadside observation, observation from a moving vehicle, and monitoring from a roadside camera.

Site selection was along sections of road where passing could be expected. They were done over the summer on Fridays and weekends, when recreational motorcycle traffic was expected to be the highest. Most of the observations were along highway 23 between St. Cloud and Foley, highway 25 between Foley and Brainerd, and 169 south of Brainerd.

There were a total of 26 hours of roadside observations. Very few centerline crossings were observed during these studies. It was found that the heaviest motorcycle traffic on weekends was around Brainerd. Most of the weekend cyclists were in groups. The logs of these observations are in appendix C. Cyclists do appear aware of the rumble strips. When traveling in pairs or groups, there was usually at least one motorcycle that would travel very close to the centerline rumble strip but not cross it. Only one motorcyclist was seen making what appeared to be unintended centerline crossing, and the vehicle returned without incident. There were no visible signs of any corrections or overcorrections when the cycles did cross the rumble strips.

Moving vehicle observations were done primarily on highway 25 south of Brainerd. These happened most frequently during trips to the stationary observation sites and were not normally planned. When driving down the road at the speed limit or slightly under, being passed is very common on this route. Most of the road is flat and straight to allow passing opportunities. In these events, it was easy to make closer observations of rider behavior during both centerline crossings. On the return crossing, the riders' right hand and foot are easy to observe to look for any throttle, brake, or steering input. Due to the nature of the events, a log book was not possible. Over the course of the study, there were twelve events where the observer was passed. All but two of them involved groups of three or more, the others were in pairs. Three of them were groups of at least ten motorcycles. The results were consistent with the stationary observations. There were no detectable corrections or movements when the riders crossed the rumble strips. It was common to see some cyclists in the larger groups riding within 5 inches of the rumble strip.

The final part of this study used a stationary camera on Highway 25. The camera was placed at the north end of a one mile straight section of road 8 miles north of Little Falls. The camera was facing south and included the entire straight section. Recording was done on a Saturday and Sunday, 15 and 16 September, to coincide with a motorcycle race at Brainerd International Raceway. Recording was done from 10:00 to 19:00 on both days.

This weekend was very late in the riding season and the motorcycle traffic was very light. There was not enough traffic on this weekend to see very much passing, so the centerline was rarely crossed. A review of the recordings showed only 44 motorcycles on Saturday and 51 (approximately) on Sunday. Most of the motorcycles were in groups, some of them with over ten riders. The groups tended to stay in a tight formation, which made counting them difficult.

There were only 4 passing events on Saturday and 2 on Sunday. Those passing events were all groups of at least three riders passing a car or truck together. There were no unusual direction changes or corrections seen in any of them. There were no instances of motorcycles crossing the rumble strips outside of those passes.

Chapter 5: Track Study

The track study was done at MHSRC in St. Cloud shown in Figure 5.1. Riders were asked to ride one loop around the outer circuit of the highway safety center. The rumble strip pattern at MHSRC was ground using the pattern shown in Figure 5.3 This is the pattern currently being used for new centerline rumble strip locations.

