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The Effectiveness of Longitudinal Rumble Strips on Indiana Roads

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16. Abstract

Rumble strips are designed and deployed to reduce run-off-road and head-on crashes by alerting drivers about near-lane departures. Although they have been widely used, their operational safety effectiveness still needs to be investigated under various operational conditions. Rumble strips may have different widths and be installed on edge, shoulder, center, or in any combination of these locations. To perform a comprehensive analysis of rumble strips' safety effectiveness on rural two-lanes roads across Indiana, both statistical analysis and field test were performed.

To statistically analyze this problem, a dataset for road segments with installed rumble strips including crash data, strips' locations, types, dimensions, and road geometry were extracted. The 2015–2022 crash data was assigned to over 5,600 road segments with homogeneous rumble strip arrangement (including no strips), traffic, and cross-section, yielding more than 20,000 miles-years of observations. To account for the potential overdispersion of crash counts and heterogeneity among segments from the same road, the random effect negative binomial model and random effect ordered logit model were estimated. The estimation results indicated that rumble strips significantly reduced the crash rates for run-off-road and head-on crashes. For roadside-only and center-only designs, the Crash Modification Factor (CMF) for target crashes at all severity levels was 0.87; the CMF (KABC) for target crashes was 0.75, and the CMF (PDO) for target crashes was 0.92. When both roadside and centerline rumble strips are present, the all-severity CMF for target crashes was 0.79; the CMF (KABC) for target crashes was 0.68, and the CMF (PDO) for target crashes was 0.84.

To test the produced noise and vibration from conventional and sinusoidal rumble strips, field tests were carried out with instrumented vehicles. The observations showed that both conventional and sinusoidal rumble strips meet the Federal Highway Administration (FHWA) recommendation of a minimum 3dB increase in sound pressure level. Conventional rumble strips increase sound levels by 4.6–7.5 dB, while sinusoidal rumble strips provide a higher increase of 5.1–11 dB. For both types of rumble strips, the magnitude of vibration also fulfills the requirements for in-cabin vibration. Higher vibration intensities were found for sinusoidal rumble strips compared to conventional ones.

17. Key Words sinusoidal rumble strips, conventional rumble strips, crash probability, crash severity, noise and vibration, field test	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

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EXECUTIVE SUMMARY

Introduction

Rumble strips significantly enhance road safety by providing both audible and vibratory warnings to drivers, which reduces the likelihood of crashes caused by fatigue, distraction, and inattention. Their installation on highway centerlines and shoulders encourages corrective actions, such as steering adjustments and speed control, which help prevent crashes or reduce their severity. Studies have shown substantial decreases in single-vehicle run-off-road crashes and overall crash rates following the implementation of rumble strips.

While rumble strips are effective in improving road safety, much research has shown that they produce considerable noise when vehicles make contact, which can be a nuisance to nearby residents. This noise issue has led to the development of sinusoidal rumble strips, which produce lower frequency noise compared to the higher frequency noise produced by conventional rumble strips, significantly reducing exterior noise while still providing sufficient vibrations. For some vehicle types, they also increase the noise inside the cabin, effectively alerting drivers.

Findings

This research includes two complementary studies: statistical analysis of the safety effect of the installed rumble strips, including sinusoidal and conventional, and field observations that compare the sound and vibration generated by the two rumble strip types. There are several observations and outcomes from the statistical analysis.

1. The safety effectiveness of rumble strips varies by their cross-sectional installation locations: centerline, roadside, or both. The results for conventional and sinusoidal rumble strips indicate a significant reduction in the rates of relevant crashes and the crash modification factors (CMF), and KABC CMFs.
    a. Rumble strips are installed on the roadside only.
        - CMF = 0.87
        - CMF (KABC) = 0.75
        - CMF (PDO) = 0.92
    b. Rumble strips are installed on the center only.
        - CMF = 0.87
        - CMF (KABC) = 0.75
        - CMF (PDO) = 0.92
    c. Rumble strips are installed on both center and roadside.
        - CMF = 0.79
        - CMF (KABC) = 0.68
        - CMF (PDO) = 0.84
2. Sinusoidal rumble strips seem to perform less effectively than the conventional ones, probably due to sample selection bias. Sinusoidal rumble strips (generally implemented later than conventional ones) tended to be installed on routes that were not prioritized for receiving rumble strips and often had more dangerous segments where there were narrower shoulders and more roadside hazards. This natural sample selection bias masked the true effectiveness of sinusoidal rumble strips. The comparison of the after-installation safety performance of sinusoidal and conventional rumble strips is very close.
3. The 16″-wide rumble strips show a slightly better crash reduction effect, although the difference is not statistically significant compared to the narrower setting (12″).

For the field noise and vibration observations, the following was concluded.

1. Both types of rumble strips tested in the trials met the Federal Highway Administration (FHWA) recommendation of a minimum 3 dB increase in sound pressure level.
2. Conventional rumble strips increased sound levels by 4.6–7.5 dB, while the newer installed sinusoidal rumble strips provided an increase of 5.1–11 dB inside the vehicle.
3. For all the vehicle speeds considered, the magnitude of intensity was relatively higher for sinusoidal rumble strips when compared to conventional ones.
4. The widths of the rumble strips tested (8″, 10″, and 12″) did not result in a significant difference in the noise and vibration produced inside the vehicle.
5. The presence of vegetation on some segments of the conventional rumble strips reduced the noise levels produced

Implementation

This study has confirmed the safety benefits of the rumble strips in reducing off-road and head-on collisions (target crashes). This countermeasure is recommended as a low-cost, effective intervention in locations where these two types of crashes occur or where there is occurrence risk based on similar cases elsewhere. Joint use of the center and roadside rumble strips provides the highest safety benefits.

The developed CMFs may be applied in cases that need a benefit-cost analysis. When rumble strips are installed only on the roadside, whether on the edge or the shoulder, the expected crash reduction factor for target crashes is 0.87 (CMF (PDO) = 0.92; CMF (KABC) = 0.75); when rumble strips are installed only on the center, the expected crash reduction factor for target crashes is also 0.87 (CMF (PDO) = 0.92; CMF (KABC) = 0.75); when the rumble strips are installed both on the center and roadside, the expected crash reduction factor for target crashes is 0.79 (CMF (PDO) = 0.84; CMF (KABC) = 0.68).

The strip width (12″ vs. 16″) does not seem to affect safety outcomes and does not affect the noise and vibration levels; thus, this dimension may be decided based on the installation cost and/or equipment availability if no bicyclists or pedestrians are expected on the shoulder. The 12″ rumble strips seem to be more justified when the presence of pedestrians or bicycles is expected.

Although field studies confirmed that there is no significant difference in noise and vibration generation between the conventional sinusoidal strips; in some cases, the vegetation presence over the strips reduced the warning effect. Thus, regular inspection and maintenance of rumble strips after implementation should be considered where needed.

Based on this safety analysis, both conventional and sinusoidal rumble strips have similar crash modification factors (CMFs), which indicate comparable effectiveness in reducing crashes. Both types also meet the NCHRP Report 641 (Torbic et al., 2009) recommendations for generating adequate noise and vibration inside the vehicle to alert drivers; however, sinusoidal rumble strips have the added benefit of producing lower noise levels outside of vehicles.

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1. INTRODUCTION

Factors such as driver fatigue, distraction, and inattention are significant contributors to lane departure incidents (Datta et al., 2015). Rumble strips exist as a preventive measure against driver error rather than deficiencies in roadway design. They work by providing audible and vibratory warnings to drivers, thereby enhancing the likelihood of corrective action in time to avoid crashes (FHWA, n.d.b). Rumble strips also can act as a guide for drivers in areas where rain, fog, snow, and dust obscure pavement edges (Noyce & Elango, 2004). Research also shows that this proactive safety treatment could aid in lessening crash severity if it occurs (Datta et al., 2015).

Although the positive effect of conventional rumble strips on safety was confirmed (Lyon et al., 2015), considerable noise produced by the rumble strips when entering in contact with a vehicle led to research on (Mathew et al., 2018; Terhaar et al., 2016), design, and implementation of sinusoidal rumble strips (Terhaar et al., 2016). The sinusoidal strips (often called mumble strips) emit lower-level noise into the road neighborhood while they still produce sufficient low-frequency vibrations felt and heard by drivers (Mathew et al., 2018). The safety effectiveness of sinusoidal rumble strips in terms of both field operations and crash reduction is not well investigated.

Apart from rumble strips type, the changed operational conditions of rumble strips also bring uncertainty on the safety effectiveness of these devices. Rural two-lane highways are often linked to a higher incidence of serious and fatal crashes, making them a significant subject of safety research (Zhu et al., 2010). Various factors contribute to the increased crash risk in these areas, such as high speeds, insufficient lighting (Stapleton et al., 2018), the prevalence and sharpness of curves, narrower lanes, and shoulders (Patel et al., 2007). All these factors contribute to making rural two-lane highways not as forgiving and increasing the risk of crashes. With the proliferation of rumble strips, including center and shoulder locations, their use on rural two-lane roads has been implemented to reduce the particularly dangerous head-on and run-off-road collisions. These are collisions that produce a high risk of fatalities due to high speeds, roadside hazards, and the relatively long time for emergency response. In addition, a concern was raised that edge and shoulder rumble strips discourage pedestrians and bicyclists from using shoulders in lieu of walking in travel lanes. Thus, narrowed shoulder strips have been proposed to reduce this negative effect on shoulder usage by vulnerable road users. The impact of these modifications on the effectiveness of rumble strips in warning drivers about near-departures needs to be assessed.

1.1 Research Problem

The first research problem lies in the effectiveness of rumble strips with different types, locations, and configurations. Although rumble strips have been proven to effectively alert drivers under experimental conditions with field tests (Finley & Miles, 2007), their operational safety performance requires further studies. Previous operational performance evaluation research (Griffith, 1999; Persaud et al., 2004; Sayed et al., 2010; Torbic et al., 2009) usually aggregates the crash data from a quite large scale (entire road) and focused on one type of rumble strips.

The analysis of aggregated geometry data could not include the safety effects of segment-level geometry, such as road segment curvature, number of curves, and shoulder width. These characteristics are known to be important risk factors for lane departure crashes. In this study, the average length of the investigated segment is around 0.7 miles, providing the opportunity to investigate more specific geometric characteristics. Including such geometric characteristics is important for an unbiased evaluation of the rumble strips' safety effectiveness.

Apart from the difference in roadway geometric conditions, rumble strips are installed in several possible lateral configurations that may have different effects on safety. In Indiana, rumble strips are installed on roadway centerlines, edge-lines, shoulders, or a combination of center and edge-line placement or center and shoulder placement. In addition, the width of the rumble strips may be 8″, 10″, 12″, or 16″. A comprehensive statistical analysis of rumble strips' safety effectiveness could help engineers better understand the performance of these devices under various design elements.

The second research problem is whether the new rumble strips type, sinusoidal, compared to conventional ones, performs in a similar manner with regards to noise and vibration feedback provided to the driver. The exterior noise generated by rumble strips, the nuisance caused by them to communities living near roads with rumble strips installed, and decreasing noise produced by sinusoidal rumble strips has been studied before. Nevertheless, limited research was found which analyzed the noise and vibration produced in the interior of the cabin by the rumble strips (Mathew et al., 2018). The aim of this part of the study is to confirm if the sinusoidal rumble strips installed in Indiana as per Indiana design guidelines meet the federal guidelines on minimum noise generated inside the vehicle and to assess the feedback received by the driver in the form of vibrations.

1.2 Research Objectives

The research's main objective is to comparatively evaluate the safety effectiveness of installed conventional and sinusoidal rumble strips on rural roads in Indiana. This objective will be achieved by estimating the crash reduction attributed to the addition of rumble strips, expressed with crash modification factors (CMFs) estimated for Indiana conditions. To obtain conclusive and significant results, rumble strips must have been installed for a sufficient length of time.

Safety effectiveness will be evaluated under various traffic and local road conditions with respect to supporting engineering decisions about where and which type of rumble strips should be installed.

The secondary objective is to evaluate the noise and vibrations produced by the rumble strips with corrugation widths of 8″, 10″, and 12″. This objective will be achieved by measuring the vibration in the steering column and the change in decibels inside the cabin produced by the rumble strips when they contact the wheels.

1.3 Research Scope

This research is focused on rural highways where the safety performance of rumble strips is evaluated. Road segments near intersections, collisions with animals, and crashes with driver impairment listed as potential causes do not fall within the presented project's scope. The consumption of alcohol or drugs can reduce a driver's ability to react to the vibration and noise produced by the rumble strips, making them less effective in preventing crashes. These effects are not investigated in this report in detail and their overall effect is included in the results among other unexplained effects combined together.

The traditional approach to developing CMFs is a longitudinal before-and-after analysis of the same location in the before and after periods. Such studies evaluate the crash pattern changes on treated roads over time and attribute them to the treatment studied. They assume that other conditions remain similar during the entire period of analysis. In the presented study, the after-observation periods were too short to conduct the before and after analysis. Therefore, a cross-sectional analysis was adopted. This method compares the safety performance of various already-treated and not-yet-treated locations during a single period while statically controlling the confounding factors such as traffic exposure and road geometry. The cross-sectional method was found to be more suitable for the purpose at hand than the mentioned before-and-after method.

The data needed for the safety analysis included: traffic volumes, operating speeds, roadway characteristics, weather conditions, types of vehicles involved, and others. These data were found and extracted from multiple sources such as: INDOT's Traffic Count Database System (TCDS), the Highway Performance Monitoring System (HPMS), INDOT's Road Network Inventory, the Automated Reporting Information Exchange System (ARIES), the National Oceanic and Atmospheric Administration (NOAA), the Indiana State Climate Office, and INRIX. Once extracted, the data was processed and integrated into data files suitable for the intended statistical analysis.

For evaluation of the noise and vehicle vibrations felt by drivers inside a vehicle, test road segments with installed rumble strips were driven by a group of drivers. They were crossing the strips at various speeds according to pre-planned scenarios. The multiplicity of crossing strips of various designs in various ways (different speeds and vehicle type) produced a sample of observations that were analyzed to correlate the crossing conditions with the measured noise and vibrations.

The measurements were executed with microphones and inertial measurement units and recorded on a computer unit to be analyzed with software developed at the Center for Road Safety (CRS) at Purdue University. Comparative analysis of the conventional strips with the ones of narrow widths were supposed to provide a quantitative representation of the differences in the noise and vibration production between the alternative strips' design.

1.4 Report Organization

The next chapter contains the literature review and current practice in Indiana regarding rumble strips. The third chapter introduces the safety evaluation of rumble strips. It includes the details of the data collection, the crash data analysis, and the obtained statistical methods. The fourth chapter details the noise and vehicle vibration field observations, discusses the data collection, and the analysis methods. The fifth chapter provides a summary and discussion of the results obtained from statistical analysis and field measurements. The sixth chapter summarizes the research findings, while the final chapter discusses the potential implementation of the results obtained.

2. CURRENT STATE OF PRACTICE AND KNOWLEDGE

2.1 Literature Review

According to the definitions of the Federal Highway Administration (FHWA, n.d.b), "center line rumble strips (Figure 2.1a) are placed as a countermeasure to reduce head-on, opposite direction sideswipe, and run-off-road to the left crashes. While shoulder (Figure 2.1b) and edge (Figure 2.1c) rumble strips are installed to reduce the run-off-road to the right crashes." Rumble strips have been identified as a cost-effective and easily implementable method to enhance road safety. Their effectiveness in reducing crash rates and severity while maintaining low costs of installation and maintenance makes them a valuable tool in traffic safety management (Karkle, 2011; Patel et al., 2007). Figure 2.1 illustrates the typical installation of rumble strips in a roadway (FHWA, n.d.a).

Consistently with the INDOT's established naming practice, this report refers to the lateral dimension of the rumble strips as *width* instead of *length* (Figure 2.2). The revised term is consistent with the current meaning of *width* applied to the lateral dimension of a lane and of a shoulder.

The safety improvements from the use of rumble strips can be found in several prior evaluations. The following examples can be found in the literature.

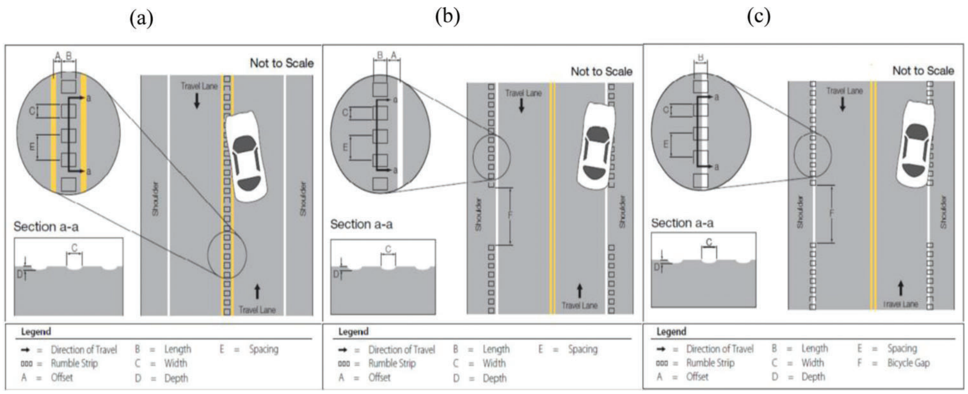

Figure 2.1 Rumble strips installation.

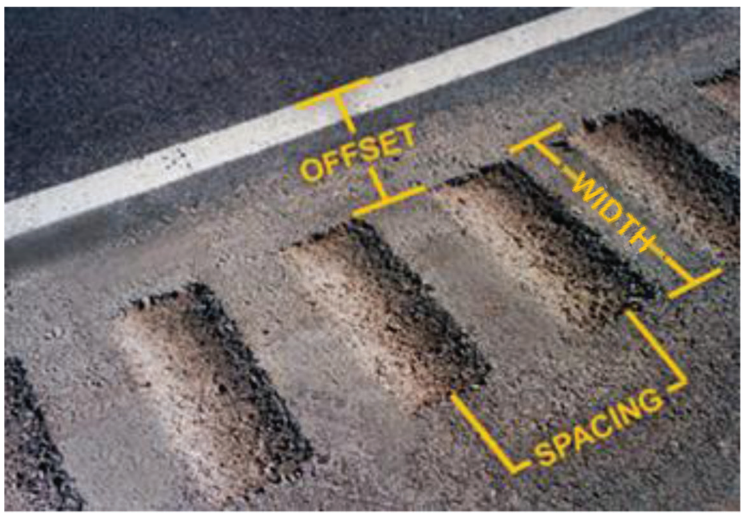

Figure 2.2 Dimension terms applied to rumble strips.

- Data from the state of Illinois reported that after the installation of rumble strips, the single-vehicle-run-off-road (SVROR) crashes reduced 18.3% in all freeways and reduced 21.1% on rural freeways (Patel et al., 2007).
- Similarly, the implementation of 183 miles of shoulder rumble strips on two-lane rural highways in Minnesota resulted in a 13% reduction in total SVROR crashes and an 18% reduction in injury SVROR crashes (Patel et al., 2007).
- The installation of 210 miles of center rumble strips showed a 14% reduction in total injury crashes and a 25% reduction in head-on crashes and opposing-direction side-swipe across seven states (California, Colorado, Delaware, Maryland, Minnesota, Oregon, and Washington) (Persaud et al., 2004).
- In British Columbia, Canada, the installation of rumble strips reduced all injury collisions by 18% (Sayed et al., 2010).
- NCHRP Report 641 estimated for rural two-lane roads a reduction of 15% in SVROR crashes and 29% reduction for SVROR fatal and injury crashes after the installation of shoulder rumble strips (Torbic et al., 2009).
- According to the CMF Clearinghouse (n.d.), based on NCHRP Report 641, CMFs for two-lane rural roads vary by the offset of rumble strips from the edge-line. However, INDOT installs rumble strips directly on the edge-line (no offset) or with offsets of 6″ or 8″, making this research comparable only to the first CMF category. The CMFs from the Clearinghouse are as follows.
    - CMF = 0.67 for offsets between 0 and 8 inches.
    - CMF = 0.62 for offsets between 9–20 inches.
    - CMF = 0.43 for offsets of 21 inches or wider.

Although rumble strips expect to provide safety benefits for vehicles, research has identified discomfort and other adverse effects for bicyclists and an increased roadside noise undesirable in residential areas (Gates et al., 2014). For rumble strips to be effective, they need to produce sufficient inside-vehicle noise and vibration to alert the driver without causing excessive discomfort that might lead to undesirable driver behavior (Sexton, 2014).

While rumble strips are meant to generate in-vehicle noise and vibrations to alert drivers, this noise spreads outside vehicles, where it does not contribute to safety but may become a nuisance to residents in developed areas along the roads (Sexton, 2014). Torbic et al. (2009) made the following recommendations.

"To be effective, rumble strips should produce a sound level increase of 10 to 15 A-weighted decibels (dBA) above in-cabin levels while the vehicle is in the travel lane. However, some reports suggest that in-cabin sound level increases may be reduced to about 6 to 12 dBA when roadways are adjacent to residential land uses."

Noise propagation from rumble strips to the exterior is influenced by a variety of factors. Research indicates that the propagation of sound varies based on several factors, including the method of installation (Bucko & Khorashadi, 2001), the width and spacing of the strips (Finley & Miles, 2007; Sexton, 2014), vehicle speed and type (Bucko & Khorashadi, 2001; Karkle, 2011), as well as environmental factors like air temperature, humidity, and wind speed (Lamancusa, 2009; Mathew et al., 2018).

To address the high-frequency noise problems from conventional rumble strips, a sinusoidal profile was created in order to redistribute some of the higher frequencies into lower frequencies (Caltrans, n.d.). Research indicates that when a typical light vehicle encounters the sinusoidal or "mumble" strip, the sound levels produced outside the vehicle are lower compared to regular rumble strips (Caltrans, n.d.). While studies on sinusoidal rumble strips are limited, findings suggest a significant reduction in exterior noise compared to traditional designs (Mathew et al., 2018).

In conclusion, the effectiveness of rumble strips in enhancing road safety is well-documented across various studies. Results from the mentioned research underscore the importance of rumble strips as a cost-effective and easy-to-implement strategy for reducing lane departure incidents, enhancing driver safety by providing critical auditory and tactile warnings that help drivers correct their course (Datta et al., 2015; FHWA, 2022).

However, while rumble strips offer clear safety benefits, their implementation must be carefully managed to mitigate potential adverse effects such as increased roadside noise. The noise produced by rumble strips, necessary for their effectiveness, can become a nuisance to nearby residents, highlighting the need for designs that balance safety and noise reduction, such as sinusoidal strips (Mathew et al., 2018; Sexton, 2014).

2.2 Indiana Practice

Although recommendations can be found in the existing manuals, DeCarlo et al. (2023, p. 1) noted that "Departments of Transportation (DOTs) have varied practices for the design, installation, and maintenance of rumble strips. Decisions on where to include rumble strips, dimensions, whether to seal them, and how to re-apply pavement markings are not standardized across states." In Indiana, INDOT implements rumble strips directly on the edge-line (no offset) or with offsets varying between 6″ and 8″ from the edge-line and within the shoulder width.

The Indiana Department of Transportation (INDOT) began experimenting with sinusoidal rumble strips in 2012 and 2013 to start installing them systematically by 2015. The sinusoidal rumble strips were used to address the concern of residents exposed to the noise generated by conventional rumble strips (Boruff, 2019, p. 6, 7). To mitigate these exterior noises, INDOT evaluated different widths, wavelengths, and milling options of sinusoidal rumble strips. Results of their evaluation was that a 12″ wavelength sinusoidal rumble strip was the pattern, which satisfied all the requirements related to in-cabin and exterior noise (Mathew et al., 2018). Furthermore, the mentioned study provided the basis for rumble strips recommendations by INDOT Office of Traffic Administration (Boruff, 2019, p. 6, 7). The FHWA-recommended three locations of rumble strips (see Figure 2.1) are recommended in five combinations that depend on the speed limit and the cross-sectional road dimensions are as follows.

If the following is true, use centerline (Figure 2.1a) and edge (Figure 2.1c) line rumble strips in combination.

- The posted speed limit is 50 mph or above.
- The lane width is at least 11 ft.
- The paved shoulder width is at least 2 ft but less than 4 ft.

If the following is true, use centerline (Figure 2.1a) and shoulder (Figure 2.1b) rumble strips in combination.

- The posted speed limit is 50 mph or above.
- The lane width is at least 11 ft.
- The paved shoulder width is at least 4 ft.

If the following is true, use centerline (Figure 2.1a) rumble strips only.

- The posted speed limit is 50 mph or above.
- The lane width is at least 10 ft but less than 11 ft.

If the following is true, use edge line (Figure 2.1c) rumble strips only.

- The posted speed limit is 50 mph or above.
- The paved shoulder width is at least 2 ft but less than 4 ft.

If the following is true, use shoulder (Figure 2.1b) rumble strips only.

- The posted speed limit is 50 mph or above.
- The paved shoulder width is at least 4 ft.

The following chapters summarize the data collected for rural roads in Indiana and they present the method of analysis employed to these data. This includes the conditions under which the rumble strips were studied and the methods employed to evaluate their safety, vibration, and noise impacts.

3. STATISTICAL ANALYSIS

Statistical models were developed using collected crash data and other data to quantitatively analyze and to evaluate the safety performance of the studied types of rumble strips. This chapter introduces the data collection efforts, the statistical methodology, and the modeling results.

3.1 Data Collection

3.1.1 Rumble Strips

The research team provided INDOT with a survey questionnaire to facilitate data collection and to consolidate information about rumble strips installed across Indiana. The survey was designed to gather detailed information without restricting responses and allowing INDOT staff to fill in the requested details. The survey asked for the following information: name of the route, associated contract number, construction acceptance date, substantial completion date, location description (start and end points of the route), start point (linear reference or stationing), end point (linear reference or stationing), rumble strip type, and placement (center, edge, or shoulder). INDOT distributed the survey among all its districts with a request for completion. Figure 3.1 presents the questionnaire layout with example data entered. The questionnaire was not restricted to any specific rumble strip type or dimensions.

In the next step, the research team created a shapefile in ArcGIS (Figure 3.2), enabling the visualization of collected data in map format and the assignment of spatial attributes. After all routes were registered in ArcMap, the major intersections along the analyzed routes were removed to focus the analysis only on road segments free of these intersections' effect.

Next, for every road section included for analysis in the shapefile, a road section similar by length, traffic, and geometry was found and referenced to the original route to be used as a control element in the cross-sectional analysis.

When all the information was registered and organized in a single shapefile, the rumble strip locations on the road were visually identified. Using Google Earth (Figure 3.3), every route from the survey was selected at a specific point, and the information on the location of the rumble strips (center, edge, and shoulder) was verified. In the case that the survey did not confirm the visual inspection of Google Earth images, a correction of the location in the database of the rumble strips was made.

3.1.2 Crash Data

The crash records from 2015 to 2022 were extracted from the ARIES database and assigned to the segments in the shapefile. The analysis was focused on run-off-road crashes and head-on crashes that were the result of lane departures. These events are supposed to be prevented with the rumble strips installed on these roads. Therefore, the frequency of these crashes and their severity are believed to be most affected by both the presence and the design of rumble strips installed there. In the analysis of this report, both the target crashes (run-off-road and head-on) were analyzed using statistical models. Furthermore, crashes of all types were combined on each analyzed segment and analyzed for analysis completeness.

After assigning the analyzed crashes one by one to every segment (Figure 3.4), the crash database was reorganized. First, the analyzed crashes were grouped into three categories: run-off-road, head-on, and other crashes. Crashes in the sample were distributed as follows: approximately one-third were classified as run-off-road or head-on crashes, while about half involved collisions with animals.

The quality control analysis discovered that run-off-road and head-on crashes were incorrectly categorized in a considerable number of cases. Some of the registered crashes classified by the police as head-on crashes were in fact collisions with off-road objects, almost always trees. These crashes were reclassified as run-off-road crashes. According to the crash reports, drivers lost control of their vehicles, left the road, and then hit an off-road obstruction. On the other hand, events of vehicles crossing the center line and colliding with an upcoming vehicle were misclassified as run-off-road crashes and not as head-on collisions.

To correct the identified classification cases, the reported causes of crashes and the manners of collisions were inspected. The identified misclassified crashes were corrected. Although the head-on and run-off-road crashes were analyzed separately, they were eventually combined after the test of the models' justified the treatment. Thus, these two crash types were analyzed with a single model. Nevertheless, any discrepancies in the results between the two crash types led to estimating these results for each type separately but within the same model. This approach helped using the sample information in the most effective manner to increase the results accuracy.

3.1.3 Traffic, Climate, and Geometry Data

Once the crashes had been correctly classified and assigned to each segment, road characteristics and traffic information were added into the database. Traffic volume was determined and assigned to each segment using the INDOT's annual traffic data shapefiles. Then, the road characteristics included in the INDOT's road repository shapefiles: lane width, shoulder width, and shoulder type were copied to the model sample file.

Indiana weather conditions tend to vary significantly across the state; counties with similar weather observed over several years were grouped together using SAS

Route	Contract	Construction acceptance date	Substantial completion date	Location Description	From	To	Rumble Stripe Type	Placement		
					Route Or MM	Route Or MM		Center	Edge	Shoulder
SR 39	RS-42019-A	7/17/2019	3/27/2020	From .19 mi E of SR 39 E Jct to 1.01 mi W of SR 67 (White Lick Creek Br - East End)	55+82	61+67	Sinusoidal	16	12	
SR 234	RS-39328-A	10/16/2019	10/9/2019	From SR 47 to 7.3 mi E of US 231 (1 mi E of Ladoga)	34+28	45+40	Sinusoidal	16	12	
US 231	RS-39259-A	2/12/2020	1/26/2022	1000 ft south of US 231-US 40 intersection to the US 231-US 40 intersection	39+99	48+52	Sinusoidal	16	12	

Figure 3.1 Example of INDOT survey regarding the installed rumble strip.

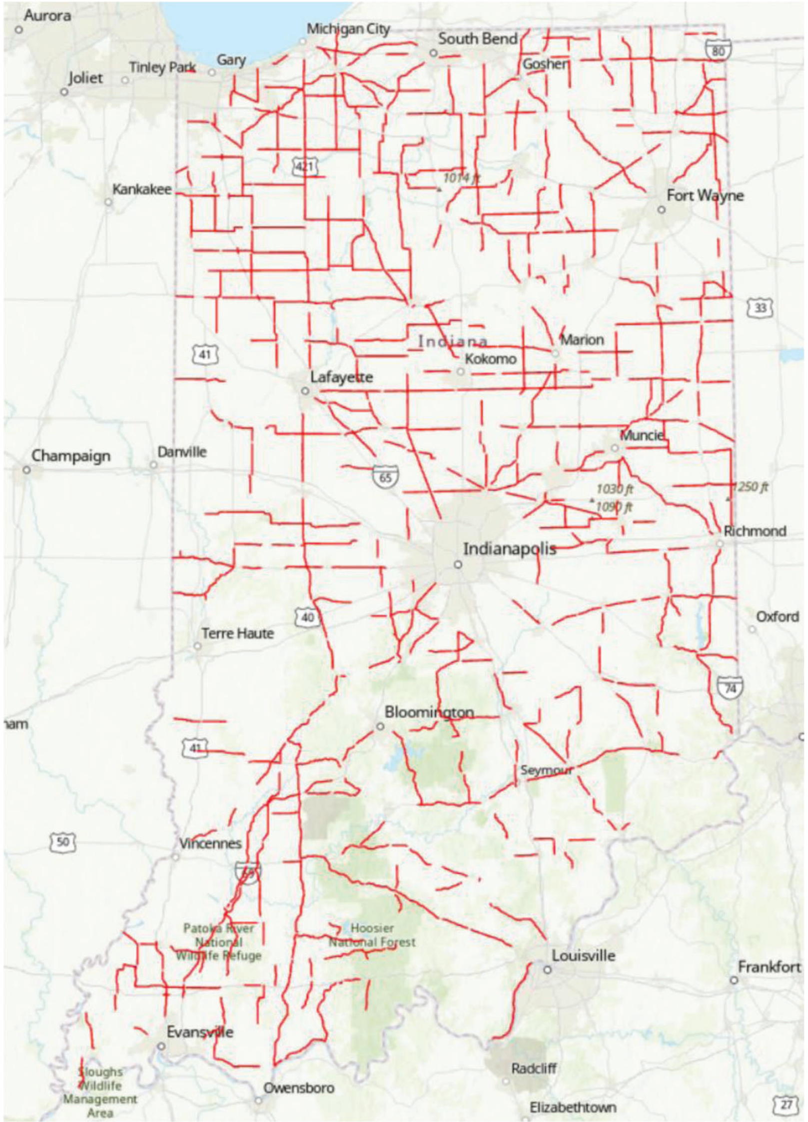

Figure 3.2 Shapefile with road sections covered with the surveys.

Figure 3.3 Example of visual recognition of rumble strips using Google Earth.

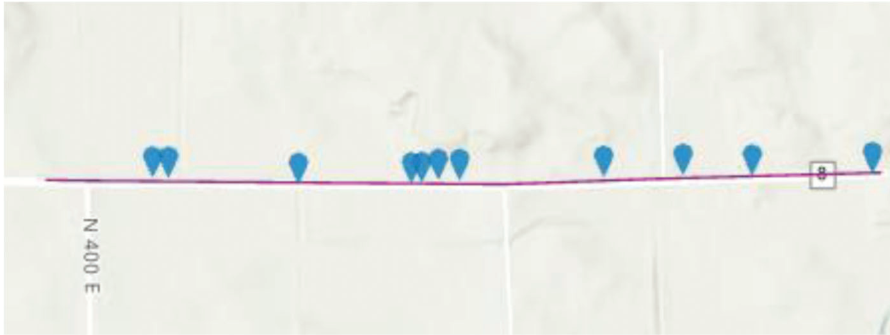

Figure 3.4 Identified and assigned crashes to a single segment.

Institute clustering procedures (SAS Institute Inc., 2016). The weather conditions were represented with the monthly averages of the maximum temperature, minimum temperature, and precipitation. After the spatial and temporal aggregation, the obtained aggregated weather characteristics were included in the model for analysis.

A road segment horizontal alignment was represented with geometry characteristics aggregated at the segment level. These characteristics included: the total deflection angle along segment to the left and separately to the right; the degree of curvature per mile; the maximum degree of curvature on the segment; and the number of curves along the segment. These quantities were calculated with software developed by the Center for Road Safety (CRS) and applied to the curvature characteristics for each segment estimated from the shapefiles provided by INDOT.

Calculating the curvature of a segment represented with a polyline involved finding the curvature at discrete points along the polyline. Thus, the segment curvature is a measure of horizontal curve sharpness estimated based on a series of connected polyline segments. This could be obtained by considering angles between consecutive polyline segments. To calculate angles, segment curvature, and number of curves, the following operations were followed.

For each consecutive triplet of points (P_{i-1}, P_i, P_{i+1}), two vectors were calculated:

$$\vec{v_i} = P_i - P_{i-1}, \vec{w_i} = P_{i+1} - P_i \quad \text{(Eq. 3.1)}$$

Then, the angle θ_i between these two vectors obtained:

$$\theta_i = \arccos\left(\frac{\vec{v_i} \cdot \vec{w_i}}{|\vec{v_i}||\vec{w_i}|}\right) \quad \text{(Eq. 3.2)}$$

The total segment deflection angle δ along the segment (small individual errors tend to cancel out when summed along the segment):

$$\delta = \sum_{i=1}^{n-1} |\theta_i| \quad \text{(Eq. 3.3)}$$

The total segment deflection angle to left δ_L and to right δ_R (turn direction determined with the sign of the vectors cross product) was:

$$\delta_L = \sum_{i=1}^{n-1} \begin{cases} |\theta_i| \text{ if cross product is positive} \\ 0 \text{ if cross product is negative} \end{cases}$$
$$\delta_R = \sum_{i=1}^{n-1} \begin{cases} |\theta_i| \text{ if cross product is negative} \\ 0 \text{ if cross product is positive} \end{cases} \quad \text{(Eq. 3.4)}$$

The deflection rates were calculated as the total deflection rate divided by the segment length. The sequences of deflection angles of the same sign and of sufficient length indicated the presence of horizontal curves.

Other road segment horizontal alignment characteristics derived from their polylines were not found to significantly affect road safety and they are not presented here.

3.2 Data Description

3.2.1 Rumble Strips

Information was obtained from a survey sent by INDOT to every Indiana's district. The information included the road where the rumble strips were installed, the contract associated with the construction, the construction acceptance and substantial completion dates, the location description, the start and end stations of the route, the type of rumble strip (conventional or sinusoidal), the placement of the rumble strips (center, edge, and shoulder), and the width of the rumble strips. Table 3.1 provides the amounts of data obtained for analysis expressed with the number of miles for each type of rumble strip analyzed. Only rumble strips with widths of 16″ and 12″ were reported by the districts. No report mentioned the installation of rumble strips with widths of 8″ or 10″. The complete set of survey responses is presented in Appendix B.

3.2.2 Segment Length

To improve the accuracy of the analysis, every prolonged road section was divided into segments. Most of the segments extended between two intersections were shorter than 1 mile. The 250-foot portions of

TABLE 3.1
Number of miles per width and location of the rumble strips

	Rumble Strips Width			
Location	16″	12″	16″ & 12″	16″ & 16″
Center	1,228	–	–	–
Edge	13	28	–	–
Shoulder	25	165	–	–
Center + Edge	–	–	226	122
Center + Shoulder	–	–	390	125

these segments at their ends were excluded to eliminate the influence of the intersections on the segment ends. In segments longer than 1 mile, they were divided into equal parts of length not exceeding 1 mile.

3.2.3 Crash Records

Police crash reports were accessed from the ARIES database. The information contains details about the crash, location, number of vehicles involved, type of crash, type of vehicles, and manner of collision. The latitude and longitude of every crash were used to assign individual crashes to segments for analysis. In total, 19,636 run-off-road and 3,468 head-on crashes were identified in a period from 2015 to 2022.

3.2.4 Traffic Data

The information of the volume of traffic on rural roads in Indiana was obtained through the shapefiles provided online by INDOT. The historic traffic zone shapefiles are published yearly and are free to access. If information about the annual average daily traffic (AADT) is missing for a road in a specific year, then the missing information is calculated by taking the AADT of a different year for that road and dividing it by the adjustment factors also provided by INDOT.

3.2.5 Road Inventory

INDOT's road inventory datasets provided information about the current functional classification of road segments and basic geometry. The classification of the roads was an important element to consider, given that the scope of the research only included two-lane rural roads. To further evaluate the conditions of the rural roads, geometric characteristics such as lane width, shoulder width, and shoulder type were extracted for analysis.

3.2.6 Climate Zones

Neighboring counties tend to have similar weather conditions while distant counties do not. By clustering the counties based on the monthly averages of the maximum and minimum temperatures, and the monthly average precipitation, results support latitude as the variable which produces the most significant influence by defining almost horizontal climatic areas. The results of the clustering procedure allowed dividing Indiana into three climatic regions of relatively similar characteristics.

The following is a list of the clustered counties.

- *Cluster 1* (North): Adams, Allen, Benton, Blackford, Carroll, Cass, De Kalb, Delaware, Elkhart, Fountain, Fulton, Grant, Henry, Howard, Huntington, Jasper, Jay, Kosciusko, Lagrange, Lake, Laporte, Marshall, Miami, Montgomery, Newton, Noble, Porter, Pulaski, Randolph, St. Joseph, Starke, Steuben, Tippecanoe, Tipton, Wabash, Warren, Wells, White, Whitley.
- *Cluster 2* (Center): Bartholomew, Boone, Brown, Clay, Clinton, Dearborn, Decatur, Fayette, Franklin, Greene, Hamilton, Hancock, Hendricks, Jackson, Johnson, Lawrence, Madison, Marion, Martin, Monroe, Morgan, Ohio, Owen, Parke, Putnam, Ripley, Rush, Scott, Shelby, Sullivan, Union, Vermillion, Vigo, Wayne.
- *Cluster 3* (South): Clark, Crawford, Daviess, Dubois, Floyd, Gibson, Harrison, Jefferson, Jennings, Knox, Orange, Perry, Pike, Posey, Spencer, Switzerland, Vanderburgh, Warrick, Washington.

3.2.7 Curvature

Total angle of deflection, average degree of curvature, number of curves per segment, and minimum and maximum radius of the curves were calculated from computations based on the shapefile polylines. Computations were performed for each road segment to estimate its horizontal alignment characteristics for better understanding of the road curvature.

A descriptive summary of the variables used in the analysis is presented in Table 3.2. The rumble strips variables *Side*, *Center*, and *Center+Side* reflect the location of the rumble strips. When the rumble strips are installed only at *Edge* or *Shoulder*, the binary variable *Side* is set to 1; when rumble strips are installed only at *Center* (road centerline), the binary variable *Center* is set to 1; and when rumble strips are installed at both *Center* and *Side*, the binary variable *Center+Side* is set to be 1.

3.3 Statistical Methods

To evaluate the safety effectiveness of sinusoidal rumble strips, advanced statistical models were developed to associate the crash frequency and severity with the studied rumble strips presence, traffic, and road geometry. Over 4,000-mile rural two-lane highways across Indiana were included in the analysis. Specifically, 8 years of crash data from 2015 to 2022 were assigned to over 5,600 homogeneous segments on these highways. For each segment, traffic AADT, geometry (such as length, number of curves, deflection angle rate, lane width, shoulder width) and rumble strips settings (type, location, width) were collected and used for analysis.

TABLE 3.2
Data descriptive summary

Variable	Description	Mean	Std Dev	Min	Max
Crash	Lane departure crash count	2.20	3.14	0.00	42.00
YearCount	Number of years	4.92	2.34	1.00	8.00
Length	Segment length in mile	0.73	0.22	0.05	1.42
AADT	Annual average daily traffic	4,854	5,514	33	50,748
Geometry					
SpdLmt	Speed limit in mile/h	55.30	3.45	50.00	70.00
LaneWidth	Lane width in ft	10.98	1.06	8.00	13.00
ShdWidth	Shoulder width in ft	1.14	2.08	0.00	12.00
TotalAngle	Total deflection angle in degree	18.96	34.12	0.00	810.81
DeflectionAnglRate	Deflection angle rate (degrees/mile)	26.11	44.97	0.00	986.46
NumCurve	Number of curves on the segment	1.21	1.71	0.00	20.00
MaxDeflAngl	Maximum deflection angle	10.95	17.73	0.00	185.70
SouthArea	South area of Indiana	Dummy variable: 1: 16.1%; 0: 73.9%			
CenterArea	Center area of Indiana	Dummy variable: 1: 29.1%; 0: 70.9%			
NorthArea	North area of Indiana	Dummy variable: 1: 54.8%; 0: 45.2%			
Rumble Strips					
Center	Rumble strips on the center of the road	Dummy variable: 1: 18.0%; 0: 82.0%			
Center+Side	Rumble strips on center and roadside	Dummy variable: 1: 9.6%; 0: 90.4%			
Side	Rumble strips on roadside	Dummy variable: 1: 2.3%; 0: 97.7%			

3.3.1 Sample Data Preprocessing

The information pertaining to the rumble strip installation periods involved uncertainties. To avoid inaccurate data, only the information deemed reliable was included in the analysis. It was accomplished by including in analysis segments and years only if no rumble strip construction activity was indicated on these segments during these years. In other words, years and segments with any strip installation activities during even a part of the year or even along a part of the segment were excluded from the analysis. Figure 3.5 presents example periods for Segments 1 and 5. Segment 1 experienced installation of a rumble strip along its entire distance during some part of 2020. Thus, Segment 1 has *Rumble Strip = No* for years 2015–2019, Segment 1 has year 2020 removed from the analysis, and Segment 1 has *Rumble Strip = Yes* for years 2021–2022. Segment 5 has *Rumble Strip = No* for years 2015–2022. This data filtering yielded for analysis the total of 21,737 mile-years, including 16,955 mile-years without rumble strips that served as reference segments.

Safety of a road segment during a period of several years with no changes in the configuration of rumble strips (including no rumble strip) was the observation. The configuration of rumble strips was the primary characteristic on which the analysis was focused. The exposure to crashes was the product of the segment length and the number of years. Other variables: average traffic volume, cross-section dimensions, and aggregate characteristics of the horizontal alignment were included to be able to estimate the net safety effect of the rumble strips.

Following the proposed data segmentation, 16,955 mile-years of reference data, 3,999 mile-years of conventional rumble strip data, and 783 mile-years of sinusoidal ruble strip data were analyzed. The data in Table 3.3 is summarized by rumble strip configuration. The column *Center*, *Edge*, and *Shoulder* describe the locations of the rumble strips while the values in the corresponding cells are the rumble strip widths in inches.

3.3.2 Crash Frequency Model

For crash frequency analysis, a random-effect negative binomial model is the most suitable model because it properly represents the natural overdispersion of the crash counts (compared to Poisson models) as well as the potential heterogeneity among groups (segments from the same roadway segment might share common unobserved randomness). The number of years was set as the offset variable so that the total crash counts are comparable.

The model could be expressed as in equation (Eq. 3.5), where crash counts are assumed to follow negative binomial distribution. The mean value μ is expected to have linear relationships with explanatory variables (X_1, X_2, … X_j), which include the collected traffic, geometry, and rumble strip settings. Because the proposed model assumed random effects among segments (differentiated by Rumble ID), the model intercept includes an additional term α_{ID}, which takes care of the unobserved heterogeneity. The variance value δ is the summation of two terms, mean μ and multiple of square of mean and dispersion parameter ρ. When dispersion parameter ρ is close to zero, the negative binomial model descended into a Poisson model.