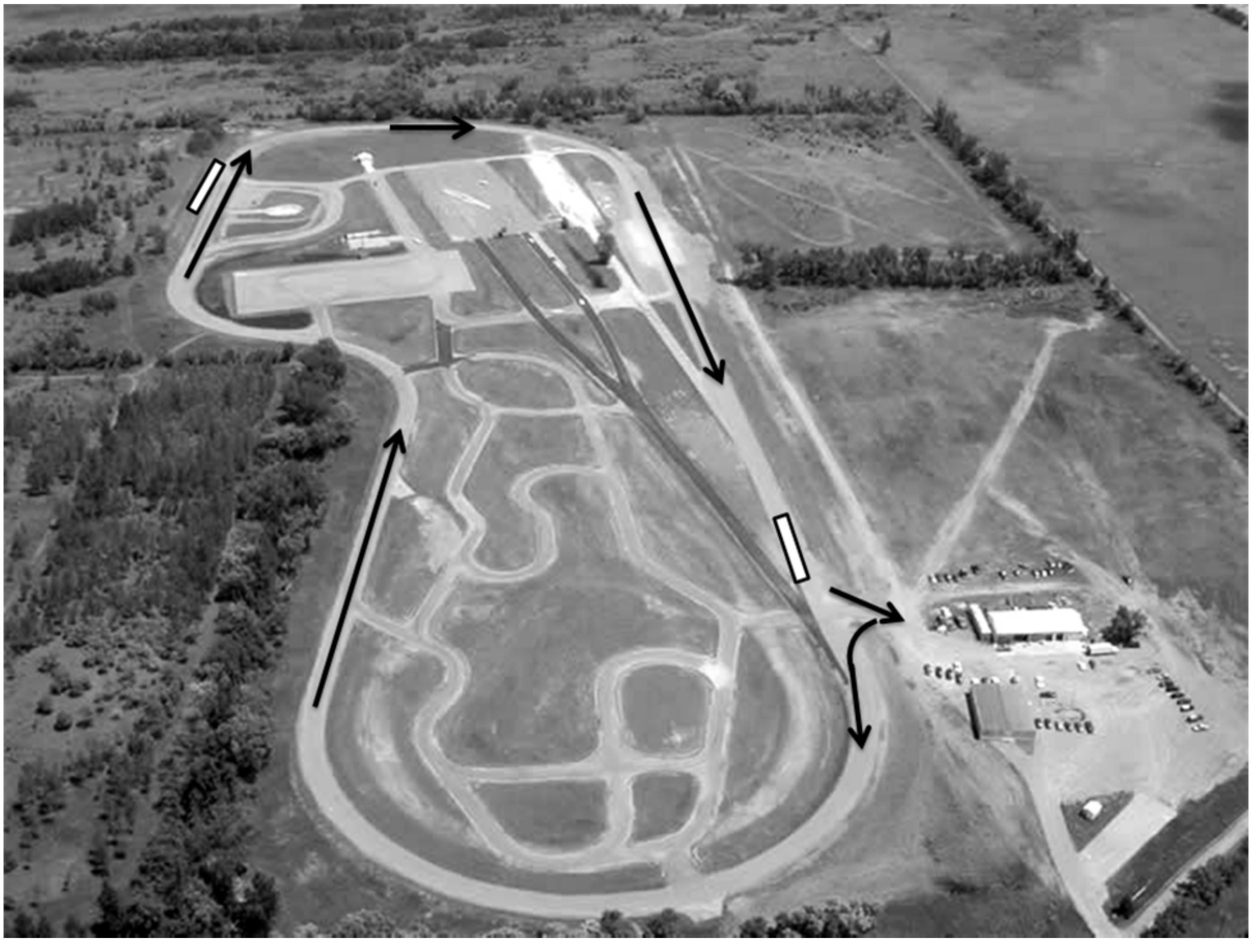

Figure 5.1 - Minnesota Highway Safety and Research Center. Riders started at the lower right, followed the course counter-clockwise, and exited at the starting point. Rumble strip locations are marked with rectangles in the upper left and immediately prior to the course exit.

Riders arriving at the safety center were informed that this is part of a motorcycle safety study. The specific interest in centerline rumble strips was not mentioned before the ride and testing was arranged so there was no interaction between incoming riders and those who had completed the circuit. Post ride interviews, however, usually included between 2 and 4 riders together.

Pre-ride instructions were minimal. Cones were set through the circuit to keep riders on the right circuit and force some lane changes. Two lane changes, marked in Figure 5.1 forced riders over the rumble strips. Riders were informed that there was a 50 MPH speed limit through the circuit, but no minimum or suggested riding speed. Four riders came with passengers on their motorcycle, but rode the course solo.

Testing was run over 5 days in June and July 2007. The weather was about the same on each day, clear with highs in the upper 80s. All testing was run between 12:00 and 18:00 so the sun was high enough that visibility and glare were not factors in the tests.

An observer was stationed next to the second rumble strip crossing on the riders' right to allow close observation of any brake, throttle, or steering input. The first few riders were also videotaped at this section, but it was abandoned after the first 5 riders. It was not possible to follow the rider and capture images with the necessary detail.

A short interview was conducted after the drive. After noting the vehicle model and tire sizes, riders were asked;

- How many years have you been riding street motorcycles?
- If you have taken a motorcycle safety course, how long ago did you attend?
- Did you encounter any challenges in the circuit you just completed?

The rumble strips were not mentioned before the ride and during the interview before this point. Once the general discussion was completed, the riders were asked specifically about rumble strips and centerline rumble strips. At a minimum, riders were asked;

- Did you notice the rumble strips before crossing them?
- Did the rumble strips cause any difficulty when you crossed them?
- Have you had any problems with rumble strips on public roads?
- Where in the lane do you normally ride?

The interview was followed with a less formal discussion of motorcycle safety and rumble strips.

A total of 32 cycles participated in the study, including two 3-wheeled motorcycles (trikes) and one 250cc scooter. A summary of the participating riders is in appendix C. Experience ranged from two riders with learner's permits to one with 41 years. Few of the riders with more than 10 years of experience had take a motorcycle safety course, and only one rider in the group had taken one since initially getting a license. The age distribution shown in Figure 5.2 showed the same two peak trend as national rider distributions.

There no visible corrections for any of the riders as they passed over the rumble strips. Two riders were still braking as they passed over the rumble strip. These riders were going too fast approaching the lane change and braked through the full maneuver. Both riders were using only the rear brake. No throttle or brake input was seen by any of the other riders. There was no visible change in the turning when the bike passed over the rumble strip.

Only two of the riders mentioned the rumble strips as challenges in the course. The track has a lot of patches throughout which had softened in the summer heat. This was mentioned as a problem by 12 of the riders covering the entire range of experience. Two of them mentioned the lane changes. Both were newer riders on sport bikes that approached the cones much too fast. Riders stayed between 40 and 45 MPH for most of the circuit and slowed to 20 MPH or less for the lane changes. Four of the newer riders appeared to be exceeding the 50 MPH speed limit, but reported speeds between 40 and 45 after the ride.

Slightly more than half of the riders (18) saw the rumble strips before crossing them and this correlated pretty closely with more experience. None of the riders reported any problems with the rumble strips or with rumble strips on public roads. There was a slight intimidation aspect mentioned by 3 riders in the circuit, stating they looked “pretty deep” immediately before crossing over. The only mention of challenges on public roads was by one rider. It was a rider on a touring bike with 10 years of experience. Highway 25 northbound from Foley has large radius left turn covering 90 degrees. He drifted into the rumble strips and was startled by the noise. There was not loss of control or other problem beyond the surprise of the event.

There was no significant trend on lane position. Riders were closely split between left of center, center, and right of center. Most stated that it varies depending on the road and if they are in a pair or group.

None of the riders considered rumble strips to be a hazard. About one third of the riders (9) considered them to be a nuisance. All but 5 of the riders said they normally spot the rumble strips on public roads when they appear. The two riders with learner’s permits do not recall encountering any.

Riders were also asked about the prospect of mid-lane rumble strips. These have been studied as an alternative to shoulder and centerline rumble strips. There was no sample available to test, so this was strictly a hypothetical case for the riders. The reaction was extremely negative. Most of the riders (27) said they would be a nuisance and 6 thought it would be dangerous. The most common reason cited was the frequency of crossing the centerline in lanes in normal travel. This was particularly true for riders that like riding in groups. It would also conflict with the normal riding location for 13 of them in the center of the lane. It was also cited as a potential hazard by collecting water and sand in the middle of the lane by several of the riders calling them dangerous.

The newer 3-wheel motorcycle rider felt it would be a major nuisance due to the difficulty in maintaining the tight vehicle position to straddle the rumble strip. The more experienced rider considered it as more of an inconvenience to maintain the riding position.