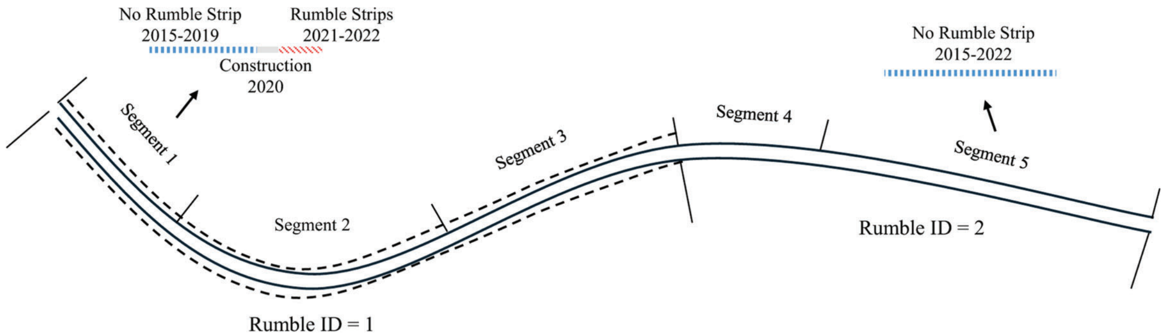

Figure 3.5 Sample data illustration.

TABLE 3.3
Sample data summary by rumble strip configurations

Profile	Rumble Strips Width			Number of Segments	Miles-Years	Rumble Strips Scenarios	Miles-Years
	Center	Edge	Shoulder				
No Strips	–	–	–	4,292	16,955	Reference	16,955
Conventional	–	–	16	29	116	Side Only	176
Conventional	–	16	–	12	60		
Conventional	16	–	–	889	2,760	Center Only	2,760
Conventional	16	–	12	38	79	Center Side	1,063
Conventional	16	–	16	138	445		
Conventional	16	12	–	59	83		
Conventional	16	16	–	124	456		
Sinusoidal	–	–	12	70	64	Side Only	74
Sinusoidal	–	12	–	14	10		
Sinusoidal	16	–	–	259	398	Center Only	398
Sinusoidal	16	–	12	115	136	Center Side	311
Sinusoidal	16	–	16	8	29		
Sinusoidal	16	12	–	82	108		
Sinusoidal	16	16	–	9	38		

$$\begin{aligned} &CrashNum_i = NegativeBinomial(\mu,\delta) \\ &\mu = \alpha_0 + \alpha_{ID} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_j X_j \\ &\alpha_{ID} \sim Normal(0,\sigma_{ID}) \\ &\delta = \mu + \rho\mu^2 \end{aligned} \quad \text{(Eq. 3.5)}$$

3.3.3 Crash Severity Model

For crash severity analysis, the random effect ordered logit model is the most suitable model because it considers the natural ordering of the crash severity as well as the potential heterogeneity among groups. Different from the crash frequency model, the crash severity model treats each crash as one observation. The model estimates the probability of falling into certain severity categories given different traffic, geometry, and rumble strip conditions. In this study, crashes are divided into three severity categories: KA (fatal and incapacitating injury), BC (non-incapacitating injury and minor injury), and PD (property damage only). It is assumed that the crash severity follows the ordering sequence as crash severity changes from PD to BC, and from BC to KA.

$$\begin{aligned} &z = \alpha_0 + \alpha_{ID} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_j X_j \\ &\alpha_{ID} \sim Normal\ (0,\sigma_{ID}) \\ &\begin{cases} Severity = 1,\ if\ z \le \mu_0 \\ Severity = 2,\ if\ \mu_0 < z \le \mu_1 \\ Severity = 3,\ if\ z > \mu_1 \end{cases} \end{aligned} \quad \text{(Eq. 3.6)}$$

The model could be expressed as (Eq. 3.6), where a latent variable z is introduced. This latent variable is specified as a linear function of explanatory variables and is used as a basis for modeling the ordinal ranking of data. When the values of this latent variable z fall into specific ranges, the samples belong to the corresponding severity level, where μ are the estimated thresholds. Because the randomness is assumed among segments, the intercept includes a random term α_{ID} following normal distribution.

3.4 Crash Frequency Model Results

The random effect negative binomial model was used to establish the relationship between crash counts and crash risk factors, including rumble strips settings.

Although both target crashes (run-off-road and head-on) and all crashes were tested with the model, only the models using target crashes as the response variable showed reasonable results. The results of all crash models were included in Appendix A, and the results of target crash were presented in the following two sections: the selected model and hypothesis test.

3.4.1 Selected Model

The estimation results of crash frequency models (target crash: run-off-road and head-on combined) are shown in Table 3.4. The results include three parts: fixed parameter, covariance parameter and model fitness.

The covariance parameters are found to be significant justifying the existence of the unobserved heterogeneity among samples from the same rumble strip ID. It indicates the correct specification of the random effect.

The model fitness includes *-2 Res Log Pseudo-Likelihood* and *Gener. Chi-Square/DF* since the estimated negative binomial model is a generalized linear model. Nevertheless, the two statistics reflect the model goodness of fit following the same principles. The model fitness is better when *-2 Res Log Pseudo-Likelihood* is smaller and *Gener. Chi-Square/DF* is closer to 1. The statistic *-2 Res Log Pseudo-Likelihood* is only comparable between nested models. Usually, this comparison of the models is performed using a likelihood ratio test between the nested models estimated with the same samples.

The fixed parameters listed in Table 3.4 in the *Estimate* column represent the effects of safety factors analyzed. The positive values indicate the growing frequency of crashes with the growing factor intensity (or level). The last column Pr > |t| represents the significance of the result. Usually, the effect is recognized as significant when the P-value is smaller than 0.05.

TABLE 3.4
Estimation results of crash frequency model

Effect	Estimate	Std. Err	t Value	Pr > |t|
Fixed Parameter				
Intercept	-5.432	0.210	-25.83	<.0001
LogAADT	0.558	0.026	21.82	<.0001
LogLength	0.603	0.047	12.95	<.0001
South Area	-0.183	0.064	-2.87	0.0041
ShdWidth	-0.008	0.009	-0.85	0.3958
DeflectionAnglRate	0.005	0.000	11.56	<.0001
NumCurve	0.031	0.011	2.70	0.0069
Side	-0.141	0.161	-0.87	0.3821
Center	-0.142	0.054	-2.60	0.0094
Center+Side	-0.241	0.071	-3.39	0.0007
Covariance Parameter				
Intercept (RumbleID)	0.138	0.017	8.28	<.0001
Scale	0.398	0.020	20.11	<.0001
Model Fitness				
-2 Res Log Pseudo-Likelihood 16,010		Gener. Chi-Square/DF 1.05		

The two variables *LogAADT* and *LogLength* representing the logarithm of the annual average daily traffic (AADT) and the segment length in mile were found to increase the crash frequency as expected. More traffic and longer travel distance will increase the probability of crashes.

The variable *SouthArea* is a binary variable indicating whether the segment is in the southern area of Indiana. The negative model estimate of this variable indicates that segments in the southern area of Indiana are generally safer than the other segments. This difference is probably due to different weather conditions.

The variable *DeflectionAnglRate* (horizontal curve deflection angle rate) and *NumCurve* (number of curve) represent the general complexity of the segment. Both variables are found to increase crash frequency as expected.

For rumble strips' effects, the model estimation results show that *Center* configuration significantly decreases crash frequency with an expected 13% crash reduction (13% = 1- exp (-0.142)). While the *Side* effect (-0.141) is very close to *Center* (-0.142), it was not significant. This insignificance might be due to lack of samples for side only scenarios. As shown in Table 3.3, the collected side only samples are very limited compared to the other two scenarios. The combination of roadside and center rumble strips is found to further decrease crash frequency significantly. The corresponding expected crash reduction is 21% (21% = 1- exp (-0.241).

3.4.2 Hypothesis Test

The estimation results presented in Table 3.4 combine *Edge* and *Shoulder* location as *Side*, merge 12″ and 16″ scenarios, and unify conventional and sinusoidal scenarios. The basis for such combinations is discussed in the following hypothesis tests.

In statistics, the likelihood-ratio test assesses the goodness of fit of two competing statistical models, usually one estimated by maximum likelihood over the entire parameter space and the other estimated after imposing some constraint, based on the ratio of their likelihoods. If the constraint (i.e., the null hypothesis) is supported by the observed data, the two likelihoods should not differ by more than sampling error.

As the sample size increases, and if the null hypothesis lies strictly within the interior of the parameter space, the test statistics are asymptotically chi-squared distributed with degrees of freedom equal to the difference in dimensionality of the two parameter spaces. Therefore, we can calculate the likelihood ratio value and compare it with the Chi-square distribution to test if two nested models perform statistically differently. This procedure is illustrated by the following equations.

$$\text{LogLikelihood}_1 - \text{LogLikelihood}_2 \sim \chi^2(def)$$
$$def = \Theta_1 - \Theta_2 \quad \text{(Eq. 3.7)}$$

In this study, the likelihood-ratio tests are used to compare the model performance between the restricted model and the unrestricted models. The unrestricted models refer to models that have no constraints, while restricted models refer to models that impose any restriction on the covariates. Nevertheless, both restricted and unrestricted models use the same statistical settings and the same other variables in the model so that their likelihoods are comparable. Three unrestricted models (Table 3.5, Table 3.6, and Table 3.7) and one restricted model (Table 3.4) are estimated.

The first unrestricted model (Table 3.5) introduces separate terms for rumble strips' locations (edge and shoulder); the second unrestricted model (Table 3.6) introduces separate terms for rumble strips' width (12″ and 16″); and the third unrestricted model (Table 3.7) introduces separate terms for two different rumble strips' profiles: conventional and sinusoidal. The restricted model ignored the differences in rumble strips' width, locations, and profiles, i.e., it assumes that width, location, and profile effects are the same. Because the restricted model forces the coefficients of the separate terms to be the same, it is a nested model compared to the larger unrestricted models and thus the likelihood ratio test can be performed to check if the model performs significantly differently when removing the restriction.

The performance of the models is assessed by the model fitness index *-2 Res Log Pseudo-Likelihood.* According to the results, all three unrestricted models performed slightly better than the restricted model, because their *-2 Res Log Pseudo-Likelihood* values are smaller. However, for the first and second models (Table 3.5 and Table 3.6), their differences of *-2 Res Log Pseudo-Likelihood* compared to the restricted model (16,010 - 16,008 = 2; 16,010 - 16,006 = 4) are

TABLE 3.5
Estimation results of crash frequency model (separate edge and shoulder)

Effect	**Estimate**	**Std. Err**	**t Value**	**Pr > |t|**
		Fixed Parameter		
Intercept	-5.433	0.211	-25.77	<.0001
LogAADT	0.558	0.026	21.78	<.0001
LogLength	0.603	0.047	12.96	<.0001
SouthArea	-0.181	0.064	-2.84	0.0046
ShdWidth	-0.007	0.009	-0.81	0.4184
DeflectionAnglRate	0.005	0.000	11.55	<.0001
NumCurve	0.031	0.011	2.68	0.0074
Edge	0.096	0.333	0.29	0.774
Shoulder	-0.213	0.185	-1.15	0.2483
Center	-0.142	0.055	-2.59	0.0095
CenterEdge	-0.288	0.105	-2.75	0.0059
CenterShoulder	-0.202	0.094	-2.14	0.0324
		Covariance Parameter		
Intercept (RumbleID)	0.1396	0.017	8.27	<.0001
Scale	0.3972	0.020	20.09	<.0001
		Model Fitness		
-2 Res Log Pseudo-Likelihood			Gener. Chi-Square/DF	
16,008			1.04	

TABLE 3.6
Estimation results of crash frequency model (separate 12″ and 16″ width)

Effect	**Estimate**	**Std. Err**	**t Value**	**Pr > |t|**
		Fixed Parameter		
Intercept	-5.436	0.211	-25.81	<.0001
LogAADT	0.559	0.026	21.81	<.0001
LogLength	0.603	0.047	12.95	<.0001
SouthArea	-0.182	0.064	-2.86	0.0043
ShouldWid	-0.008	0.009	-0.83	0.4047
DeflectionAnglRate	0.005	0.000	11.55	<.0001
NumCurve	0.031	0.011	2.7	0.0069
Side12	-0.070	0.210	-0.33	0.74
Side16	-0.236	0.246	-0.96	0.339
Center	-0.142	0.055	-2.61	0.0091
CenterSide12	-0.222	0.099	-2.25	0.0246
CenterSide16	-0.261	0.099	-2.63	0.0085
		Covariance Parameter		
Intercept (RumbleID)	0.138	0.017	8.26	<.0001
Scale	0.398	0.020	20.12	<.0001
		Model Fitness		
-2 Res Log Pseudo-Likelihood			General Chi-Square/DF	
16,004			1.04	

TABLE 3.7
Estimation results of crash frequency model (separate conventional and sinusoidal types)

Effect	**Estimate**	**Std. Err**	**t Value**	**Pr > |t|**
		Fixed Parameter		
Intercept	-5.436	0.211	-25.83	<.0001
LogAADT	0.559	0.026	21.83	<.0001
LogLength	0.603	0.047	12.95	<.0001
SouthArea	-0.182	0.064	-2.86	0.0043
ShdWidth	-0.008	0.009	-0.84	0.3984
DeflectionAnglRate	0.005	0.000	11.53	<.0001
NumCurve	0.031	0.011	2.72	0.0066
ConvSide	-0.236	0.246	-0.96	0.3379
SinuSide	-0.070	0.210	-0.33	0.74
ConvCenter	-0.166	0.060	-2.78	0.0055
SinuCenter	-0.035	0.121	-0.29	0.7726
ConvCenterSide	-0.307	0.085	-3.59	0.0003
SinuCenterSide	-0.106	0.121	-0.87	0.3827
		Covariance Parameter		
Intercept (RumbleID)	0.138	0.017	8.26	<.0001
Scale	0.398	0.020	20.13	<.0001
		Model Fitness		
-2 Res Log Pseudo-Likelihood			General Chi-Square/DF	
15,970			1.04	

too small to pass a Chi-square test with 2 degrees of freedom at 0.05 significance level (the difference should be greater than 5.99 to reject the null hypothesis). Therefore, the null hypothesis that the models performed equally cannot be rejected, indicating that there is no need to estimate the safety effects of rumble strips' location and width separately.

For rumble strips' locations (edge and shoulder), the offset is used to determine how far the rumble strips are from the lane edge markers. An *Edge* rumble strip refers to the fact that no offset exists between the rumble strips and the line that marks the edge of the road. In Indiana practice, INDOT only uses a 6 or 8 inch offset, so, the *Edge* and *Shoulder* rumble strips used in this study are both quite close to lane edge markers. Therefore, no significant performance difference was detected. This result is in line with the findings in NCHRP Report 641. They classified lateral offsets of 0″ to 8″, 9″, to 20″, and greater than 21″ and found that fewer crashes are reduced when rumble strips have an offset larger than 9″. INDOT standards align with the NCHRP Report 641, as INDOT implements offsets of only 6″ and 8″; thus, scenarios with offsets greater than 9″ could not be tested and compared.

For the width of the rumble strips, the estimate of CenterSide12 is slightly larger than CenterSide16 (-0.222 > -0.261) indicating that wider rumble strips might work better, but this difference was not significant enough to conclude that a 16″ width is better than 12″ width. It should be noted that INDOT currently uses a 10″ width for new rumble strips. Whether a 10″ width rumble strip will perform as well as 12″ and 16″ needs to be investigated in a future study.

Comparing the third unrestricted model (Table 3.7) and the restricted model, the model performance difference is 16,010 - 15,970 = 40, which is much greater than the required difference to reject the null hypothesis. Therefore, it is concluded that separating conventional and sinusoidal rumble strips is supported by the model goodness of fit. However, according to the results found in field tests, sinusoidal rumble strips can generate larger noise and vibrations compared to the conventional ones. The conflicting findings from statistical analysis and field tests indicate that there may be some bias when estimating the true effects of sinusoidal rumble strips.

After investigating the distribution of the overall crash rate (Table 3.8) for segments with different profiles, it is confirmed that this discrepancy between statistical models and field tests is due to the natural selection bias between sinusoidal and conventional rumble strips. Because sinusoidal rumble strips are newer, they tend to be installed on segments that were not prioritized for receiving rumble strips and often have narrower shoulders and more roadside hazards. In contrast, conventional rumble strips are more likely to be installed on segments with greater potential for safety improvement, which explains their seemingly higher effectiveness. As shown in Table 3.8, the crash rates after installation of the two rumble strips are very close; the main difference lies in the crash rate before installation. The conventional rumble strips seem to be more effective because there was more room for improvement for segments with conventional rumble strips.

TABLE 3.8
Crash rate (crash per mile per year) distribution

	Sinusoidal	Conventional
Before Installation	0.444	0.586
After Installation	0.426	0.419

3.5 Crash Severity Model Results

The random effect ordered logit model was used to estimate changes of crash severity distribution with and without different settings of rumble strips. The estimation results of crash severity model are shown in Table 3.9. The results include three parts: fixed parameter, covariance parameter and model fitness.

The covariance parameters are found to be significant in justifying the use of random effects. The model fitness includes two statistics *-2 Log Likelihood* and *AIC*, both of which could only be used for model fitness comparison among nested models.

The fixed parameters include five variables except the two intercepts. Because the crash severity model examines the probability of falling into higher crash severity given the occurrence of crash, the negative estimates reflect the corresponding effect tends to lower the probability of severe crashes.

Shoulder width was found to decrease the probability of severe crashes and the number of curves on the segment was found to increase the probability of severe crashes. Both effects are intuitive.

The effects from rumble strips are consistent in terms of signs (positive or negative) and all the three scenarios will decrease the probability of severe crashes. But in terms of effectiveness, it seems that only *Side* performed best (-0.407), while *Center* (-0.215) and *Center+Side* (-0.184) performed similarly. The unusually high performance of *Side* may be due to the limited sample size of this scenario.

TABLE 3.9
Estimation results of crash severity model

Effect	Estimate	Std. Err	t Value	Pr > |t|
Fixed Parameter				
Intercept 1	-1.468	0.039	-37.36	<.0001
Intercept 2	-0.834	0.037	-22.63	<.0001
SouthArea	0.171	0.070	2.45	0.0144
ShdWidth	-0.032	0.012	-2.74	0.0062
NumCurve	0.020	0.011	1.73	0.0845
Side	-0.407	0.217	-1.88	0.0602
Center	-0.215	0.072	-3.01	0.0026
CenterSide	-0.184	0.094	-1.95	0.0511
Covariance Parameter				
Intercept (RumbleID)	0.112	0.025	4.55	<.0001
Model Fitness				
-2 Log Likelihood			AIC	
18,014			18,032	

It is concluded that the effect of rumble strips on crash severity is estimated to be around -0.2 for all scenarios regardless of the rumble strips' locations.

During the analysis, a notable shift in trends for fatal or incapacitating (KA) crashes and non-incapacitating (BC) crashes were observed. This change is likely due to a 2020 revision by Indiana's police department regarding the definition of incapacitating crashes. Before 2020, any crash in which an individual was "transported from the scene" was classified as incapacitating. After the revision, this criterion was removed, causing similar crashes to no longer be categorized as incapacitating. To account for this change and ensure consistency with the updated definitions, the KA and BC categories were combined into a single KABC category.

The methodology to calculate the KABC and PDO CMF's is presented next.

1. The original crash severity distribution is (KABC: 29.8%; PDO: 70.2%). Calculate $\exp(X\beta)$.

$$\exp(X\beta) = \frac{P(KABC)}{1 - P(KABC)} = \frac{29.8\%}{1 - 29.8\%} = 0.425 \quad \text{(Eq. 3.8)}$$

2. According to crash severity model (ordered logit), the estimated shift coefficient of rumble strip effect is -0.2. Calculate the changed probability of KABC as

$$P(KABCnew) = \frac{\exp(X\beta) * \exp(-0.2)}{1 + \exp(X\beta) * \exp(-0.2)} = \frac{0.425 * 0.819}{1 + 0.425 * 0.819} = 25.8\% \quad \text{(Eq. 3.9)}$$

3. Calculate by-severity CMFs using the equations below.

$$CMF(KABC) = \frac{CMF * P(KABCnew)}{100\% * P(KABC)} \quad \text{(Eq. 3.10)}$$

$$CMF(PDO) = \frac{CMF * P(PDOnew)}{100\% * P(PDO)} = \frac{CMF * (1 - P(KABCnew))}{100\% * (1 - P(KABC))} \quad \text{(Eq. 3.11)}$$

4. For *Center Only* and *Side Only*, the overall CMF is 0.87.

$$CMF(KABC) = \frac{CMF * P(KABCnew)}{100\% * P(KABC)} = \frac{0.87 * 0.258}{0.298} = 0.753 \quad \text{(Eq. 3.12)}$$

$$CMF(PDO) = \frac{CMF * (1 - P(KABCnew))}{100\% * (1 - P(KABC))} = \frac{0.87 * (1 - 0.258)}{1 - 0.298} = 0.920 \quad \text{(Eq. 3.13)}$$

5. For *Center + Side*, the overall CMF is 0.79.

$$CMF(KABC) = \frac{CMF * P(KABCnew)}{100\% * P(KABC)} = \frac{0.79 * 0.258}{0.298} = 0.684 \quad \text{(Eq. 3.14)}$$

$$CMF(PDO) = \frac{CMF * (1 - P(KABCnew))}{100\% * (1 - P(KABC))} = \frac{0.79 * (1 - 0.258)}{1 - 0.298} = 0.835 \quad \text{(Eq. 3.15)}$$

Due to the shift of KABC crashes to PDO crashes, the CMF for PDO crashes is higher than the overall CMF, while the KABC CMF is smaller. The installation of rumble strips reduces the crash counts, and this reduction is greater for more severe crashes.

4. FIELD OBSERVATIONS

The primary goal of the field observations was to ascertain if the two rumble strip types, namely conventional and sinusoidal rumble strips, adequately warn the driver of impending departure in the form of noise and vibration. This section describes the equipment used for collecting noise and vibration data, the experimental setup, field data collected, methodology used to analyze the data and conclusions derived from the analysis.

4.1 Measurement Objectives and Sensors Used

4.1.1 Sound Pressure Level Measurement

Sound pressure level (SPL) is a measure of the fluctuations in air pressure caused by sound waves and is typically expressed in decibels (dB). The decibel scale is a logarithmic scale, and a 6 dB increase in sound pressure level corresponds to a doubling of SPL. Human ears perceive loudness differently at different frequencies. For instance, human ears are more sensitive to frequencies in the 1 kHz–4 kHz range. To account for this sound measurements are typically done using the "A" weighted decibel scale denoted with units dB(A) or dBA.

Rumble strips are designed to produce a distinct increase in sound pressure level (SPL) compared to the noise level of the adjacent road pavement. This feedback is crucial for alerting drivers and enhancing road safety. NCHRP 641 recommends the following increases in ambient in-vehicle noise levels for effective rumble strips.

- 3 dBA: minimum design value.
- 6 dBA: desirable design value.
- 15 dBA: maximum design value.