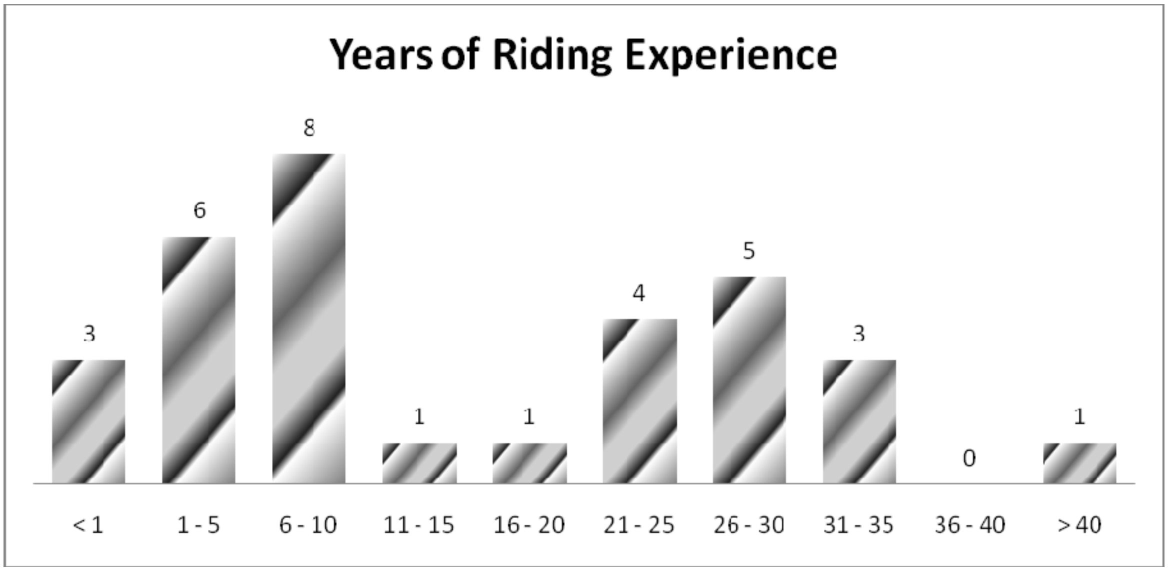

Figure 5.2 - MHSRC Test Rider Age Distribution

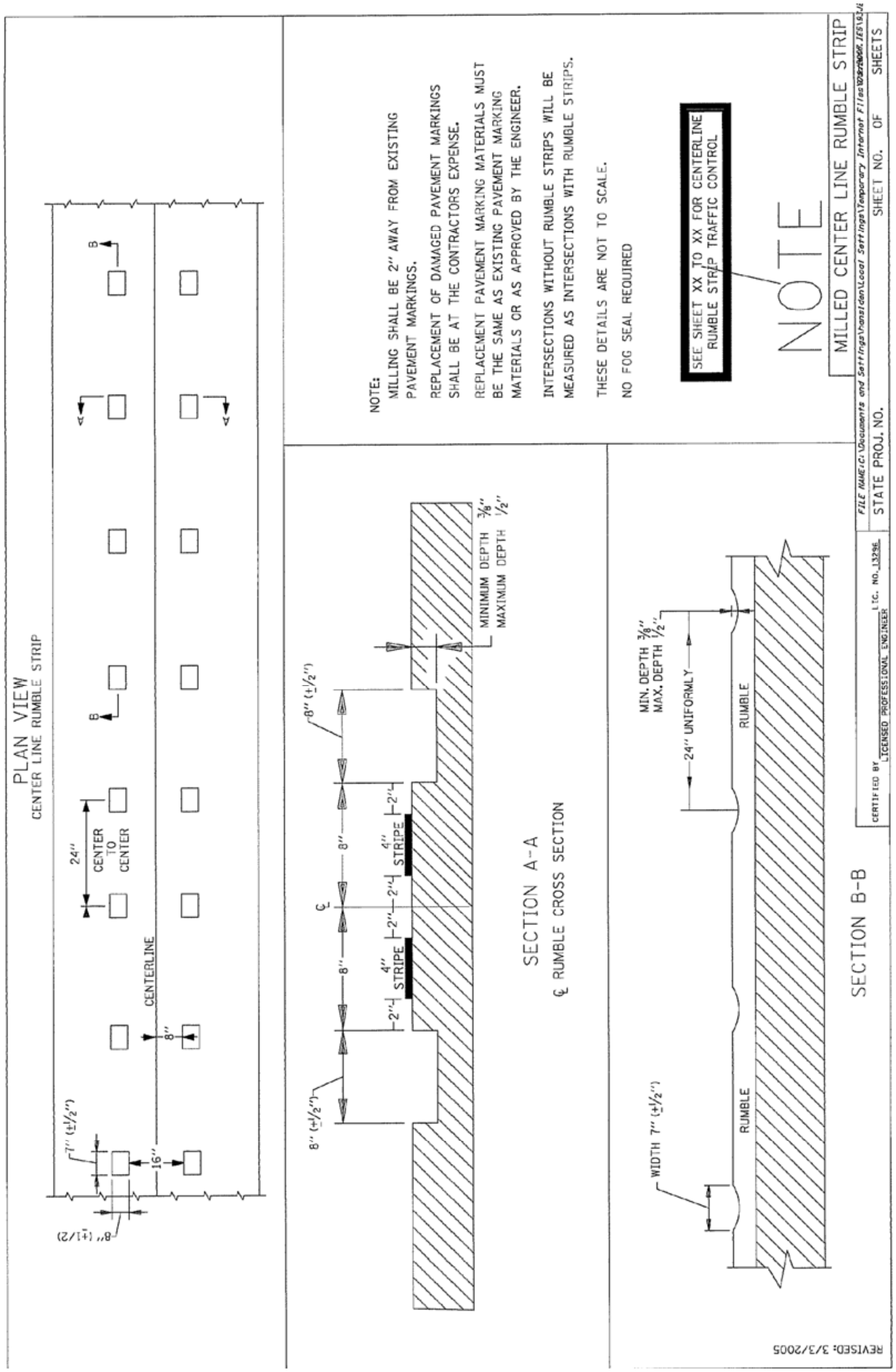

Figure 5.3 - Rumble Strip Pattern at MHSRC

Chapter 6: Conclusions

Findings

The study found no evidence to implicate centerline rumble strips as a hazard to 2 or 3 wheel cycles. A review of 9,845 motorcycle crashes since 1999 found only 29 that occurred on roads with centerline rumble strips. None of the accident reports explicit mentioned the rumble strips as a primary or contributing factor. Rumble strips were crossed during or immediately prior to 5 of those incidents, so they are considered unlikely but possible contributing factors.

Visual monitoring of existing roads yielded no unusual behavior when crossing the rumble strips. Motorcycles did not appear deterred from passing by the rumble strips and made no visible corrections in the process. This was further confirmed through the on-track testing. Closer observation of riders crossing the strips showed no change in throttle, braking, or steering when the strips were crossed.

Discussions with riders revealed no safety concerns, crashes, or near crashes. Most riders were neutral towards them with a quarter considering them to be a nuisance. Even the riders that did not notice the strip before crossing did not consider it a hazard.

Recommendations

This study gave no evidence that the rumble strips pose a safety hazard to motorcycles or 2 wheel motorcycles. Continuing to install them on rural highways should not be impeded by concerns over motorcycles. If there is any additional risk caused by them, it is small enough to be offset by the established benefits.