The key objective of field experiments is to ensure that the sound generated by the rumble strips is at least 3 dBA louder than the ambient road noise and preferably over 6 dBA. Sound level meters (SLMs) are specialized instruments used to measure SPL. These devices are calibrated to provide precise readings of sound pressure in dBA. However, for the purpose of this study, a smartphone-based application, decibelX, was employed to measure SPL.

The decibelX application is a convenient tool for recording SPL using a smartphone. According to its documentation, the application requires a simple offset calibration for accurate SPL readings. This implies that the difference between two measurements taken with the smartphone app will be consistent with the difference reported by a dedicated SLM. Therefore, the smartphone app can reliably measure the delta in SPL when transitioning from road pavement to rumble strips. One significant advantage of using the decibelX application is its capability to record video along with audio. The app overlays the SPL value and frequency spectrum of the sound being recorded on top of the video. This feature allows for easy verification and provides a better qualitative understanding of the results. By reviewing the video recordings, researchers can visually and audibly assess the impact of rumble strips in real-time.

4.1.2 Vibration Measurement

In addition to generating increased sound pressure levels (SPL), rumble strips provide crucial feedback through heightened vibrations when a vehicle traverses them. The objective of this study is to quantify the intensity of vibrations encountered by vehicles on rumble strips versus standard road pavement. Vibration analysis can be conducted using various units, including displacement, velocity, and acceleration, presented as a time waveform (TWF). Additionally, the Fast Fourier Transform (FFT) can be applied to the TWF to analyze the resulting frequency spectrum. This frequency domain analysis helps identify dominant frequencies and provides a more detailed understanding of the vibrational response induced by the rumble strips.

To measure acceleration, Vectornav's VN-200 sensors were used. The VN-200 is a GNSS-Aided Inertial Navigation System (GNSS/INS) that integrates 3-axis gyros, accelerometers, and magnetometers with a high-sensitivity GNSS receiver. This comprehensive sensor suite allows for precise measurement and analysis of the vehicle's acceleration and vibrational behavior.

4.2 Experimental Setup

To accurately estimate the sound pressure level (SPL) perceived by the driver, measurements must be taken as close to the driver's ear as possible. To facilitate this, a phone mount was securely fixed to the headrest of the driver's seat, and the phone used for measurement was attached to this mount (Figure 4.1).

When a vehicle travels over a rumble strip, the entire chassis experiences vibrations. These vibrations are transmitted to the driver through the steering wheel and the driver's seat. However, the cushion in the driver's seat dampens some of the vibrations originating from the rumble strips, making it a suboptimal location for measuring vibrations. Consequently, the optimal location for measuring vibrations is the steering wheel, where the driver most directly feels the vibrations. To capture these measurements, the VN 200 INS sensor was strategically placed behind the steering wheel, on the steering column, just in front of the instrument cluster (Figure 4.2). This placement ensures that the sensor does not obstruct the driver's view of the instrument cluster or interfere with the driver's ability to steer the vehicle.

Additionally, the GPS antenna of the INS was attached to the roof of the vehicle using a permanent magnet (Figure 4.3). This placement ensures a stable and reliable connection, essential for accurate positioning and measurement data. The IMU was configured to measure at its maximum sampling rate of 200 Hz.

Figure 4.1 Phone mount affixed to the driver's headrest.

Figure 4.2 VN200 INS sensor mounted on the steering column.

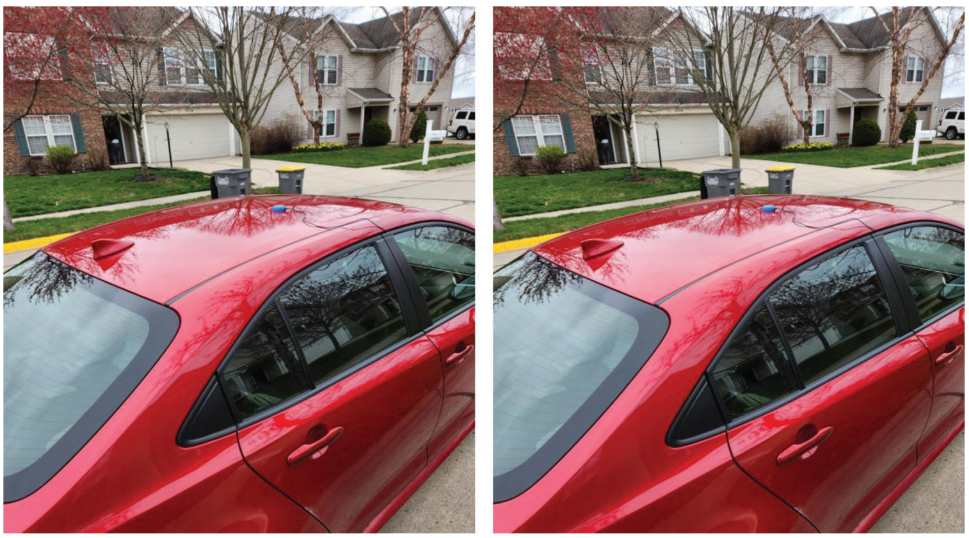

Figure 4.3 GPS antenna mounted on top of vehicle.

4.3 Field Data Collection

Field observations were made along four different stretches of road, two each of the sinusoidal profile and conventional profile. All stretches of roads had a posted speed limit of 55 mph. Data collection was focused solely on the edge-line rumble strips, as driving on the centerline rumble strips was deemed unsafe. On each stretch two vehicles, each of different class was used. This was to ascertain if different vehicle types experience different levels of noise and vibration.

The driver engaged the vehicle's cruise control to maintain consistent speeds and drove along the designated stretch, alternating between driving on the rumble strip for 7–10 seconds and on the road pavement for 7–10 seconds. This procedure was repeated three times for each chosen speed. Three different speeds were selected for the analysis: 50 mph, 55 mph, and 60 mph, corresponding to the posted speed limit, 5 mph below, and 5 mph above it, respectively.

During these trials, sound pressure levels and acceleration measurements were recorded using appropriate sensors mentioned in the previous sections. This comprehensive approach, utilizing distinct vehicle types and multiple speed variations, ensured a robust dataset for comparing the performance of the two different types of rumble strips.

The first set of observations was conducted on June 18th, 2024. Two vehicles of different classes were utilized: a sedan (Ford Fusion, second generation) and an SUV (Dodge Durango). The locations for data collection and the type of rumble strips installed are shown in Figure 4.4. US 231 had 10″ wide rumble strips on the edge-line, whereas SR 28 had 12″ wide edge-line strips.

The second set of observations were conducted on July 15th, 2024, and the vehicles used were a sedan (Ford Fusion, model year 2020) and a minivan (Dodge Caravan, model year 2020). More information on the location and type of rumble strips are provided in

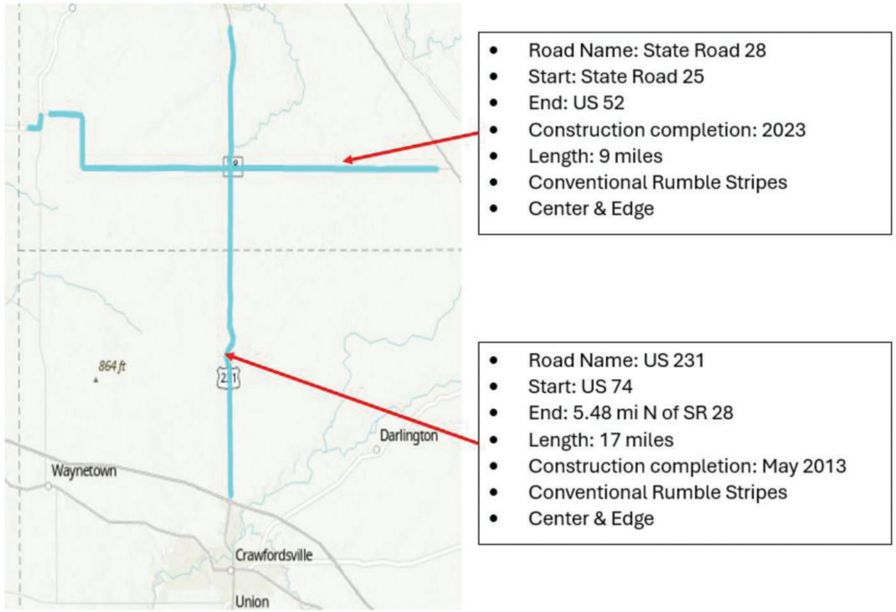

Figure 4.4 Location information of field observations conducted on June 18th, 2024.

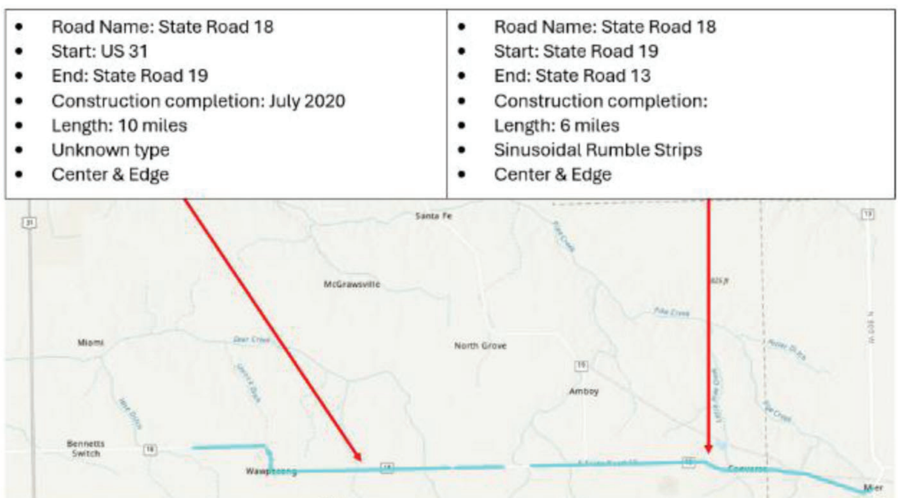

Figure 4.5 Location information of field observations conducted on July 15th, 2024.

Figure 4.5. The stretch of road from US 31 to SR 19 had 8″ strips whereas the stretch from SR 19 to SR 13 had 12″ strips.

4.4 Analysis

4.4.1 Noise Analysis

Summary of the logged sound pressure level (SPL) data for conventional rumble strips on SR 28 and US 231 are presented in Table 4.1 and Table 4.2, respectively. The data file for the sedan at 50 mph was corrupted and was unable to be used for the analysis. On average, the difference in SPL between the pavement and the conventional rumble strip is lower on US 231 than on SR 28. This disparity can be attributed to two main factors.

First, there is a significant age difference between the two road segments. The rumble strips on SR 28 were only 1 year old, whereas the conventional rumble strips on US 231 were over 10 years old at the time of data collection. The older rumble strips on US 231 had experienced considerable wear and tear, reducing their effectiveness.

Second, growing vegetation between the conventional rumble strips on US 231 (Figure 4.6) contributed to a sound dampening effect in certain segments. All three occupants in the vehicle were able to notice this intermittently reduced sound output. Despite these factors, the conventional rumble strips still induced an SPL increase of at least 3 dBA in all trials.

On SR 28, the conventional rumble strips were not continuous throughout the segment of the road.

TABLE 4.1
Sound pressure level (SPL) data summary for conventional rumble strip on SR 28

Speed (s)	Type of Vehicle	Rumble Strip Duration (s)	Rumble Strip SPL (dBA) Min	Max	Avg	Pavement Duration (s)	Pavement SPL (dBA) Min	Max	Avg	Difference in Average
50	Sedan	10	85.2	91.1	88.2	9	78	79.6	78.8	9.4
		15	78.8	90.6	86.2	16	78.5	89.5	81.1	9.7
		12	78.9	91.5	88.0	6	76.8	83.2	79.1	9.0
55	Sedan	15	82.9	93.6	89.8	8	74.1	90.8	81.8	8.1
		14	81.3	97.9	91.0	7	78.9	91.3	84.3	6.7
		11	80.2	97.5	89.6	13	77.6	91.8	81.4	8.2
60	Sedan	13	81.5	91.1	88.1	9	76.5	80.8	79.3	8.9
		14	86.8	91.5	89.3	9	76.9	80.6	79.6	9.7
		12	87.5	91	89.2	10	74.6	89.7	81.5	7.7
50	SUV	9	78.1	96.9	88.0	7	75.3	83.7	80.0	8.0
		11	82.6	94.2	88.8	10	74.4	79	77.5	11.3
		9	83.5	94	89.6	7	71.6	79.5	77.8	11.8
55	SUV	13	80.7	90.6	87.6	5	73.5	81.4	78.3	9.4
		10	83.3	88.9	87.2	5	73	78.6	76.7	10.5
		12	83.4	92.1	88.7	5	72.3	79.1	75.5	13.2
60	SUV	7	84.5	89.1	87.4	6	71.3	81.3	78.2	9.3
		8	85.6	89.8	88.4	10	74.7	83.5	79.7	8.6
		9	86.1	90	88.2	7	72.8	81.2	79.2	9.0

TABLE 4.2
Sound pressure level (SPL) data summary for conventional rumble strip on US 231

Speed (s)	Location/Type of Rumble Strip	Rumble Strip Duration (s)	Rumble Strip SPL (dBA) Min	Max	Avg	Pavement Duration (s)	Pavement SPL (dBA) Min	Max	Avg	Difference in Average
55	Sedan	8	84.8	89.4	87.5	10	77.1	83.7	81.8	5.7
		14	82.1	90.7	86.5	12	76	84.9	81.9	4.6
		14	75.1	92.1	86.9	5	78.2	82	80.2	6.7
60	Sedan	9	87.3	90.5	88.7	9	77.3	85.3	81.4	7.3
		15	82.2	95.4	89.3	8	79.3	87	83.6	5.8
		13	83.2	93.5	88.7	6	79.8	85.5	82.9	5.8
50	SUV	13	80.9	88.3	84.9	6	76.3	84.5	80.7	4.3
		12	83.1	87.2	85.0	6	75.8	83.8	80.1	4.9
		10	85.8	87.9	87.0	4	78.6	82.5	80.9	6.1
55	SUV	6	84	87.4	86.3	7	76.6	82.6	80.4	5.9
		7	84.6	89	86.2	7	79	88.7	82.5	3.7
		7	82.6	88.8	86.6	6	78.7	82.9	81.0	5.6
60	SUV	8	83.6	88.1	86.3	7	78.6	82.5	81.3	5.0
		13	83.6	89	85.9	5	79.2	84.1	81.5	4.4
		10	84.4	90.1	87.0	3	77.4	81.5	80.1	6.9

Instead, these rumble strips included bicycle gaps, i.e., a short stretch with no rumble strips (Figure 2.1). These gaps, however, resulted in momentary reductions in sound pressure level (SPL) as vehicles traversed them. Consequently, when the SPL measurements were averaged over a duration of several seconds, the obtained values were lower than they would have been if the rumble strips were continuous.

Table 4.3 summarizes the recorded SPL data for sinusoidal rumble strips on SR 18 between US 31 and SR 19, whereas Table 4.4 does the same for SR 18 for the stretch between SR 19 and SR 13.

Figure 4.6 Vegetation growing in between rumble strips: US 231.

TABLE 4.3
Sound pressure level (SPL) data summary for sinusoidal rumble strips on SR 18 (between US 31 and SR 19)

		Rumble Strip				Pavement				
			SPL (dBA)				SPL (dBA)			
Speed (s)	**Type of Vehicle**	**Duration (s)**	**Min**	**Max**	**Avg**	**Duration (s)**	**Min**	**Max**	**Avg**	**Difference in Average**
50	Sedan	14	83.3	88.3	86.8	12	71.9	90.1	78.9	7.9
		12	86.9	89	87.6	11	70.6	78.8	77.0	10.6
		15	85.1	88.9	87.8	14	73.9	79.6	77.7	10.1
55	Sedan	15	83.3	91	88.5	13	74.6	80.4	79.1	9.4
		20	84.4	92.2	89.5	15	78.7	85	80.0	9.5
		19	82.9	91	88.8	16	78.4	80.3	79.2	9.6
60	Sedan	10	84.2	92.1	89.1	9	71.5	81.3	79.4	9.7
		18	85.1	92.8	89.6	11	70.2	83.6	80.3	9.3
		13	86.1	91.3	89.6	8	78.9	81.8	80.3	9.3
50	Minivan	9	78.1	96.9	88.0	7	75.3	83.7	80.0	8.0
		11	82.6	94.2	88.8	10	74.4	79	77.5	11.3
		9	83.5	94	89.6	7	71.6	79.5	77.8	11.8
55	Minivan	13	80.7	90.6	87.6	5	73.5	81.4	78.3	9.4
		10	83.3	88.9	87.2	5	73	78.6	76.7	10.5
		12	83.4	92.1	88.7	5	72.3	79.1	75.5	13.2
60	Minivan	12	84.5	89.1	87.4	6	71.3	81.3	78.2	9.3
		8	85.6	89.8	88.4	10	74.7	83.5	79.7	8.6
		9	85.4	89.7	87.6	7	72.8	81.2	79.2	9.0

Another method to analyze the sound recordings is to look at the frequency spectrum of the sound recorded when the vehicle is over the road versus when the vehicle is over the rumble strip.

The graphs in Figure 4.7 and Figure 4.8 are amplitude versus frequency plots show the amplitude of each frequency present in the recorded sounds. From the two graphs, it can be shown that sinusoidal rumble strips produce lower amplitude signals when compared to conventional rumble strips.

4.4.2 Vibration Analysis

The IMU unit was mounted behind the steering wheel on the steering column. The surface on which the sensor was mounted was not perpendicular to gravity. Thus, the IMU's estimated roll and pitch angles are used to reorient the frame of reference such that the three axes of the IMU are parallel to that of the vehicle. Then the constant acceleration due to gravity experienced by the accelerometer is removed by subtracting -9.806.

TABLE 4.4
Sound pressure level (SPL) data summary for sinusoidal rumble strips on SR 18 (between SR 19 and SR 13)

		Rumble Strip				Pavement				
			SPL (dBA)				SPL (dBA)			
Speed (s)	Type of Vehicle	Duration (s)	Min	Max	Avg	Duration (s)	Min	Max	Avg	Difference in Average
50	Sedan	18	88.9	92.1	90.8	6	75.3	80.9	79.5	11.3
		16	90	92.4	91.1	10	74	81.3	79.0	12.1
		7	90.4	92.7	91.2	7	75	81.2	78.3	13.0
55	Sedan	10	88.8	92.6	90.0	11	76.5	82.2	80.5	9.5
		11	88.4	90.8	89.6	11	74.3	80.6	79.4	10.1
		13	88.4	91.5	90.0	6	75.6	80.5	78.8	11.3
60	Sedan	11	90.2	93.1	91.4	12	70.1	81.8	79.4	12.0
		12	89.8	91.6	90.6	13	71.5	83.2	80.8	9.8
		12	86.7	92.9	90.6	7	73.7	82.2	80.2	10.5
50	Minivan	20	87.1	96.9	88.1	7	75.3	83.7	77.5	10.6
		7	84.6	94.2	86.8	10	74.2	79.7	78.1	8.7
		10	85.5	94	89.6	7	71.6	79.5	76.9	12.7
55	Minivan	9	87.7	91.6	89.6	7	73.5	83.2	78.6	11.0
		14	88.3	90.9	87.2	15	73	78.6	76.7	10.5
		9	88.4	92.1	88.7	8	75.3	79.1	77.6	11.1
60	Minivan	7	84.5	89.1	87.4	5	71.3	81.3	78.2	9.3
		9	85.6	89.8	88.4	12	74.7	83.5	79.7	8.6
		10	86.1	90	88.2	10	72.8	81.2	79.2	9.0

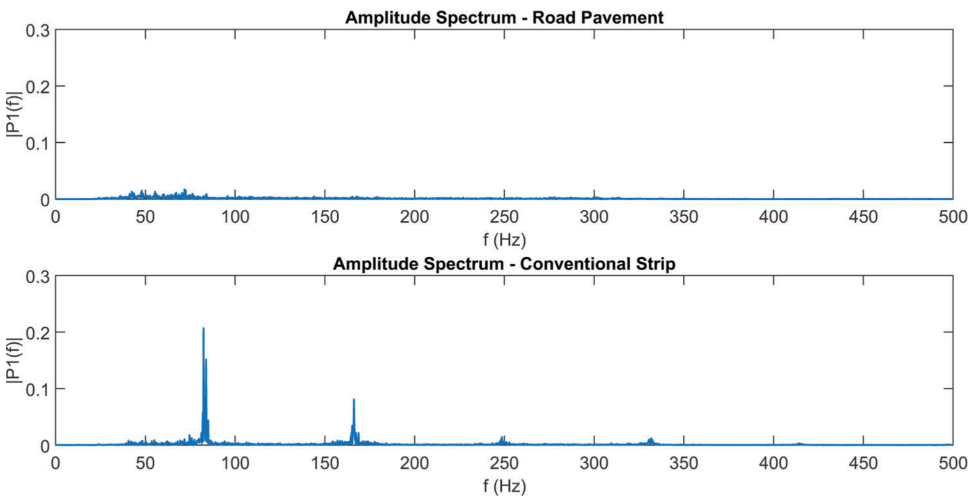

Figure 4.7 Amplitude spectrum of sound recording for a sedan on SR 28: sinusoidal rumble strips.

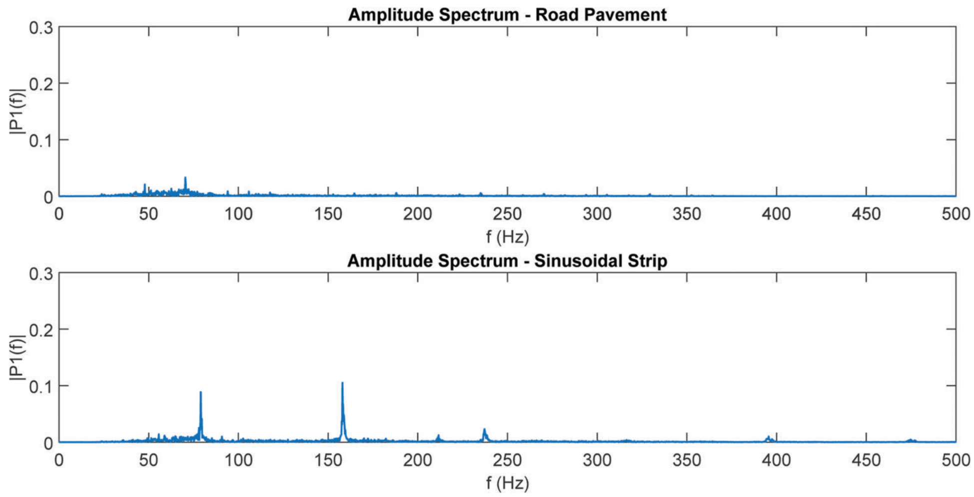

Figure 4.8 Amplitude spectrum of sound recording for a sedan on SR 18: sinusoidal rumble strips.