The cyclists interviewed all claimed to be aware of roads with rumble strips, so there is no indication that signage is justified. Most of the concern for cyclists is over intimidate over the first encounters. It is recommended that new cyclists become aware of the rumble strips early in their experience. Including rumble strips in motorcycle safety courses and possibly riding examinations can insure riders are not alarmed in their first encounters.

Future Studies

Some follow-up work in this area is appropriate to improve knowledge in this area. The accident study of the report is the one area that can definitely indicate when rumble strips are causing problems. There were only 26 accident reports used in this study, which is a relatively small sample. Both the number of motorcyclists and road miles with rumble strips have been increasing and so a follow-up study of accidents in two to three years is warranted.

In addition, a study similar to the one done by Porter et. al [9] specifically targeting motorcycles will provide some useful insight. Since such a large proportion of cycles travel in groups, their lane use is much different from the following practice for cars and trucks.

References

1. Kathleen Harder, John Bloomfield and Benjamin Chihak, *The Effects of In-Lane Rumble Strips on the Stopping Behavior of Attentive Drivers*, Mn/DOT 2002-11, 2001, St. Paul, MN.

2. Kathleen Harder and John Bloomfield, *The Effects of In-Lane Rumble Strips on the Stopping Behavior of Sleep-Deprived Drivers*, Mn/DOT 2005-11, 2005, St. Paul, MN.

3. William Outcalt, *Centerline Rumble Strips*, Colorado Department of Transportation, Report CDOT-DTD-R-2001-8, 2001, Denver, CO.

4. Margaret Parkhill , *Synthesis of Practices for the Implementation of Centreline Rumble Strips*, Fredericton, New Brunswick: 15th Annual Canadian Multidisciplinary Road Safety Conference, 2005

5. Michael Griffith, *Safety Evaluation of Continuous Shoulder Rumble Strips Installed on Freeways*, Transportation Research Board, Report TRB 990162, 1999, Washington, D.C.