Then for each individual axis, vibration intensity expressed as a moving Root Mean Square (RMS) value is calculated using the formula:

$$RMS_t = \sqrt{\frac{1}{s}\sum_{i=t}^{t+s-1} \alpha_i^2} \quad \text{(Eq. 4.1)}$$

Where:

- RMS_t is the root mean square value at time t.
- α_i is the acceleration value at time i.
- s is the window size. In this analysis a window size equal to sampling frequency is used.

The combined or total vibration intensity experienced by the sensor is the vector sum of RMS values along the three component axes

$$RMS_{\text{Total}} = \sqrt{RMS_{\text{lateral}}^2 + RMS_{\text{longitudinal}}^2 + RMS_{\text{vertical}}^2} \quad \text{(Eq. 4.2)}$$

Figure 4.9 shows the vibration intensity recorded along each axis for three different speeds in a sedan when the vehicle is passing over conventional rumble strips. The regions with elevated vibration intensity are when the vehicle was passing over the rumble strips. It can be seen in the figure that as speed increases the total vibration intensity increases.

Figure 4.10 shows vibration intensity experienced by the sedan when passing over sinusoidal rumble strips. The regions with elevated vibration intensity are when the vehicle was passing over the rumble strips. It can be seen in the figure that as speed increases the total vibration intensity increases.

The raw acceleration values over time when visualized does not provide any information about the constituent frequencies that make up the signal. By using Fast Fourier Transform, a powerful mathematical technique in the domain of signal processing, we can convert the signal from time domain to frequency domain. The resulting spectrum displays how much of each frequency is present in the original signal.

Figure 4.11 shows the amplitude spectrum for sedans moving at 55 miles per hour on conventional rumble strips. It can be seen in the figure that along all three axes, when the vehicle is on the road, there are no large spikes, indicating that the road is relatively "smooth." Along all three axes, there is a spike at 82.2 Hz when the sedan is on the rumble strips. This corresponds to a linear distance of approximately 12″ (11.78″) which is the spacing between two consecutive rumble strips. This confirms that the rumble strips induce a significant vibration on to the vehicle. Analysis on other trails also shows a spike in frequency corresponding to the spacing of the rumble strips. This value of 82.2 Hz is close to the value of 82 Hz obtained from the frequency spectrum of the recorded audio signal shown in Figure 4.7.

Figure 4.12 shows the amplitude spectrum for the test car moving at 55 miles per hour over sinusoidal rumble strips. Similarly to Figure 4.11, Figure 4.12 shows that when the vehicle is on the road pavement, there is no significant vibration over a specific frequency. When the vehicle is travelling on the sinusoidal rumble strip, there is a sharp spike at a frequency of 79.5 Hz. This corresponds to approximately 12″ (12.16″) which is the spacing between two consecutive crests of the sinusoidal rumble strips. This is very close to the value of 79.2 Hz obtained from the frequency spectrum of the audio recorded (Figure 4.8).

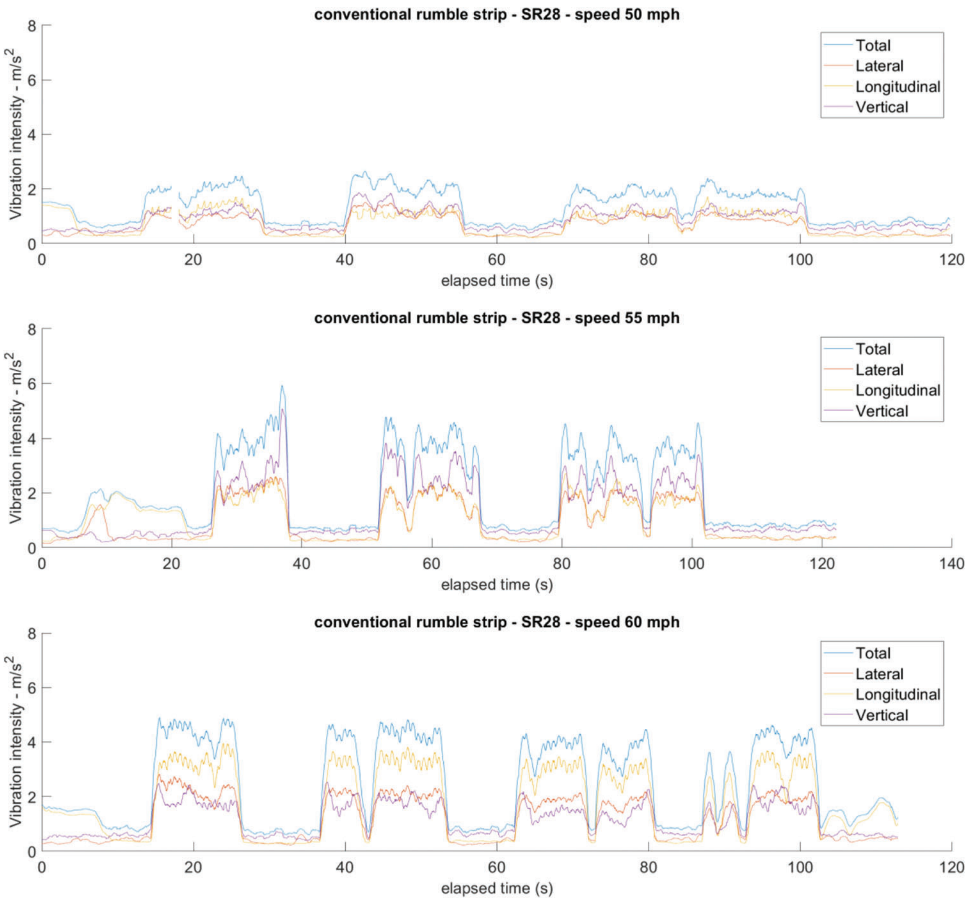

Figure 4.9 Vibration intensity results for sedan on SR 28: conventional rumble strips.

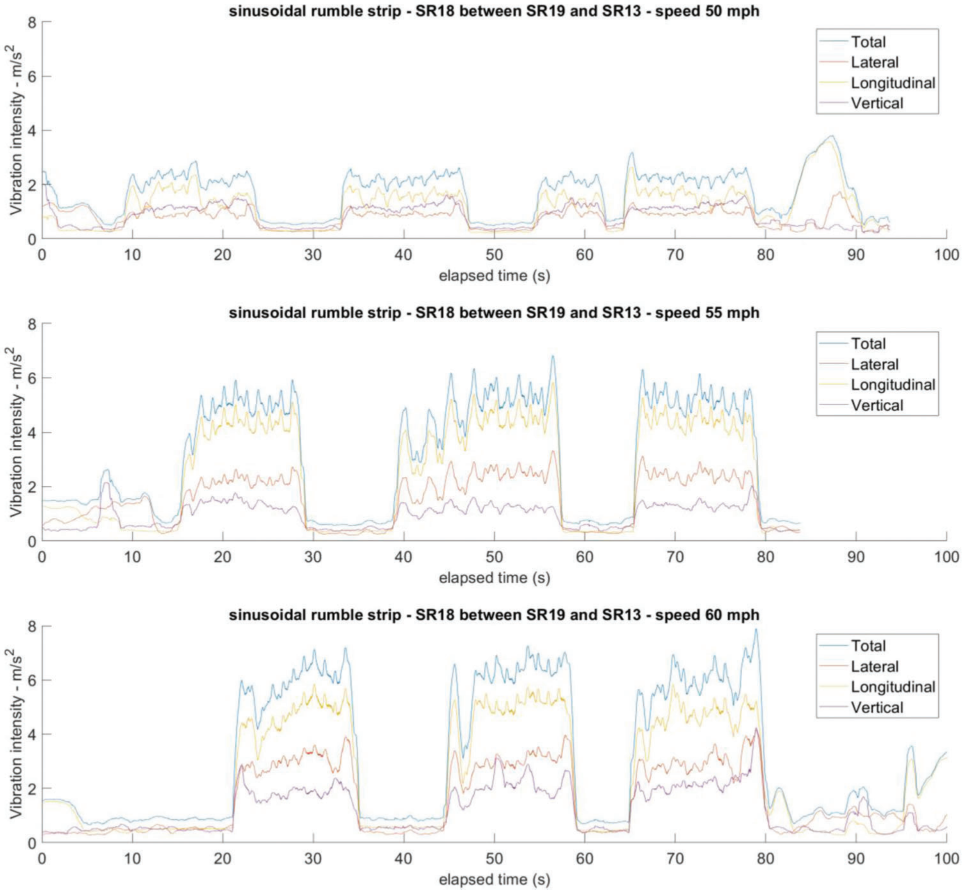

Figure 4.10 Vibration intensity results for sedan on SR 18 between SR 19 and SR 13: sinusoidal rumble strips.

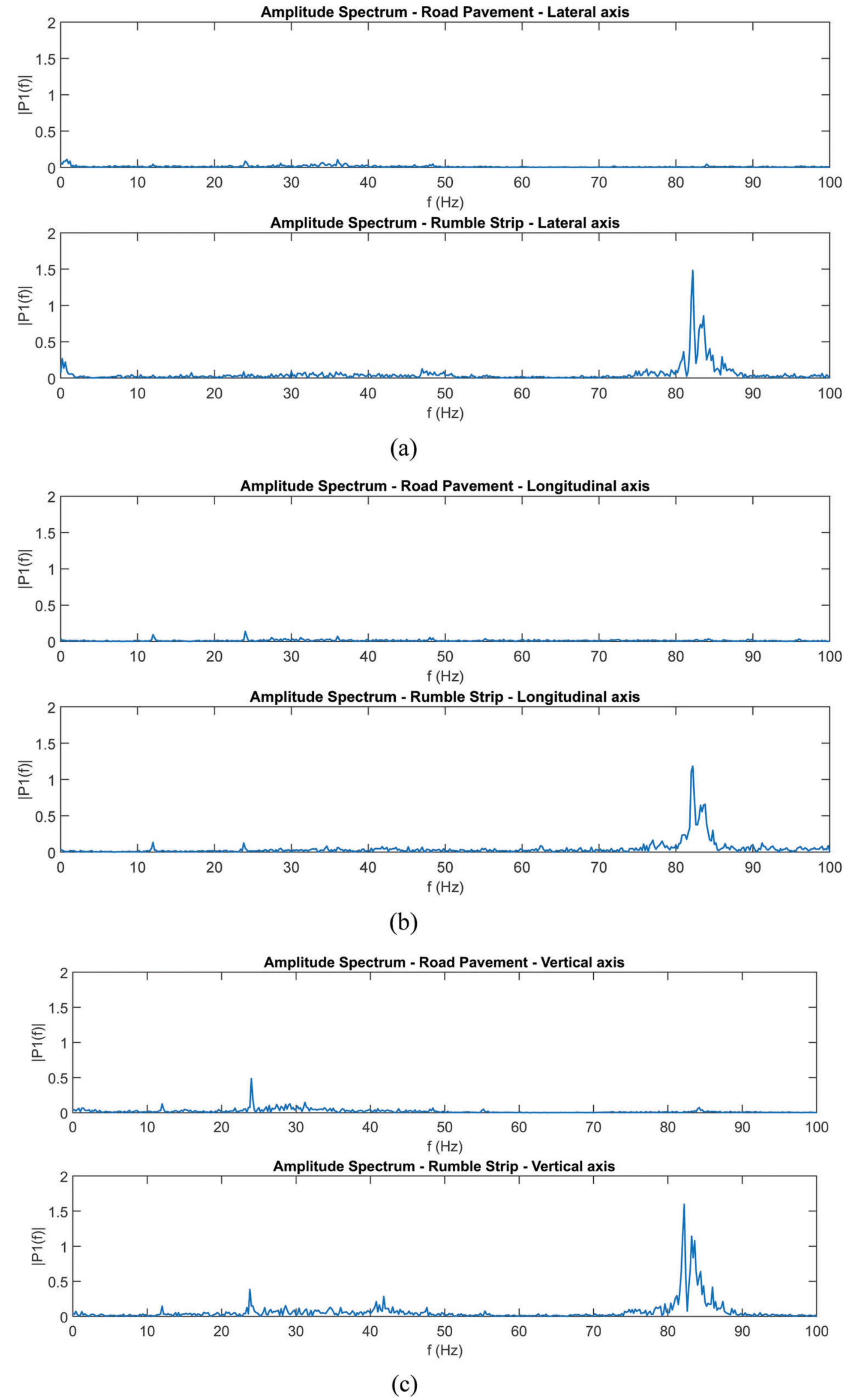

Figure 4.11 Amplitude spectrum of vibrations for a sedan moving at 55 mph on SR 28: conventional rumble strips.

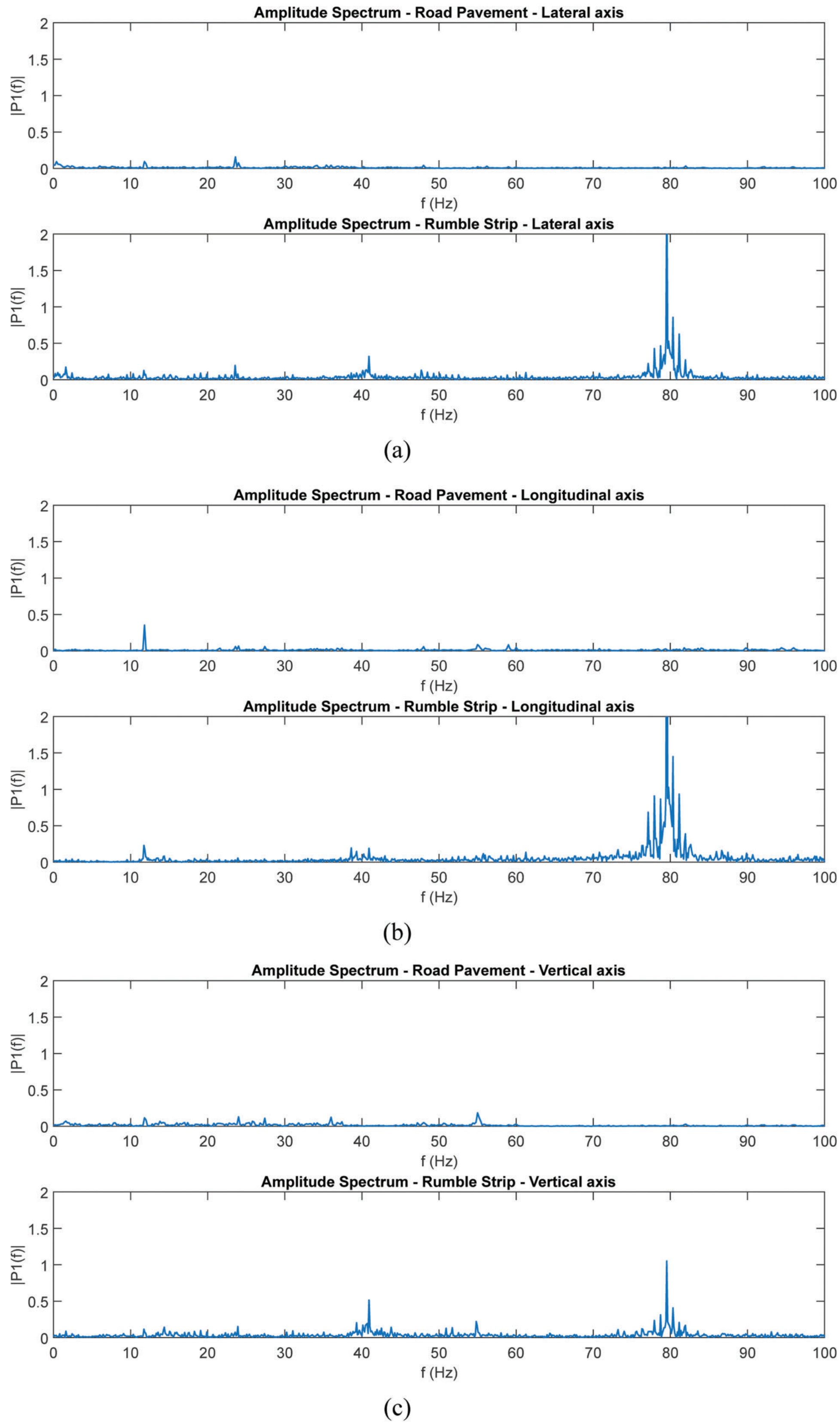

Figure 4.12 Amplitude spectrum of vibrations for a sedan moving at 55 mph on SR 18 between SR 19 and SR 13: sinusoidal rumble strips.

5. RESULTS SUMMARY

5.1 Safety Analysis Summary

Both crash frequency and crash severity models are developed to analyze the safety effectiveness of rumble strips. For crash frequency analysis, the negative binomial model with random effects was adopted and the likelihood ratio tests were performed to justify the model selection.

The model selection results show the following findings.

1. The 16″ width rumble strips show a slightly better crash reduction effect, although the difference is not statistically significant compared to the narrower setting (12″).
2. The analysis indicates no significant differences in safety performance between edge and shoulder rumble strips at the studied locations. This is likely due to the relatively small offsets of 6″ or 8″ used for shoulder rumble strips as mandated by INDOT standards. These findings align with existing literature, which suggests that rumble strips with offsets greater than 9″ tend to be less effective.
3. Sinusoidal rumble strips seem to perform less effectively than the conventional ones. However, it was identified that sinusoidal rumble strips (usually implemented later than conventional ones) tended to be installed on routes that were not prioritized for receiving rumble strips and often had more dangerous segments where there are narrower shoulders and more roadside hazards. This natural sample selection bias masked the true effectiveness of sinusoidal rumble strips. Moreover, a comparison of the post-treated safety performance shows that sinusoidal rumble strips could reduce crash rate to a similar level as conventional ones. To make solid statistical conclusions about rumble strips' safety effectiveness, it was suggested that the conventional and sinusoidal rumble strips samples analyzed together.

The crash frequency model itself shows the following important findings.

1. The significant covariant parameters justified the inclusion of random effect term. Such model specification assures that the estimated effects are not biased by the unobserved heterogeneity among segments.
2. The two exposure factors, *LogAADT* and *LogLength* representing the logarithm of the AADT and the segment length in mile, were found to increase the crash frequency as expected. More traffic and longer travel distance will increase the probability of crashes.
3. The geometry related variable *DeflectionAnglRate* (horizontal curve deflection angle rate) and *NumCurve* (number of curves) were found to significantly increase crash probability. This result confirmed the need for analyzing the rumble strips' safety effects within short homogeneous segments.
4. The safety effectiveness of rumble strips varies by their location configurations. The model estimation results for run-off-road or head-on crashes show that only *Center* or *Side* configuration could decrease the crash frequency with an expected 0.87 crash modification factor, although the effect for *Side* was not statistically significant. The lack of significance may be due to the small variation in the distances from the offset to the edge-line (6″ and 8″), which likely results in no observable effect. The combination of the roadside and center rumble strips is found to further decrease crash frequency with a 0.79 crash modification factor.

For crash severity analysis, the ordered logit model with random effects was adopted. The estimation results showed the following findings.

- Geometry settings were found to significantly affect crash severity. Shoulder width was found to decrease the probability of severe crashes while the number of curves on the segment was found to increase the probability of severe crashes.
- The effects of rumble strips vary across different location configurations (*Side*, *Center*, *Center+Side*), although all of them were found to reduce the crash severity levels for run-off-road or head-on crashes. It was suggested that a consistent rumble strips' effect (exp (-0.2) = 0.82) was used to estimate the shift of severity levels after installation of rumble strips. This shift of severity distribution together with the overall CMF yielded different CMFs by severity. For only *Center* or *Side* configuration (overall CMF = 0.87), the PDO CMF is 0.92 and the KABC CMF is 0.75. For *CenterSide* configuration (overall CMF = 0.79), the PDO CMF is 0.84 and the KABC CMF is 0.68.

Previous research has consistently demonstrated the safety effectiveness of rumble strips in reducing crashes across various roadway types. For instance, Patel et al. (2007) reported an 18.3% reduction for crashes in Illinois and a 13% reduction in Minnesota, while the NCHRP Report 641 estimated a 15% reduction for rural two-lane roads. Similarly, Persaud et al. (2004) found a 25% reduction in head-on and opposing-direction sideswipe crashes with centerline rumble strips across several states. This research estimates the crash modification factors (CMFs) for rumble strips installed on the roadside or centerline are both 0.87, indicating a 13% reduction in crashes. When rumble strips are installed on both the center and roadside, a CMF of 0.79 reflects a 21% reduction in crashes. Overall, the findings align closely with existing literature, reinforcing the efficacy of rumble strips as a critical intervention for enhancing roadway safety. It should be noted that this analysis was based on the targeted crashes (run-off-road and head-on), the obtained CMFs should be applied to such crashes instead of all crashes. The percentage of run-off-road and head-on crashes should be used to perform any benefit and cost analysis in practice.

5.2 Noise and Vibration Analysis Summary

Two different types of rumble strips were compared in this field study namely, conventional milled rumble strips and sinusoidal rumble strips for their ability to induce noise and vibration inside the vehicle.

Both these types of rumble strips, in each of the trials, provided the recommended minimum increase of 3 dBA in sound pressure level specified in NCHRP Report 641 (Torbic et al., 2009). The older conventional rumble strips on US 231 provided a 4.6–7.5 dBA increase whereas the newer conventional rumble strip on SR 28 and sinusoidal rumble strips on SR 18 all provided a minimum 7 dB increase in sound pressure level.

The increase in noise level for a sedan was different when compared to an SUV or a minivan. This could be due to a combination of several factors such as noise isolation properties of the vehicle cabin, tire age and material, weight of the vehicle etc. Nevertheless, the increase in sound pressure level was higher than 7 dBA regardless of vehicle type on the newer rumble strips. The data from US 231 showed the importance of maintenance of rumble strips. The presence of vegetation on the rumble strips decreases their effectiveness significantly.

Both sets of rumble strips provided noticeable vibrations at the steering wheel. The magnitude of vibration increased with the increase in driving speed. Vibration intensity is relatively higher for sinusoidal rumble (Figure 4.10) strips when compared to conventional ones (Figure 4.9) for all the three speeds considered. The width of the rumble strips did not result in a significant difference in the noise and vibration produced inside the cabin by the rumble strips.

6. IMPLEMENTATION REMARKS

Both field tests and statistical analysis were performed to investigate the safety effectiveness of rumble strips on Indiana rural roads. According to the results summary, the following implementation suggestions were provided.