6. National Highway Traffic Safety Administration, *Traffic Safety Facts, 2004 Data*, Washington DC, NHTSA Center for Statistics and Analysis, 2004

7. Minnesota Department of Public Safety, *Minnesota Motor Vehicle Crash Facts 2005,* St. Paul, MN, 2005

8. Kathleen Harder, John Carmody, and John Bloomfield, *The Effect of Centerline Treatments on Driving Performance*, Mn/DOT 2002-35, 2002, St. Paul, MN.

9. R. J. Porter, Eric T. Donnell, and Kevin M. Mahoney, "Evaluation of Effects of Centerline Rumble Strips on Lateral Vehicle Placement and Speed", *Journal of the Transportation Research Board*, No. 1862, 2004

Appendix A

Accident Report Narratives

Original narratives are in italics.

1. Single Vehicle crash
V1 S/B on US TH 169. D1 leaned incorrectly during cornering, lost control, and crossed over the N/B lane and tipped over on the right shoulder of the N/B lane. Witnesses stated that V1 narrowly avoided a collision with a N/B vehicle, nearly came to a complete stop and then tipped over onto its right side. Marks on the pavement and shoulder were consistent with this account. D1 was transported from the scene by the Onamia Ambulance service to the Onamia Hospital where she was treated for bruises to the ribs and minor road rash. V1 had minor damage to the right side of the fuel tank and the right foot peg. V1 was trailered from the scene.

2. Single Vehicle crash
D1 was travelling E/B on US TH 14 near Nicollet County Road 37 when he lost control of motorcycle and skidded upon asphalt.

3. Single vehicle crash following a trailer. Names are replaced with blanks
Veh#1 was S/B on Hwy 25. A tractor pulling a chop box was S/B on Hwy 25 directly in front of Veh#1. Veh#1 was attempting to pass the tractor. The tractor attempted a left hand turn into the field approach. Veh#1 laid the motorcycle down to avoid a collision with the tractor. Tractor was equipped with working turn signals. Drive of the tractor stated he didn't signal the turn. The chop box trailer was not equipped with signals or lights. The trailer did have a slow moving sign attached. The signals from the tractor are not able to be seen with the chop box directly behind. Driver of the tractor was ______. Owner of the tractor was _______.

4. Two vehicle crash, both motorcycles.
V2 was eastbound on MNTH 95, and V1 was behind V2. V2 and V1 passed a passenger car. Immediately after the pass V2 applied the brakes because V2 was getting close to another motorcycle. Once V2 applied the brakes V1 rear ended V2. V1 then rolled over and D1 was thrown from the motorcycle.

5. Two vehicle crash. V1 was a 3 axle truck and V2 was a motorcycle.
Vehicle 1 was eastbound on Hwy. 95, when westbound Vehicle 2 crossed the center line and struck V1 on the left side. V2 then impacted the left outside tire on the 2nd axel of V1 and V2 and the driver were flung into the air. Witnesses approximately 300 yards behind V2 stated it appeared the motorcycle pulled out to go around something, but there was no other vehicles or objects around in front of V2. D1 stated the operator of V2 was reaching down and behind with his right arm and did not appear to be looking at the roadway. D2 was fatally injured.

Appendix B

Observation Logs

Table B.1 - Observation Log

Times	Route	Mile	Non-motorcycle crossing	Motorcycle Count / crossing	Notes
19 May 2007 (Saturday) – Observer 1					
10:00	25	122	5	8 / 0	
11:30	25	140	3	20 / 7	Crossed in two groups
14:00	18	Note 1	1	18 / 1	
16:00					
25 May 2007 (Friday) – Observer 2					
14:15	23	216	2	1 / 0	
15:10	25	101	1	0 / 0	
15:35	25	105	4	2 / 0	
16:00	25	102	2	7 / 3	
17:00					
8 June 2007 (Friday) – Observer 2					
15:30	25	104	1	2 / 1	Slightly crossed center then returned
16:10	25	114	0	3 / 0	
17:10	23	217	2	9 / 1	
18:00					
9 June 2007 (Saturday) – Observer 2					
12:30	23	215	2	7 / 1	
13:00	23	218	0	1 / 0	
14:20	25	155	0	21 / 1	Most riders in groups of 2 to 5
14:50	18	Note 1	0	15 / 0	
16:15	25	104	0	10 / 0	