1. The study has confirmed the safety benefits of the rumble strips in reducing run-off-road and head-on collisions (target crashes). This countermeasure is proposed as both low-cost and effective where these two types of crashes occur or there is a risk of their occurrence based on similar cases elsewhere.
2. The configurations of rumble strips' locations will influence their effectiveness. When rumble strips are installed only on the roadside, whether on edge or shoulder, the expected crash reduction factor for target crashes is 0.87 (CMF (PDO) = 0.92; CMF (KABC) = 0.75); when rumble strips are installed only on the center, the expected crash reduction factor for target crashes is also 0.87 (CMF (PDO) = 0.92; CMF (KABC) = 0.75); when the rumble strips are installed both on the center and roadside, the expected crash reduction factor for target crashes is 0.79 (CMF (PDO) = 0.84; CMF (KABC) = 0.68). Therefore, joint configuration is recommended for areas with a high risk of run-off-road or head-on crashes.
3. Although the sinusoidal rumble strips show less effectiveness due to sample selection bias, both profiles of rumble strips provide close safety outcomes. This suggests that these two types of rumble strips are considered equivalent to each other in terms of safety.
4. The width of the rumble strips does not affect their safety performance and noise and vibration feedback performance significantly. Current INDOT Standard Drawings that took effect with September 2023 use a width of 18″ for the centerline and 10″ as the width for edge-line or shoulder rumble strips. The previous version that was in effect from March 2019 to September 2023 used a width of 16″ for the centerline and 12″ as the width for edge-line or shoulder rumble strips. The width of rumble strips may be determined by their implementation conditions (lane width, shoulder width, etc.), along with factors such as the installation cost, and/or equipment availability. However, in areas where pedestrian or bicyclist presence is expected, the 8″, 10″ or 12″ rumble strips seem to be more justified.
5. Both sinusoidal and conventional rumble strips could provide sufficient noise as recommended by NCHRP Report 641 (Torbic et al., 2009). Also, both types of rumble strips generated enough vibration in the steering wheel to alert the driver. The widths of the rumble strips tested (8″, 10″, and 12″) did not affect the noise and vibration performance of the rumble strips. Therefore, it is recommended to consider that both types of rumble strips are equivalent in terms of providing feedback to the driver.
6. Previous studies have proven that sinusoidal rumble strips have the added benefit of producing lower noise levels outside the vehicle, this could be a factor for selecting them over the conventional type.
7. The vegetation on the rumble strips decreases their effectiveness significantly in terms of produced noise and vibration. Hence, the results from the research highlight the importance of regular maintenance for rumble strips.

7. CLOSING REMARKS

7.1 Conclusions

Rumble strips are designed to enhance road safety by providing audible and vibratory warnings to drivers, reducing the likelihood of crashes caused by fatigue, distraction, and inattention. These strips are typically installed on highway centerlines and shoulders to encourage corrective actions such as steering adjustments and speed control, which help prevent crashes or reduce their severity.

To understand the rumble strips' safety effectiveness under various operational conditions, this study performed a comprehensive operational safety effectiveness analysis on rumble strips across Indiana and field tests were carried out to investigate the effectiveness of rumble strips on providing noise and vibration to drivers.

For the statistical analysis part, the installation time and configurations (location, width, etc.) of rumble strips installed in Indiana were collected. Eight years of road departure crashes were assigned to homogeneous roadway segments. Segment level geometry features including deflection angle rate, shoulder width and number of curves were obtained. The random effect negative binomial model and random effect ordered logit model were proposed to analyze the crash frequency and crash severity. The model estimation results justified the introduction of random effects and confirmed the significant adverse effects from horizontal curves. For roadside only and center only designs, the crash modification factor (CMF) for target crashes at all severity levels was 0.87; the CMF (KABC) for target crashes was 0.75, and the CMF (PDO) for target crashes was 0.92. When both roadside and centerline rumble strips are present, the all-severity CMF for target crashes was 0.79; the CMF (KABC) for target crashes was 0.68, and the CMF (PDO) for target crashes was 0.84.

In-vehicle noise and vibration evaluation indicate that both conventional and sinusoidal rumble strips meet the NCHRP Report 641 (Torbic et al., 2009) recommendation of a minimum 3dB increase in sound pressure level. Conventional rumble strips increase sound levels by 4.6–7.5 dB, while sinusoidal rumble strips provide a higher increase of 5.1–11 dB. Vibration tests showed that higher vibration intensities were found for sinusoidal rumble strips compared to conventional ones. One possible factor for the difference in vibrations is that the segments with conventional rumble strips were installed several years prior to the sinusoidal ones. It is also determined that the width of the rumble strips did not result in a significant difference in the noise and vibration produced inside the cabin by the rumble strips. Finally, it is important to highlight that vegetation on some segments of conventional rumble strips was found to reduce the noise levels produced when vehicles made contact.

The results of this study confirmed the effectiveness of rumble strips, in terms of both crash reduction and generated noise and vibration, on rural roads and provided engineers with quantified crash modification factors for different rumble strips settings.

7.2 Future Research

Future research on rumble strips should focus on several key areas to enhance their effectiveness and minimize any negative impacts. First, there is a need to collect more data from roads where sinusoidal rumble strips have been installed and correlate these segments with the annual crash records on each road.

Second, further investigation is needed to determine the effectiveness of rumble strips in conjunction with other common crash countermeasures, such as shoulder width and raised pavement markers. This will help identify the optimal conditions for using each element.

Third, research should explore the long-term durability and maintenance requirements of rumble strips to ensure they continue to provide effective vibration and noise warnings over time, according to the standards. Also, future research is needed to study the effectiveness of sinusoidal rumble strips in wet conditions, i.e., when the troughs of the sinusoids are filled with water.

Additionally, exploring different widths and alternative corrugation types for rumble strips, such as football-shaped, or other strip configurations, could offer new insights into their performance. Understanding how various shapes impact noise levels and vibration feedback to the driver could lead to more effective implementations.

Finally, it would be beneficial to investigate the potential of integrating rumble strips with other emerging technologies, such as lane departure warning systems in connected vehicles. Understanding how these technologies can interact with rumble strips could lead to innovative solutions that further enhance road safety and efficiency.

Overall, continued research and development in these areas will be key to optimizing the design, implementation, and performance of rumble strips, ensuring they provide maximum safety benefits.

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APPENDICES

Appendix A. Crash Frequency Model

Appendix B. Rumble Strip's Survey

APPENDIX A. CRASH FREQUENCY MODEL

The estimated crash frequency model using all crash as the response variable is shown in Table A.1. Although the estimated effects of other factors, like traffic volume (LogAADT), length LogLength), and geometry (DeflectionAnglRate, NumCurve) are close to those of target crash model Table 3.4), the effects of rumble strips are quite different. In all crash model, the effect of *Side* is significant and strong, but the effects of *Center* and *Center+Side* were insignificant with unexpected direction (positive estimates indicating the increase of crash probability when rumble strips are implemented). One possible explanation of these insignificance is that the effectiveness of rumble strips on target crashes (run-off-road and head-on) is masked by other crashes when summing up all crashes as the response variable. In this study, it seems that rumble strips are effective only for target crashes (run-off-road and head-on). This finding conflicts with previous studies where the authors claimed reduction of crashes regardless of the crash types.

Table A.1 Estimation results of crash frequency model (all crash as response variable)

Effect	Estimate	Std. Err	t Value	Pr > |t|
Fixed Parameter				
Intercept	-4.323	0.175	-24.66	<.0001
LogAADT	0.546	0.021	25.67	<.0001
LogLength	0.603	0.030	19.90	<.0001
SouthArea	-0.140	0.055	-2.55	0.0109
ShdWidth	0.001	0.0002	4.81	<.0001
DeflectionAnglRate	0.031	0.008	3.78	0.0002
NumCurve	-4.323	0.175	-24.66	<.0001
Side	-0.317	0.129	-2.46	0.0137
Center	0.041	0.041	1.00	0.3165
Center+Side	0.013	0.053	0.25	0.8058
Covariance Parameter				
Intercept RumbleID)	0.173	0.016	10.8	<.0001
Scale	0.424	0.013	32.6	<.0001
Model Fitness				
-2 Res Log Pseudo-Likelihood		**Gener. Chi-Square / DF**		
16,372		1.04		

APPENDIX B. RUMBLE STRIP'S SURVEY

Table B.1 Crawfordsville rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From	To	Rumble Stripe Type	Width	Placement		
					Route or MM	Route or MM			Center	Edge	Shoulder
SR 39	RS-42019-A	7/17/2019	3/27/2020	From .19 mi E of SR 39 E JCT to 1.01 mi W of SR 67 White Lick Creek Br - East End	55+82	61+67	Sinusoidal		16	12	
SR 234	RS-39328-A	10/16/2019	10/9/2019	From SR 47 to 7.3 mi E of US 231 1 mi E of Ladoga	34+28	45+40	Sinusoidal		16	12	
US 231	RS-39259-A	2/12/2020	1/26/2022	1,000 ft south of US 231-US 40 intersection to the US 231-US 40 intersection	39+99	48+52	Sinusoidal		16	12	
VA 1019	T-40026-A	1/22/2020	4/29/2021	Various locations for Crawfordsville District rumble stripe FY 21	**N/A**	**N/A**	Sinusoidal		16	12	
SR 63	B-40104-A	4/8/2020	10/7/2021	NB bridge over Jordan Branch, 1.53 mi of SR 32	20+16	20+16	Sinusoidal		16	12	
US 231	RS-39328-A	10/16/2019	11/15/2021	From 0.19 mi S of US 36 to 0.07 mi S of SR 234	158+44	169+85	Sinusoidal		16	12	
SR 26	R-37797-A	2/26/2020	**ACTIVE**	From 0.62 mi E of US 421 to 0.38 mi E of SR 75	52+23	55+65	Sinusoidal		16	12	
SR 39	RS-41007-A	8/13/2020	1/5/2022	From SR 42 N JCT to US 40 Belleville	29+13	35-95	Sinusoidal		16	12	
US 36	R-40571-A	10/26/2021	12/20/2022	From 0.05 mi E. of US 231 to 4.42 mi E of US 231 Bainbridge	35+64	39+89	Sinusoidal		16	12	
US 231	RS-39328-A	10/16/2019	11/15/2021	0.07 mi S of SR 234 to 0.18 mi S of SR 32 S JCT	169+85	176+73	Sinusoidal		16	12	
SR 267	R-41870-A	9/10/2020	9/6/2022	From 0.40 mi N of I-74 to I-65	22+106	28+72	Sinusoidal		16	12	
US 421	RS-40107-A	11/22/2019	3/3/2021	From 0.08 mi N of SR 32 to 0.08 mi S of SR 47	99+70	106+0	Sinusoidal		16	12	
SR 38	R-40528-B	2/17/2022	**ACTIVE**	From 1.16 mi E of I-65 to US 421	5+60	16+43	Sinusoidal		16	12	
US 136	R-40575-A	1/19/2022	**ACTIVE**	5.14 mi E of SR 32/SR 47 JCT, Culvert over unnamed ditch	3+40	3+40	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
I 65	R-43521-B	5/11/2021	2/22/2022	From 4.81 mi N of SR 47 to 4.94 mi N of SR 47 Brush Creek Bridge	165+0	167+94	Sinusoidal		16	12	
SR 236	R-39964-A	3/18/2021	**ACTIVE**	From US 231 E JCT to 0.39 mi W of SR 75	18+94	32+28	Sinusoidal		16	12	
SR 28	R-38772-A	1/21/2021	**ACTIVE**	From US 231 to US 52 W JCT	37+48	47+86	Sinusoidal		16	12	
SR 28	RS-41879-A	7/22/2019	12/11/2020	From SR 25 to US 231	26+65	37+48	Sinusoidal		16	12	
SR 47	RS-41691-A	4/17/2020	**ACTIVE**	From .49 mi W of SR 75 to US 52	42+62	45+68	Sinusoidal		16	12	
SR 25	B-39761-A	11/25/2020	9/21/2022	Bridge over Big Shawnee Creek 3.05 mi S of SR 28	15+20	15+20	Sinusoidal		16	12	
VA 1019	T-41262-A	1/21/2021	7/25/2022	Various locations for Crawfordsville District rumble stripe FY21	**N/A**	**N/A**	Sinusoidal		16	12	
SR 28	RS-40106-A	1/28/2020	4/9/2021	From US 421 to 8.02 mi E of US 421 County Line	66+56	73+48	Sinusoidal		16	12	
SR 341	R-41871-A	1/29/2021	3/14/2022	From US 136 N JCT to SR 28	10+78	22+70	Sinusoidal		16	12	
VA 1019	T-43377-A	2/17/2022	**ACTIVE**	Various locations for Crawfordsville District rumble stripe FY21	**N/A**	**N/A**	Sinusoidal		16	12	
I-65	R-43521-B	5/11/2021	2/22/2022	From 3.44 mi S of SR 38 to 0.5 mi S of SR 38	165+0	167+94	Sinusoidal		16	12	
US 421	R-38762-A	7/17/2019	6/18/2021	1.50 mi S of SR 28 S JCT	104+89	104+89	Sinusoidal		16	12	
US 421	R-42054-A	9/21/2021	1/27/2023	From 1 mi N of Boone Cnty Line to SR 32	93+95	99+62	Sinusoidal		16	12	
SR 38	32007	10/14/2010	12/27/2011	SR 38, from SR 39 to US 421	25+79	34+10	Sinusoidal		16	16	16
US 231	35162	8/16/2012	5/17/2013	US 231, from 0.54 mi N of I-74 to 5.48 mi N of SR 28	181+29	198+98	Conventional		16	16	16
SR 25	34768	7/19/2013	5/14/2014	VA VARI, SR 25 (6.47 mi , SR 43 5.10 mi , US 421 5.43 mi , SR 267 4.33 mi)	**N/A**	**N/A**	Conventional		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
SR 43	34768	7/19/2013	5/14/2014	VA VARI, SR 25 (6.47 mi , SR 43 5.10 mi , US 421 5.43 mi , SR 267 4.33 mi)	**N/A**	**N/A**	Conventional		16	16	16
US 421	34768	7/19/2013	5/14/2014	VA VARI, SR 25 (6.47 mi , SR 43 5.10 mi , US 421 (5.43 mi , SR 267 4.33 mi)	**N/A**	**N/A**	Conventional		16	16	16
SR 267	34768	7/19/2013	5/14/2014	VA VARI, SR 25 (6.47 mi , SR 43 5.10 mi , US 421 5.43 mi , SR 267 4.33 mi)	**N/A**	**N/A**	Conventional		16	16	16
US 421	31504	8/16/2013	10/17/2014	US 421, from 0.13 mi S of SR 47 to 0.50 mi N of the S JCT with SR 38	106+3	111+39	Conventional		16	16	16
US 421	31620	8/16/2013	11/5/2014	US 421, from 1.75 mi N of SR 75 to the SR 38 N JCT	125+78	129+8	Conventional		16	16	16
US 231	31610	9/18/2013	10/7/2015	US 231, from 1.61 mi N of SR 240 to 0.19 mi S of US 36	150+67	158+42	Conventional		16	16	16
SR 236	35274	9/17/2014	1/4/2016	SR 236, from US 41 to W JCT SR 59	0+0	7+48	Conventional		16	16	16
SR 39	34754	10/17/2014	1/20/2016	SR 39, from 2.85 mi North of US 40 to US 36	38+81	43+44	Conventional		16	16	16
SR 26	37893	4/10/2015	1/5/2016	SR 26, from Illinois/Indiana State Line to US 41	0+0	7+87	Conventional		16	16	16
SR 163	37894	4/10/2015	3/10/2016	SR 163, from Illinois/Indiana State Line to SR 63	0+0	5+43	Conventional		16	16	16
US 36	31597	11/18/2015	5/12/2017	US 36, from 0.02 mi W of SR 75 to 0.96 mi E of SR 39 East JCT	48+6	55+60	Conventional		16	16	16
US 421	34387	12/15/2015	2/22/2017	US 421, from N JCT SR 38 to SR 26	129+8	134+32	Conventional		16	16	16
SR 240	30226	10/19/2016	2/7/2018	SR 240, from 4.25 mi E of US 231 to SR 75	4+17	10+14	Conventional		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 41	35174	12/16/2016	11/21/2017	US 41, from 3.88 mi N of S JCT SR 55 S Council St in Attica) to 0.2 mi N of SR 55 N JCT	174+62	176+13	Conventional		16	16	16
Various	35422	1/10/2017	2/6/2018	VA VARI various locations in the Crawfordsville District	**N/A**	**N/A**	Conventional		16	16	16
Various	35517	4/12/2016	2/16/2017	VA VARI various locations on SR 39, SR 236, SR 32 2 sites , SR 341, SR 59 3 sites	**N/A**	**N/A**	Conventional		16	16	16
US 421	37796	2/15/2019	1/14/2020	US 421, from SR 29 to 4.3 mi N of SR 29	117+15	121+37			16	12	
US 231	38651	3/9/2018	5/31/2019	US 231, from 0.34 mi N of SR 42 Doe Creek) to 0.03 S of SR 240	139+32	149+6	Conventional		16	16	16
SR 42	39018	5/11/2016	1/30/2017	SR 42, from 0.06 mi E of SR 39 N JCT to 0.48 mi W of SR 267 Br over White Lick Creek	55+66	61+58	Conventional		16	16	16
SR 29	39019	5/11/2016	2/16/2017	SR 29, US 421 to SR 26	0+0	9+41	Conventional		16	16	16
SR 234	39325	3/14/2019	2/25/2019	SR 234, from 7.3 mi E of US 231 1 mi E of Ladoga) to SR 75	45+40	53+30			16	12	
Various	39716	3/21/2018	1/28/2019	VA VARI various locations within the Crawfordsville District	**N/A**	**N/A**	Conventional		16	12	
SR 28	39978	7/20/2018	11/13/2019	SR 28, US 52 E JCT to 6.32 mi E of I 65	49+72	57+16	Conventional		16	12	
Various	40023	1/25/2019	11/26/2019	VA VARI various locations in Crawfordsville District	**N/A**	**N/A**			16	12	
SR 26	40520	11/30/2018	5/10/2021	SR 26, from 1.35 mi E of I-65 NB to 0.62 mi E of US 421	41+1	52+23	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 52	41360	8/17/2018	7/17/2019	US 52, 4th St Polland Hill Rd) to 30th St	47+70	49+34	Conventional		16	12	
SR 28	41879	7/22/2019	12/11/2020	SR 28, from SR 25 to US 231	26+65	37+48			16	12	
SR 42	42019	7/17/2019	3/27/2020	SR 42, from .19 mi E of SR 39 E JCT to 1.01 mi W of SR 67 White Lick Creek Br - East End	55+82	61+67			16	12	
US 421	35166	11/29/2016	4/30/2021	US 421, from 0.50 mi N of SR 38 N Corp Limit Kirklin) to N JCT SR 28	111+35	117+18	Conventional		16	16	16
US 36	37295	3/17/2017	2/3/2020	US 36, from Illinois/Indiana state line to 1.70 mi E of SR 63 Wabash River Bridge	0+0	8+50	Conventional		16	16	16
US 36	37295	3/17/2017	2/3/2020	US 36, from 1.88 mi E of SR 63 (W corporate limit of Montezuma) to US 41	8+75	16+62	Conventional		16	16	16
SR 163	39163	8/16/2017	6/25/2019	SR 163, from 2.5 mi E of SR 63 Wabash Rv) to US 41	7+98	8+83	Conventional		16	16	16
US 41	39163	8/16/2017	6/25/2019	US 41, 0.02 mi S of SR 163 to 0.63 mi S of US 36	126+55	137+9	Conventional		16	16	16
SR 43	39271	4/11/2019	4/27/2020	SR 43, from 0.43 mi N of SR 225 to 0.61 mi S of S JCT SR 18	30+91	35+70			16	12	
US 421	39465	7/20/2018	7/30/2021	US 421, from 2.94 mi S of SR 18 N JCT (Hamilton St) to 1.66 mi S of SR 18 N JCT	147+51	148+87	Conventional		16	12	
SR 234	39328	10/16/2019	11/15/2021	SR 234, from SR 47 to 7.3 mi E of US 231 1 mi E of Ladoga	34+28	45+40			16	12	
US 231	39328	10/16/2019	11/15/2021	US 231, from 0.19 mi S of US 36 to 0.07 mi S of SR 234	158+44	169+85			16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 231	39328	10/16/2019	11/15/2021	US 231, 0.07 mi S of SR 234 to 0.18 mi S of SR 32 S JCT	169+85	176+73			16	12	
SR 234	39328	10/16/2019	11/15/2021	SR 234, from 1.50 mi W of US41 (ECL of Kingman to 3.57 mi E of SR 341 Mont/Fntn C/L	15+6	25+14			16	12	

Table B.2 Fort Wayne rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width/ Wavelength	Placement		
									Center	Edge	Shoulder
120	RS-30769	5/17/2011	4/24/2013	From SR 13 to SR 5	14+71	19+99	Conventional		16	16	16
33	RS-31396	1/2/2013	10/21/2013	From .5 mi N of SR 109 to US 6	59+11	68+69	Conventional		16	16	16
19	RS-35536	8/5/2013	3/19/2014	From .5 mi N of US 6 to .2 mi S of SR 119	99+79	103+52	Conventional		16	16	16
6	RS-33571	3/6/2014	4/6/2017	From 1.5 mi E of I-69 to Ohio Line	136+33	149+40	Conventional		16	16	16
20	T-34998	8/20/2013	4/16/2014	From ECL of Lagrange to Lagrange/Steuben CL	0+0	0+0	Conventional		16	16	16
6	T-34998	8/20/2013	4/16/2014	From ECL of Kendallville to I-69	0+0	0+0	Conventional		16	16	16
6	RS-33571	3/6/2014	4/6/2017	From 1.8 mi W of SR 427 to 3.6 mi E of SR 1	136+33	149+40	Conventional		16	16	16
33	RS-33569	12/19/2013	3/6/2017	From 1.5 mi N of US 30 to .5 mi N of SR 205	38+56	47+4	Conventional		16	16	16
15	RS-32679	9/2/2014	11/1/2016	From US 33 N JCT To .5 mi S of US 20	82+1	87+20	Conventional		16	16	16
18	RS-33574	3/17/2010	6/29/2011	From ECL of Montpelier to SR 1	**N/A**	**N/A**	Conventional		16	16	16
1	RS-34875	8/12/2015	8/9/2016	From .9 mi S of US 6 to SR 427	182+84	192+16	Conventional		16	16	16
19	RS-34921	11/18/2015	6/22/2017	From US 30 to 7.9 mi N of US 30	85+86	93+77	Sinusoidal	24 in. wavelength	16	16	16
27	RS-34905	10/16/2015	4/4/2017	From SR 218 to .1 mi N of SR 116	72+25	75+87	Sinusoidal	24 in. wavelength	16	16	16
25	RS-34328	12/15/2015	6/22/2017	From Mentone to Warsaw	111+15	122+75	Sinusoidal	24 in. wavelength	16	16	16
1	RS-34930	1/22/2016	4/17/2017	From SR 218 to .2 mi S of SR 116	118+88	123+58	Sinusoidal	24 in. wavelength	16	16	16
105	RS-34932	1/22/2016	2/21/2017	From US 24 to SR 16	17+1	20+73	Conventional		16	16	16
524	RS-34920	2/24/2016	2/20/2017	From US 24 to State Park	0+0	2+18	Conventional		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width/ Wavelength	Placement Center	Placement Edge	Placement Shoulder
19	RS-38326	3/8/2016	4/20/2017	From SR 119 to US 20	103+93	112+63	Sinusoidal	24 in. wavelength	16	16	16
120	RS-38330			From Lagrange/Steuben CL to WCL of Orland			Conventional		16	16	16
1	RS-38286	2/11/2016	5/31/2017	From 2.0 mi E of I-69 to Dekalb CL	160+11	169+56	Sinusoidal	Various wavelengths	16	16	16
9	RS-38695	12/30/2016	1/8/2018	From .5 mi N of US 20 to 2 mi N of SR 120	188+43	195+54	Sinusoidal	12 in. wavelength	16	12	
13	RS-38695	12/30/2016	1/8/2018	From 2.6 mi N of US 20 to .3 mi N of Toll Rd	133+65	137+96	Sinusoidal		16	12	
20	RS-38695	12/30/2016	1/8/2018	From SR 5 to 4 mi W of SR 5	107+82	111+85	Sinusoidal	12 in. wavelength, 12 in. SLRS	16	12	
33	RS-39652	12/22/2016	3/23/2018	US 6 to 6.6 mi N of US 6	74+47	82+54	Sinusoidal		16	12	
1	RS-35102	2/23/2017	4/2/2018	From Allen/Dekalb CL to SR 8	169+54	177+57	Sinusoidal	12 in. wavelength	16	12	
15	RS-39653	3/17/2017	1/11/2018	From SR 120 E JCT to Michigan SL	91+59	94+82	Conventional		16	12	
9	RS-40082	7/19/2017	5/4/2018	From SR 26 to US 35	94+14	100+28	Conventional	12 in. SLRS	16	12	
15	RS-38560	11/23/2016	10/5/2018	From SR 9 to .6 mi N of SR 13	7+38	14+31	Sinusoidal	12 in. wavelength	16	12	
27	RS-38670	12/1/2017	3/18/2021	From SR 116 to 1.0 mi S of SR 124 Berne excepted	77+56	77+66	Conventional	8 in. ELRS	16	12	
114	RS-40253	2/15/2018	4/29/2019	From SR 15 to SR 13	47+8	51+94	Sinusoidal	12 in. wavelength	16	12	
33	RS-36046	2/22/2018	6/7/2019	From .45 mi N of SR 205 to SR 9	47+4	54+4	Sinusoidal	12 in. wavelength	16	12	
101	R-39636	3/21/2018	4/9/2020	From .42 mi S of old 24 to 8.49 mi N of old 24	65+3	73+34	Sinusoidal	12 in. wavelength	16	12	
33	RS-36046	2/22/2018	6/7/2019	From 1,600 ft N of SR 9 to 600 ft S of US 6	0+0	0+0	Sinusoidal	12 in. wavelength	16	12	
5	RS-39417	9/21/2018	5/8/2020	From .61 mi N of SR 14 to .37 mi S of US 30	48+51	55+56	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width/ Wavelength	Placement Center	Placement Edge	Placement Shoulder
9	RS-39417	9/21/2018	5/8/2020	From SR 14 to SR 205	143+21	148+39	Conventional		16	12	
13	RS-40908	10/18/2020	7/7/2020	From SR 26 to SR 18	35+75	46+12			16	12	
18	RS-40908	10/18/2020	7/7/2020	From .09 mi E of SR 19 to .12 mi W of SR 13 W JCT	89+13	94+71			16	12	
35	RS-40908	10/18/2020	7/7/2020	From 0.09 mi W of SR 15 to SR 13	78+85	89+30			16	12	
1	RS-41287	2/15/2019	5/12/2020	From SR 18 to SR 218	111+82	118+88			16	12	
327	R-35100	1/25/2019	12/22/2020	From SR 4 to SL	15+55	23+87			16	12	
8	RS-40918	1/30/2019	3/12/2020	From 3.07 mi E of I-69 to 4.06 mi E of SR 1 E JCT	65+12	77+50			16	12	
14	R-40917	1/25/2019	12/16/2020	From .56 mi E of SR 15 to SR 13	88+24	95+46			16	12	
1	RS-41825	7/17/2019	2/4/2021	From SR 116 to .39 mi N of I-469	133+66	139+77			16	12	
119	RS-40919	7/20/2018	4/13/2020	From SR 19 to 1.9 mi W of SR 15	18+26	26+62	Conventional		16	12	
18	RS-41823	9/18/2019	12/28/2021	From I-69 to .05 mi W of SR 3	109+73	119+33			16	12	
20	RS-38558	12/4/2019	12/21/2020	From 0.18 mi E of SR 9 to 1.05 mi W of SR 327	121+45	132+79			16	12	
120	RS-38558	12/4/2019	12/21/2020	From I-69 to 0.93 mi W of SR 827	51+64	54+35			16	12	
14	RS-40081	12/19/2019	5/11/2021	From SR 114 to .36 mi W of SR 15	78+94	87+32			16	12	
13	RS-40081	12/19/2019	5/11/2021	From SR 14 to 1.1 mi S of US 30	83+44	92+52			16	12	
13	RS-40081	12/19/2019	5/11/2021	From US 30 to 9.46 mi N of US 30	93+61	103+7			16	12	
15	RS-41819	1/21/2020	1/27/2021	From .5 mi S of US 30 to US 6	63+78	72+0			16	12	
15	RS-38561	1/22/2020	3/29/2022	From 1,200 ft N of US 24 to .05 mi N of SR 16	26+68	34+26			16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width/ Wavelength	Placement Center	Placement Edge	Placement Shoulder
114	RS-40467	1/22/2020	1/15/2021	From ECL of North Manchester to SR 105	52+5	61+1			16	12	
114	RS-40467	1/22/2020	1/15/2021	From SR 105 to SR 9	61+1	69+75			16	12	
218	RS-41905	2/28/2020	2/18/2021	From 0.61 mi E of SR 5 E JCT to SR 3	58+34	58+26			16	12	
116	RS-38562	2/19/2020	9/30/2021	From 0.15 mi E of US 224 to 0.25 mi E of SR 124 N JCT	0+0	11+13			16	12	
13	M-42553	3/26/2020	10/1/2020	From 2.02 mi N of SR 16 to SR 114	72+45	76+49			16	12	
3	RS-41823	9/18/2019	12/28/2021	From 1.39 mi N of SR 26 to SR 18	153+61	159+16			16	12	
1	RS-41907	4/24/2020	12/8/2020	From SR 8E to 4.1 mi N of SR 8E	178+61	182+70			16	12	
101	RS-41083	8/13/2020	5/4/2022	From 2.60 mi N of SR 37 to SR 8E	73+41	79+41			16	12	
827	RS-41073	8/21/2020	1/26/2021	From 0.62 mi E of SR 127 to 1.06 mi S of SR 120	0+0	0+62			16	12	
8	RS-39901	7/16/2020	8/17/2021	From SR 3 to SR 327	55+0	59+22			16	12	
205	RS-39901	7/16/2020	8/17/2021	From SR 3 to SR 327	28+84	32+21			16	12	
33	RS-39901	7/16/2020	8/17/2021	From SR 9 to SR 109	54+0	58+52			16	12	
427	RS-41083	8/13/2020	5/4/2022	From US 6 to SR 1N	0+56	10+0			16	12	
20	RS-40465	9/18/2020	4/22/2022	From 7.97 mi W of I-69 to 0.35 mi E of I-69	132+79	140+82			16	12	
20	RS-40465	9/18/2020	4/22/2022	From 0.58 mi E of SR 127 to 10.08 mi E of SR 127	143-95	153+50			16	12	
218	RS-41084	9/10/2020	6/9/2022	From 0.99 mi E of US 27 to 8.15 mi E of US 27	84+26	91+46			16	12	
33	RS-41084	9/10/2020	6/9/2022	From 8.44 mi E of US 27 to 2.96 mi E of US 27	0+0	5+48			16	12	
124	RS-41084	9/10/2020	6/9/2022	From 0.98 mi E of US 27 to 7.97 mi E of US 27	60+43	67+36			16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From	To	Rumble Stripe Type	Width/ Wavelength	Placement		
					Route or MM	Route or MM			Center	Edge	Shoulder
9	RS-39891	10/15/2020	4/11/2022	From US 24 to SR 114	20+68	26+71			16	12	
13	RS-41111	10/28/2020	4/22/2022	From US 33 to SR 4	124+57	124+77			16	12	
22	RS-39809	11/18/2020	9/2/2022	From 0.22 mi E of I-69 to 2.96 mi E of I-69	46+0	48+76			16	12	
18	RS-41081	11/18/2020	10/6/2022	From SR 13 W. JCT to 1.08 mi W of SR 9	94+71	102+9			16	12	
205	R-41086	12/17/2020	4/12/2022	From US 30 to 0.65 mi S of US 33	116+90	117+28			16	12	
114	RS-39890	12/22/2020	4/11/2022	From 0.90 mi E of SR 14 to SR 15	39+34	47+8			16	12	
19	RS-41113	12/17/2020	10/18/2022	From 0.70 mi N of SR 14 to 1.97 mi S of US 30	52+66	52+76			16	12	
19	R-39912	1/29/2021	10/17/2022	From 5.53 mi S of US 6 to 0.49 mi N of US 6	85+0	94+42			16	12	
6	R-39912	1/29/2021	10/17/2022	From 1.64 mi W of SR 19 to 0.12 mi E of SR 15	93+77	99+79			16	12	
101	M-43535	11/3/2021	3/14/2023	From 5.55 mi N of US 224 to 3.56 mi S of US 30	47+62	50+81			16	12	
218	R-41874	12/16/2021	**ACTIVE**	From SR 3 to SR 1	66+37	66+37			16	12	
101	R-40486	12/16/2021	**ACTIVE**	From SR 124 to US 224	34+41	36+52			16	12	
SR 5	R-40477	3/2/2022	**ACTIVE**	From 2.57 mi S of SR 120 to SR 120	93+61	96+18			16	12	

Table B.3 Greenfield rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
SR 121	RS-41091-A	4/8/2020	8/15/2022	From US 52 to SR 44	0+0	15+29	Sinusoidal		16	12	
SR 28	R-39829-A	12/17/2020	1/6/2022	From SR 3 to SR 67	120+18	122+54	Sinusoidal		16	12	
SR 44	RS-41105-A	12/17/2020	4/18/2022	SR 44, from 0.31 mi E of SR 3 to 7.40 mi E of SR 3 WCL - Rush Co.	55+49	62+60	Sinusoidal		16	12	
SR 38	RS-41045-A	12/17/2020	3/4/2022	From 0.35 mi E of SR 9 to SR 109	73+5	78+19	Sinusoidal		16	12	
SR 26	R-42022-A	7/17/2019	5/3/2021	From 931 to SR 13	76+32	92+25	Sinusoidal		16	12	
SR 101	B-41194-A	1/21/2021	4/21/2023	Over Hannah Creek, 3.78 mi S. of US 27	30+63	30+63	Sinusoidal		16	12	
SR 227	R-42023-A	7/17/2019	3/30/2020	3.03 mi S of US 36 Wayne/Randolph Co Line) to US 36	25+29	28+32	Sinusoidal		16	12	
I 74	R-40506-A	5/11/2021	**ACTIVE**	From 0.44 mi W of N CR 400 W to 0.15 mi E of N CR 400 W	106+63	107+22	Sinusoidal		16	12	
I 69	B-40009-B	4/8/2020	3/17/2022	SB over Pipe Creek, 03.95 N SR 28	248+72	248+72	Sinusoidal		16	12	
SR 38	RS-39287-A	4/8/2020	5/26/2022	SR 38 from Madison/Henry County Line to SR 3	81+33	92+38	Sinusoidal		16	12	
SR 32	R-39995-A	1/21/2021	11/7/2022	From SR 9 N JCT to Perdiue Rd	108+97	120+82	Sinusoidal		16	12	
US 36	RS-40588-B	7/16/2020	**ACTIVE**	Over Lick Creek 02.51 E SR 13	83+65	83+65	Sinusoidal		16	12	
US 27	RS-40596-B	4/8/2020	7/22/2021	0.17 mi N of I-70 to 1.46 mi N of I-70 End of Dual Lanes	25+8	26+37	Sinusoidal		16	12	
US 31	B-38540-C	10/15/2020	**ACTIVE**	4.117 mi N of SR 28	152+32	152+32	Sinusoidal		16	12	
IR 1090	R-39682-A	11/22/2019	6/3/2021	Strawtown Ave from 1,100 ft W of Prairie Baptist to 400 ft E of Prairie Baptist	**N/A**	**N/A**	Sinusoidal		16	12	
SR 32	RS-39988-A	1/22/2020	6/2/2021	From SR 37 to 6.78 mi E of SR 13 WCL Anderson)	86+13	100+43	Sinusoidal		16	12	
US 31	B-38540-C	10/15/2020	**ACTIVE**	5.567 N SR 38	141+29	141+29	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
US 27	R-39734-A	11/18/2020	11/23/2022	4 mi N of SR 26/SR 67 Votaw St) at CR 400N	69+2	69+24	Sinusoidal		16	12	
SR 1	R-42139-A	12/17/2020	**ACTIVE**	From E. JCT SR 44 to 1.56 mi S of US 40 NCL Milton	45+21	57+1	Sinusoidal		16	12	
SR 109	RS-41045-A	12/17/2020	3/4/2022	From SR 234 to SR 38	9+36	15+6	Sinusoidal		16	12	
I 70	R-40616-A	2/18/2021	**ACTIVE**	From 5.03 mi E of SR 9 to 0.24 mi E of SR 109 Montgomery Creek	108+86	115+61	Sinusoidal		16	12	
US 36	R-39819-A	10/15/2020	12/8/2022	From US 27 to SR 227	132+22	138+17	Sinusoidal		16	12	
SR 44	B-44235-A	3/22/2022	**ACTIVE**	1.71 mi W of US 52	53+48	53+48	Sinusoidal		16	12	
US 36	R-39819-A	10/15/2020	12/8/2022	From SR 227 to 1.00 mi E of SR 227 Indiana/Ohio St Ln	138+17	139+5	Sinusoidal		16	12	
SR 227	B-41134-A	9/10/2020	7/19/2022	SR 227 over Dismal Creek, 2.31 mi S of SR 32-1800322	35+10	35+10	Sinusoidal		16	12	
SR 67	B-40531-A	2/12/2020	4/6/2023	From 3.76 mi W SR 3 to SR 3	146+56	150+32	Sinusoidal		16	12	
I 74	R-40506-A	5/11/2021	**ACTIVE**	From 0.13 mi W of N Michigan Rd to 0.15 mi E of N Michigan Rd	111+30	111+59	Sinusoidal		16	12	
US 36	RS-40588-B	7/16/2020	**ACTIVE**	From SR 13 to N JCT SR 9/SR 67	81+70	89+4	Sinusoidal		16	12	
I 74	R-40506-A	5/11/2021	**ACTIVE**	From 0.11 mi W of SR 244 to 0.11 mi E of SR 244	118+44	118+66	Sinusoidal		16	12	
US 35	RS-41098-A	10/15/2020	3/16/2022	From 1.27 mi W of SR 213 (WCL Greentown) to SR 19	97+46	100+14	Sinusoidal		16	12	
I 74	R-40506-A	5/11/2021	**ACTIVE**	From 0.4 mi W of Brandywine Creek to 0.09 mi E of Brandywine Creek	108+22	108+71	Sinusoidal		16	12	
SR 103	R-40507-A	2/17/2022	**ACTIVE**	3.08 mi S of SR 38 CR 300 S to 2.21 mi S of SR 38 SCL New Castle	5+56.5	6+42.8	Sinusoidal		16	12	
SR 167	RS-39282-A	2/26/2020	8/17/2021	From SR 67 to 4.24 mi N of SR 67 SCL Dunkirk	0+0	4+24	Sinusoidal		16	12	
US 35	RS-40613-A	10/15/2020	9/2/2021	From SR 1 to 0.44 mi Northwest of US 36	23+28	27+65	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
ST 1104	R-40284-A	7/16/2020	**ACTIVE**	East St. N Ext. From East St at 196th St to SR 38 at Anthony Rd	**N/A**	**N/A**	Sinusoidal		16	12	
SR 19	RS-41093-A	9/10/2020	**ACTIVE**	From 6.80 mi N of SR 32 NCL Cicero to 9.03 mi N of SR 32 ncl arcadia	6+79	9+6	Sinusoidal		16	12	
US 40	RS-40597-A	11/18/2020	**ACTIVE**	From 0.39 mi E of SR 103 Cherry St) to 2.98 mi E of SR 103 WCL Straughn)	121+12	123+71	Sinusoidal		16	12	
SR 67	RS-40585-A	9/18/2019	5/18/2021	From US 35/SR 3 to SR 28 S JCT	158+25	161+21	Sinusoidal		16	12	
US 40	RS-40597-A	11/18/2020	**ACTIVE**	From 3.53 mi E of SR 103 ECL Straughn) to 3.22 mi W of SR 1 WCL Dublin	124+26	128+6	Sinusoidal		16	12	
US 35	B-38532-A	8/13/2020	1/24/2022	3.85 mi S I-69, over Big Killbuck Creek	56+26	56+26	Sinusoidal		16	12	
SR 9	RS-39993-B	8/31/2020	11/28/2022	From US 52 to East CR 300 N	39+91	49+7	Sinusoidal		16	12	
SR 1	R-42139-A	12/17/2020	**ACTIVE**	From NCL Milton to US 40	57+1	58+60	Sinusoidal		16	12	
US 27	RS-39992-A	1/22/2020	5/10/2022	From 0.31 mi N of SR 44 (NCL Liberty) to 0.86 mi S of US 40 (S O Street	8+17	20+62	Sinusoidal		16	12	
SR 67	R-41803-A	4/8/2020	6/16/2020	From 0.17 mi N of SR 42 to 3.58 mi E of SR 42 Marion County Line	96+14.3	100+45.3	Sinusoidal		16	12	
SR 234	RS-41045-A	12/17/2020	3/4/2022	From SR 109 to 2.70 mi E of SR 109 Hancock/Henry Co. Line	69+28	71+66	Sinusoidal		16	12	
SR 26	R -40496-A	1/19/2022	**ACTIVE**	From SR 13 to SR 9	92+25.2	100+24.9	Sinusoidal		16	12	
SR 67	R -41803-A	4/8/2020	6/16/2022	At I-465 Ramp Terminals SW Indianapolis	104+53	104+75	Sinusoidal		16	12	
SR 1	R -41102-A	1/21/2021	1/6/2022	SR 1, from SR 32 N. JCT to SR 28	85+93	93+92	Sinusoidal		16	12	
IR 1066	R -37740-A	10/17/2019	**ACTIVE**	236th Street, between Deming Road and Tollgate Road	**N/A**	**N/A**	Sinusoidal		16	12	
US 35	RS-40689-B	8/14/2019	6/28/2021	From CR 80 W to District Line	109+46	113+60	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From	To	Rumble Stripe Type	Width	Placement		
					Route or MM	Route or MM			Center	Edge	Shoulder
I 69	B-40009-B	4/8/2020	3/17/2022	NB over Pipe Creek, 03.95 N SR 28	248+72	248+72	Sinusoidal		16	12	
SR 38	RS-40587-A	8/14/2019	4/8/2021	From Lindley Farm Rd to SR 32 W JCT	50+11	56+75	Sinusoidal		16	12	
SR 3	B-40531-A	2/12/2020	4/6/2023	From SR 67 to US 35	129+64	131+14	Sinusoidal		16	12	
SR 67	R-41803-A	4/8/2020	6/16/2022	3.58 mi E of SR 42 Marion Co Line) to I-465	99+55	104+0	Sinusoidal		16	12	
SR 38	RS-40612-A	8/13/2020	3/23/2022	From Lindley Farm Rd to SR 32 W JCT	132+15	138+29	Sinusoidal		16	12	
SR 26	30321	7/19/2010	7/1/2014	SR 26, from 4.5 mi E of SR 29 to 2.18 mi W of US 31	66+71	74+132	Conventional		16	16	16
SR 44	31335	9/18/2013	4/4/2017	SR 44, from US 27 to the Indiana/Ohio State Line	83+83	89+75	Conventional		16	16	16
SR 28	34572	9/18/2013	3/21/2016	SR 28, from Mississinewa Ave to SR 1	127+49	132+15	Conventional		16	16	16
SR 32	34571	10/17/2013	5/23/2016	SR 32, from 425 Feet W of 200 E to 1.01 mi N of SR 227 SCL of Union City	148+60	155+72	Conventional		16	16	16
SR 38	34771	10/17/2013	4/19/2016	SR 38, from SR 109 to 3.41 mi E of SR 109 CR 975 W)	78+16	81+57	Conventional		16	16	16
SR 9	30148	12/30/2016	9/12/2019	SR 9, from 2.10 mi N of S JCT SR 9 Fall Creek) to I-69	62+22	64+35	Conventional		16	16	16
SR 28	31340	11/20/2013	5/11/2017	SR 28, from SR 37 to SR 9	96+54	103+82	Conventional		16	16	16
SR 37	31410	11/20/2013	2/28/2017	SR 37, from 2.38 mi N of SR 32/SR 38 end of Dual Lanes to SR 213	177+42	181+83	Conventional		16	16	16
SR 32	30482	12/19/2013	6/6/2016	SR 32, from 5.64 mi W of US 31 to 1.6 mi W of US 31	72+87	76+91	Conventional		16	16	16
SR 44	34856	10/17/2014	8/27/2015	SR 44, from RP 48.16 to RP 54.53 near Rushville	48+16	54+53	Conventional		16	16	16
SR 44	31334	1/30/2015	5/16/2017	SR 44, from 0.82 mi E of SR 1 ECL Connersville) to US 27	73+7	83+35	Conventional		16	16	16
US 35	35482	1/30/2015	1/12/2017	US 35, US 35; from 0.45 mi north US 36 to SR 3 Muncie bypass RP 27+65-41+35)	27+65	41+35	Conventional		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
SR 3	37758	3/13/2015	7/26/2016	SR 3, from US 40 to SW ramp at I-70 RP 105+08 - 108+80)	105+8	108+80	Conventional		16	16	16
SR 19	31432	7/17/2015	9/16/2016	SR 19, from 2.92 mi N of SR 32 206th St) to 6.82 mi N of SR 32 Cicero Ck	2+92	6+82	Conventional		16	16	16
SR 37	37898	2/5/2016	2/4/2019	SR 37, from SR 28 to SR 26	195+59	207+37	Conventional		16	16	16
SR 26	29385	3/8/2016	7/13/2018	SR 26, from SR 1 to SR 67	130+40	138+0	Conventional		16	16	16
SR 9	30148	12/30/2016	9/12/2019	SR 9, from 2.10 mi N of S JCT SR 9 Fall Creek) to I-69	62+22	64+35	Conventional		16	16	16
SR 67	30322	5/17/2017	3/28/2018	SR 67, from S JCT with SR 28 to SR 167, Albany	161+20	166+34	Conventional		16	16	16
US 35	35458	3/14/2017	5/2/2019	US 35, from I-70 to US 35/SR 38 split	7+25	8+51	Conventional		16	16	16
SR 234	35609	12/30/2016	7/11/2018	SR 234, from 2.70 mi E SR 109 (Hancock/Henry CO LN) to SR 38	71+66	80+.3	Conventional		16	16	16
US 27	38673	4/12/2017	5/3/2018	US 27, from NCL of Portland to SR 18/SR 67	65+93	72+23	Conventional		16	16	16
SR 26	39103	2/8/2017	4/3/2018	SR 26, from SR 167 to SR 1	127+20	129+90	Conventional		16	16	16
SR 101	39265	3/21/2018	4/24/2019	SR 101, from 7.85 mi S of US 27 District Line to US 27	26+55	34+40	Conventional		16	12	
US 35	39787	5/16/2018	11/13/2019	US 35, from SR 3/SR 67 to SR 28	41+5	50+10	Conventional		16	12	
SR 13	40279	3/21/2018	8/28/2018	SR 13, from the S. JCT of SR 37 to the N. JCT SR 37	17+15	23+30	Conventional		16	12	
SR 67	40585	9/18/2019	5/1821	SR 67, from US 35/SR 3 to SR 28 S JCT	158+25	161+21			16	12	
US 35	40689	8/14/2019	6/28/2021	US 35, from CR 80 W to District Line	109+46	113+60			16	12	
US 35	40787	7/20/2018	10/6/2020	US 35, from N JCT SR 3 to I-69	50+10	60+11	Conventional		16	12	
SR 227	42023	7/17/2019	3/30/2020	SR 227, 3.03 mi S of US 36 Wayne/Randolph Co Line) to US 36	25+29	28+32	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
Special SR 35X	39048	9/22/2016	6/1/2017	SP 35X from 350 ft E of Meeker Ave to SR 3X Macedonia Ave)	**N/A**	**N/A**	Conventional		16	16	16
Special SR OSR3	39048	9/22/2016	6/1/2017	SP OSR3 SR 3X from 200 ft S of Fuson Road to US 35X 29th Street	**N/A**	**N/A**	Conventional		16	16	16
SR 32	39159	3/14/2017	9/23/2019	SR 32, from SR 1 to 1.50 mi W of US 27	139+22	145+60	Conventional		16	16	16
SR 32	39159	3/14/2017	9/23/2019	SR 32, from 3.82 mi E of US 35 CR 650 E to SR 1	130+2	137+24	Conventional		16	16	16
SR 38	39160	2/23/2017	3/16/2018	SR 38, from SR 32 to SR 13	60+26	66+59	Conventional		16	16	16
SR 38	39160	2/23/2017	3/16/2018	SR 38, from SR 13 to I-69	66+55	70+53	Conventional		16	16	16
SR 227	39251	4/11/2019	5/27/2021	SR 227, from US 36 to SR 32	28+32	37+40			16	12	
SR 28	39251	4/11/2019	5/27/2021	SR 28, from US 27 to Plum Street	141+79	151+42			16	12	
SR 38	40587	8/14/2019	4/8/2021	SR 38, from Lindley Farm Rd to SR 32 W JCT	50+11	56+75			16	12	
SR 32	40587	8/14/2019	4/8/2021	SR 32, from 1,000 ft east of East St. to .2 mi East of Cicero Creek"	79+30	84+20			16	12	
SR 26	42022	7/17/2019	5/3/2021	SR 26, from 931 to SR 13	76+32	92+25			16	12	
SR 26	42022	7/17/2019	5/3/2021	SR 26, from SR 13 to I-69	92+25	106+74			16	12	
US 35	40908	10/18/2018	7/7/2020	US 35, 0.09 mi W of SR 15 to SR 13	78+85	89+30	Conventional		16	12	