Times	Route	Mile	Non-motorcycle crossing	Motorcycle Count / crossing	Notes
17:00	23	Note 2	0	4 / 1	
18:30					
10 June 2007 (Sunday) – Observer 1					
12:00	25	140	1	5 / 1	
13:15	18	Note 4	2	24 / 2	Two passing next to each other
15:30	169	215	0	15 / 1	
16:30	169	219	3	20 / 10	Counts approximate, bikes were in two large groups
18:00					
6 July 2007 (Friday) – Observer 2					
17:15	169	Note 3	0	20 / 0	
18:01	25	115	0	16 / 1	
18:30					
7 July 2007 (Saturday) – Observer 2					
12:00	18	Note 4	0	10 / 0	
12:40	169	227	0	15 / 0	Positioned in a curve looking for bikes drifting wide
13:05	169	224	0	35 / 0	Positioned in a curve
14:00					

Notes:

1 – mile marker was not found. Location about 18 miles east of Brainerd

2 – mile marker not noted. Location about 6 miles East of St. Cloud

3 – mile marker not noted. Location about 3 miles south of highway 18

4 – mile marker not noted. Location 8 miles east of Brainerd

Appendix C

Track Survey

Table C.1 - Riders in MHSRC Tests

Motorcycle		Tires[1]				
Type	**Engine (cc)**	**Front**	**Rear**	**Years Riding[2]**	**Safety Course[3]**	**Saw Strips**
Cruiser	1500	150 / 80 R17	170 / 70 R15	22	22	Yes
Cruiser	1340	130 / 90 R16	130 / 90 R16	29		Yes
Cruiser	1340	130 / 90 R16	130 / 90 R16	30		Yes
Trike	1500	130 / 70 R18	P235 / 60 R15	41 / 4[3]		No
Tour	1200	120 / 90 R18	130 / 90 R16	< 1		Yes
Tour	1400	130 / 70 R18	160 / 80 R16	10	3	No
Cruiser	1520	150 / 80 R17	180 / 70 R16	33		Yes
Scooter	250	110 / 90 R13	130 / 70 R12	0[4]		Yes
Sport	600	120 / 70 R17	180 / 55 R17	0[4]	0	Yes
Sport	600	120 / 70 R17	180 / 55 R17	4		Yes
Sport	750	120 / 70 R16	180 / 55 R17	4		No
Sport	999	120 / 70 R17	180 / 55 R17	8	8	No
Sport	1000	120 / 70 R17	190 / 50 R17	10	10	Yes
Cruiser	1440	130 / 90 R16	140 / 80 R16	5	5	No
Cruiser	1340	130 / 90 R16	130 / 90 R16	21		Yes
Cruiser	800	130 / 90 R16	140 / 90 R16	10	9	Yes
Cruiser	1520	150 / 80 R17	180 / 70 R16	25		Yes
Trike	1600	130 / 70 R18	P235 / 60 R15	35 / 0[3]		No
Sport	600	110 / 80 R17	130 / 80 R17	25		Yes
Cruiser	1508	130 / 90 R16	160 / 80 R16	8	8	No
Tour	1520	130 / 70 R18	160 / 80 R16	21		Yes
Tour	1520	130 / 70 R18	160 / 80 R16	20		Yes
Tour	1832	130 / 70 R18	160 / 80 R16	32	5	Yes
Sport	600	120 / 70 R17	180 / 55 R17	2	2	Yes
Sport	750	120 / 70 R17	180 / 55 R17	5	5	No
Sport	750	120 / 70 R17	180 / 55 R17	4	4	No
Sport	1000	120 / 70 R18	120 / 60 R18	15	15	No
Cruiser	1340	130 / 90 R16	130 / 90 R16	10	10	No
Cruiser	1340	130 / 90 R16	130 / 90 R16	10	10	Yes
Cruiser	1508	130 / 90 R16	160 / 80 R16	8	8	Yes
Cruiser	1440	130 / 90 R16	140 / 80 R16	30		No
Cruiser	1340	130 / 90 R16	130 / 90 R16	30		No

[1] *Alpha and inch tire sizes have been converted to metric designations*

[2] *Experience applies only to street riding*

[2] *Total years motorcycle experience / 3-wheel motorcycle experience*

[3] *Safety course is approximate years since last taking a safety course. Blank if the rider has never taken one.*

[4] *New rider with a learner's permit*