Table B.4 La Porte rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
SR 10	RS-40089-A	8/22/2019	10/19/2021	From SR 23 to SR 17 W JCT	58+98	63+90	Sinusoidal		16	12	
US 35	R-41024-A	3/13/2020	**ACTIVE**	From 0.33 mi N. of SR 16 to N JCT of SR 14	141+68	155+78	Sinusoidal		16	12	
US 20	R-39883-A	5/22/2020	8/2/2021	0.25 mi W of CR 700 E/Cougar Rd to 0.25 mi E of CR 700 E/Cougar Rd	68+90	69+40	Sinusoidal		16	12	
SR 149	R-40651-A	2/18/2021	3/16/2022	From SR 130 to US 12	0+0	8+71	Sinusoidal		16	12	
US 6	R-41032-A	4/8/2020	5/12/2021	US 31 to W. JCT of SR 106	69+58	74+99	Sinusoidal		16	12	
SR 331	R-41216-A	12/22/2020	**ACTIVE**	From US 30 to SR 106 S JCT	9+72	19+91	Sinusoidal		16	12	
US 24	R-42222-A	2/17/2022	3/29/2023	0.68 mi E of US 421/SR 43 to 2.65 mi W of SR 39 CR 300 E)	35+75	38+28	Sinusoidal		16	12	
US 20	R-39883-A	5/22/2020	8/2/2021	From SR 2 to 3.95 mi E of SR 2 LaPorte/St Joseph County Line	56+62	60+57	Sinusoidal		16	12	
US 6	R-41032-A	4/8/2020	5/12/2001	US 6 over East Branch Bunch Ditch, 00.12 mi E SR 106	75+11	75+11	Sinusoidal		16	12	
SR 8	RS-40089-A	8/22/2019	10/19/2021	From SR 39 to US 35	24+6	30+13	Sinusoidal		16	12	
US 35	R-38751-A	1/22/2020	2/22/2021	Boyd Blvd to Kingsbury Ave	195+5	197+58	Sinusoidal		16	12	
US 24	R-39804-A	5/15/2020	8/24/2021	Illinois State Line to US 41	2+0	4+65	Sinusoidal		16	12	
US 231	R-40645-A	12/17/2020	10/7/2022	I-65 to N JCT of SR 55	288+0	291+72	Sinusoidal		16	12	
SR 39	R-39804-A	5/15/2020	8/24/2021	From the N JCT of SR 16 to SR 14	132+0	143+0	Sinusoidal		16	12	
US 41	R-42221-A	1/19/2022	**ACTIVE**	From SR 14 to SR 10	229+6	239+48	Sinusoidal		16	12	
US 30	R-41023-A	4/8/2020	8/20/2021	From 2.65 mi W of W JCT of SR 2 CR 250 W) to 0.6 mi E of SR 49 Industrial Dr	21+72	27+10	Sinusoidal		16	12	
SR 23	RS-41203-A	8/13/2020	4/8/2021	0.15 mi N of US 6 Tyler St to 0.42 mi S of SR 4 Pine St	18+75	24+13	Sinusoidal		16	12	
SR 2	R-42219-A	12/22/2021	**ACTIVE**	0.88 mi N of US 231 to US 30	23+15	35+73	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 35	R-41202-A	3/18/2021	**ACTIVE**	SR 218 to S JCT of US 24	120+15	126+14	Sinusoidal		16	12	
SR 39	R-38751-A	1/22/2020	2/22/2021	From US 35 N JCT) to US 20	186+0	189+51	Sinusoidal		16	12	
US 231	B-42683-A	5/22/2020	3/11/2021	@.-Barnard Ditch, 3.08 mi N of SR 10	274+63	274+63	Sinusoidal		16	12	
US 421	R-38757-A	3/13/2020	2/11/2021	From SR 18 W JCT to 1.79 mi E of SR 18 W JCT (Bridge over Wabash River	148+87	150+53	Sinusoidal		16	12	
SR 17	R-41199-A	7/23/2020	5/24/2021	From SR 14 to SR 10	22+94	34+84	Sinusoidal		16	12	
SR 130	R-39882-A	2/21/2021	**ACTIVE**	From SR 51 to SR 149	1+0	7+8	Sinusoidal		16	12	
US 24	R-35144-A	4/8/2020	**ACTIVE**	From 2.65 mi W of SR 39 CR 300 E) to US 421 E JCT	38+30	41+1	Sinusoidal		16	12	
US 6	RS-42588-A	5/15/2020	3/16/2022	From SR 39 to US 35 E JCT	44+59	51+76	Sinusoidal		16	12	
US 421	R-39804-A	5/15/2020	8/24/2021	N JCT of US 24 to SR 16	168+0	175+73	Sinusoidal		16	12	
SR 2	R-42492-A	1/28/2022	3/14/2023	IL State Line to the S JCT of US 41	0+0	3+43	Sinusoidal		16	12	
SR 10	RS-41026-A	8/14/2019	10/29/2020	From SR 49 to US 421	28+19	36+23	Sinusoidal		16	12	
US 35	R-38751-A	1/22/2020	2/22/2021	From US 6 W JCT) to Boyd Blvd	191+0	195+46	Sinusoidal		16	12	
US 6	B-41204-A	10/28/2020	7/19/2022	EB@.-SR 49 SB/NB, 4.06 mi E of SR 149	27+35	27+35	Sinusoidal		16	12	
SR 130	R-39882-A	1/21/2021	**ACTIVE**	SR 130 at CR 450 W	6+22	6+22	Sinusoidal		16	12	
US 35	R-41202-A	3/18/2021	**ACTIVE**	0.15 mi N of SR 18 to .55 mi S of SR 218 CR 700 E)	113+75	119+61	Sinusoidal		16	12	
US 20	R-42651-A	10/12/2021	3/2/2023	From SR 152 to SR 912	7+19	9+77	Sinusoidal		16	12	
SR 331	B-40600-A	12/9/2021	**ACTIVE**	5.48 mi S of US 33	30+8	30+8	Sinusoidal		16	12	
SR 10	RS-42483-A	5/19/2020	2/24/2021	SR 110 to W JCT of US 231	17+19	20+39	Sinusoidal		16	12	
SR 106	RS-42645-A	4/8/2020	**ACTIVE**	From US 6 W JCT) to US 6 E JCT	0+0	4+32	Sinusoidal		16	12	
SR 218	R-41202-A	3/18/2021	**ACTIVE**	From SR 29 to US 35	13+84	25+25	Sinusoidal		16	12	
US 6	B-41204-A	10/28/2020	7/19/2022	WB@.-SR 49 SB/NB, 4.06 mi E of SR 149	27+39	27+39	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
SR 114	RS-40086-A	3/13/2020	3/22/2021	From I-65 to Iroquois River Bridge	16+7	21+17	Sinusoidal		16	12	
US 35	30340	5/20/2011	7/2/2012	US 35, from US 24 to SR 16	131+92	141+27	Conventional		16	12	
US 231	30917	11/29/2011	1/9/2013	US 231, from I-65 to US 24	227+43	233+10	Conventional		16	12	
SR 10	32727	3/26/2012	6/10/2013	SR 10, from US 41 to CR 400E	3+99	11+25	Conventional		16	12	
SR 10	30497	5/20/2013	5/11/2016	SR 10, from the Illinois State Line to US 41	0+0	3+99	Conventional		16	16	16
SR 119	32471	4/16/2014	8/29/2016	SR 119, from SR 16 E JCT to US 35	4+58	18+20	Conventional		16	16	16
SR 10	34653	8/13/2014	3/10/2016	SR 10, from I-65 to SR 110	13+78	17+26	Conventional		16	16	16
SR 8	34652	8/28/2014	4/4/2016	SR 8, from 0.65 mi E of US 421 to SR 39	16+5	24+9	Conventional		16	16	16
SR 16	34429	11/25/2014	10/21/2015	SR 16, from SR 39 S JCT to SR 119	37+	41+	Conventional		16	16	16
SR 16	34429	11/25/2014	10/21/2015	SR 16, from SR 39 N JCT) to SR 39 S JCT near Buffalo	35+55	37+16	Conventional		16	16	16
US 231	34717	12/30/2014	2/8/2016	US 231, from I-65 to SR 16	242+99	246+88	Conventional		16	16	16
US 231	34432	2/12/2015	1/28/2016	US 231, from SR 10 W JCT to North Corporate Limits of DeMotte	271+53	273+59	Conventional		16	16	16
SR 110	34644	3/17/2015	12/10/2015	SR 110, from SR 10 to US 231	0+	2+	Conventional		16	16	16
SR 16	34719	3/17/2015	1/28/2016	SR 16, from US 231 to US 421	14+75	29+15	Conventional		16	16	16
SR 14	34351	4/10/2015	6/24/2016	SR 14, US 41 to railroad tracks in Town of Parr, 3.5 mi E of I-65	0+0	12+94	Conventional		16	16	16
SR 16	37921	4/10/2015	5/31/2016	SR 16, from 2.54 mi East of SR 55, East Corporate Limits of Brook, to US 231	4+25	14+75	Conventional		16	16	16
SR 23	35209	7/15/2015	1/26/2016	SR 23, SR 23 from Osborn Rd. to US 20/31	24+57	35+81	Conventional		16	16	16
SR 2	35209	7/15/2015	1/26/2016	SR 2, SR 2 from US 421, N JCT to SR 39, W JCT	49+8	58+32	Conventional		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
SR 39	34054	8/12/2015	5/23/2016	SR 39, from US 30 to US 6	169+23	176+97	Conventional		16	16	16
SR 17	34645	10/19/2015	10/18/2016	SR 17, from SR 16 to SR 14	7+96	22+97	Conventional		16	16	16
SR 2	35208	11/23/2015	10/14/2016	SR 2, SR 2 from Hebron North Town Limit to US 30, W. JCT	22+90	35+74	Conventional		16	16	16
US 231	37073	11/18/2015	12/27/2016	US 231, from SR 16 to Iroquois River Bridge 0.19 mi S of SR 114	246+88	251+64	Conventional		16	16	16
SR 8	34436	12/15/2015	12/13/2016	SR 8, from SR 49 to 0.65 mi E of US 421	9+6	16+5	Conventional		16	16	16
SR 104	34709	12/15/2015	10/14/2016	SR 104, from SR 4 to US 6	0+	9+	Conventional		16	16	16
US 24	35347	11/18/2015	9/28/2016	US 24, from SR 55 E JCT) to US 231 W JCT	11+9	19+53	Conventional		16	16	16
SR 16	37076	1/22/2016	9/16/2016	SR 16, from US 421 to SR 39 N JCT	29+15	35+55	Conventional		16	16	16
SR 4	34718	2/11/2016	2/7/2017	SR 4, from SR 104 to SR 23 North Liberty Corp. Line	6+53	16+88	Conventional		16	16	16
SR 18	34441	3/8/2016	2/6/2017	SR 18, from SR 75 to SR 18	54+99	62+23	Conventional		16	16	16
SR 331	34056	3/11/2016	5/15/2017	SR 331, from SR 106 to US 20	19+185	33+20	Conventional		16	16	16
SR 2	34431	1/10/2017	10/29/2018	SR 2, from SR 49, RP 38+1.13 to US 421, RP 48+08	35+287	48+109	Conventional		16	16	16
US 20	36660	2/15/2018	9/2/2020	US 20, from SR 212 to SR 39	43+95	48+79	Conventional		16	12	
SR 2	33630	4/12/2017	3/28/2018	SR 2, I-65 to US 231 W JCT	15+81	20+11	Conventional		16	16	16
US 231	33905	4/19/2018	5/16/2019	US 231, from SR 10 E JCT to SR 10 W JCT	269+0	271+53	Conventional		16	12	
SR 51	34008	8/16/2017	**ACTIVE**	SR 51, from US 30 to US 20	0+0	9+56	Conventional		16	16	16
SR 39	37731	1/25/2017	2/15/2018	SR 39, from US 20 to the Michigan State Line	189+51	194+85	Conventional		16	16	16
SR 55	37733	2/15/2019	1/15/2020	SR 55, from SR 14 to SR 10	71+9	80+16			16	12	
SR 49	37734	12/18/2018	1/5/2021	SR 49, from SR 8 to US 30	20+47	29+23	Conventional		16	12	
SR 25	39466	5/15/2019	3/17/2020	SR 25, from SR 110 to SR 19	106+84	111+5			16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
US 231	39470	4/11/2019	4/8/2020	US 231, from Demotte Corp Limit to Hebron Corp Limit	273+59	278+55			16	12	
SR 18	40823	2/15/2019	**ACTIVE**	SR 18, 0.46 mi E of SR 43, Brookston Corp. Limit to US 421 - FDR	35+78	42+61			16	12	
SR 14	40878	5/22/2018	4/24/2020	SR 14, from US 41 to 3.39 mi E of I-65 CSX RR in Parr	0+0	12+79	Conventional		16	12	
SR 10	41026	8/14/2019	10/29/2020	SR 10, from SR 49 to US 421	28+19	36+23			16	12	
US 231	33957	5/16/2018	**ACTIVE**	US 231, from W JCT of SR 55 to US 41	291+80	297+29	Conventional		16	12	
US 20	34057	2/7/2017	6/12/2018	US 20, from LaPorte/St. Joseph County Line to East side of US 31 interchange	60+60	70+32	Conventional		16	12	
US 421	35154	1/25/2017	12/27/2017	US 421, 0.5 mi S of CR 200 N to Hamilton St in the Town of Delphi	145+99	147+51	Conventional		16	16	16
SR 18	35154	1/25/2017	12/27/2017	SR 18, US 421 to SR 75	49+0	54+99	Conventional		16	16	16
SR 16	35211	3/21/2018	4/1/2019	SR 16, from SR 119 to US 35	41+	50+	Conventional		16	12	
US 421	35211	3/21/2018	4/1/2019	US 421, 1.5 mi S of US 24 Tippecanoe River) to 0.23 mi S of US 24 (Harrison St	160+13	161+63	Conventional		16	12	
SR 14	37687	10/18/2018	1/8/2020	SR 14, from SR 39 to US 35	38+8	46+99	Conventional		16	12	
SR 14	37687	10/18/2018	1/8/2020	SR 14, from SR 49 to US 421	22+9	30+12	Conventional		16	12	
US 24	38631	3/26/2018	9/23/2019	US 24, from White/Cass County Line to US 35	51+4	60+78	Conventional		16	12	
SR 4	39467	7/20/2018	12/12/2019	SR 4, from 0.34 mi E of SR 23 to US 31	17+70	25+40	Conventional		16	12	
SR 933	39467	7/20/2018	12/12/2019	SR 933, from 0.2 mi W of SR 331 to SR 23	105+70	111+24	Conventional		16	12	
SR 218	41298	8/17/2018	11/13/2019	SR 218, SR 218, from 0.35 mi E of SR 75 to SR 29	6+19	13+84	Conventional		16	12	
SR 218	41298	8/17/2018	11/13/2019	SR 218, SR 218 from SR 25 to 0.3 mi W of SR 75	1+76	5+57	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement Center	Placement Edge	Placement Shoulder
SR 2	34431	1/10/2017	10/29/2018	SR 2, from SR 49, RP 38+1.13 to US 421, RP 48+08	35+287	48+109	Conventional		16	12	
SR 17	34438	3/10/2017	3/5/2019	SR 17, 3.29 mi S of US 30 (Olive Ln) to US 30	47+15	50+44	Conventional		16	12	
SR 17	34438	3/10/2017	3/5/2019	SR 17, from SR 8 to 3.29 mi S of US 30 (Olive Trail/Plymouth Corp. Line	40+1	47+15	Conventional		16	12	
SR 55	35213	5/17/2017	8/30/2018	SR 55, US 24 to SR 16	50+87	58+40	Conventional		16	12	
SR 114	35213	5/17/2017	8/30/2018	SR 114, 1.09 mi E of US 231, Rensselaer Corp. Limit to US 421	20+98	33+60	Conventional		16	12	
US 24	35213	5/17/2017	8/30/2018	US 24, from 0.5 mi E of I-65 to 3.95 mi E of I-65 Wolcott Corp Limit	21+84	25+34	Conventional		16	12	
SR 117	37738	3/14/2019	2/12/2020	SR 117, from SR 10 to SR 110	0+0	4+44			16	12	
SR 23	37738	3/14/2019	2/12/2020	SR 23, from SR 8 to US 30	4+0	10+85			16	12	
US 35	37738	3/14/2019	2/12/2020	US 35, from 0.81 mi S of SR 8 N JCT) to US 30	173+21	179+48			16	12	
SR 9	38695	12/30/2016	1/8/2018	SR 9, 0.48 mi N of US 20 to 1.98 mi N of SR 120	188+43	195+54	Conventional		16	12	
SR 17	39465	7/20/2018	7/30/2021	SR 17, from 1.42 mi N of SR 25 Northern Ave to SR 16	1+30	7+87	Conventional		16	12	
US 24	39465	7/20/2018	7/30/2021	US 24, from US 421 E JCT to White/Cass Co Line	41+1	51+0	Conventional		16	12	
SR 10	40089	8/22/2019	10/19/2021	SR 10, from SR 23 to SR 17 W JCT	58+98	63+90			16	12	
SR 8	40089	8/22/2019	10/19/2021	SR 8, from SR 39 to US 35	24+6	30+13			16	12	
SR 10	40089	8/22/2019	10/19/2021	SR 10, from US 31 to Juniper St in Argos	73+90	75+48			16	12	
US 421	34044	5/16/2018	11/9/2020	US 421, SR 10 S. JCT) to US 30	197+81	214+87	Conventional		16	12	
US 6	34044	5/16/2018	11/9/2020	US 6, from SR 49 to SR 39	26+80	44+59	Conventional		16	12	
SR 3	35102	2/23/2017	4/2/2018	SR 3, from US 20 to SR 120	217+15	223+52	Conventional		16	12	
SR 23	38629	3/21/2018	3/29/2019	SR 23, from SR 10 to SR 8	0+	4+	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 421	39469	10/18/2018	2/28/2023	US 421, from SR 2 N JCT) to 0.3 mi S of I 94 CR 300 N)	223+70	229+97	Conventional		16	12	
SR 53	34439	5/17/2017	**ACTIVE**	SR 53, from US 231 to 93rd Ave	0+0	3+35	Conventional		16	12	

Table 10.5 Seymour rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
SR 135	RS-40939-A	11/25/2020	8/16/2022	0.95 mi N of W JCT SR 46 Ridgeway Dr) to 0.33 mi S of W JCT of SR 252	100+43	111+97	Sinusoidal		16	12	
SR 135	RS-40939-A	11/25/2020	8/16/2022	E JCT of SR 252 to SR 144	118+64	126+7	Sinusoidal		16	12	
US 31	RS-40061-A	8/14/2019	11/24/2020	5.76 mi S of I-65 Washington St) to 0.33 mi S of I-65	71+57	76+104	Sinusoidal		16	12	
SR 62	RS-40938-A	7/16/2020	8/26/2022	US 421 to 1.6 mi E of US 421 (Old SR 62	195+92	197+47	Sinusoidal		16	12	
SR 46	B-40058-A	11/20/2019	4/8/2021	0.99 mi E of W JCT SR 135 over North Fork Salt Creek	74+4	74+4	Sinusoidal		16	12	
SR 3	RS-40068-A	2/12/2020	3/24/2021	9.54 mi S of W JCT SR 46 (Westport NCL) to W JCT SR 46	57+9	66+70	Sinusoidal		16	12	
SR 1	RS-40451-A	9/10/2020	5/4/2022	US 50 to SR 46	0+0	16+75	Sinusoidal		16	12	
SR 111	R-40707-A	2/18/2021	1/27/2023	3.25 mi N of SR 211 Knob Creek Bridge) to 0.87 mi S of I-64 Corydon Pike	15+84	23+59	Sinusoidal		16	12	
SR 144	RS-40063-A	1/10/2020	2/19/2021	From SR 135 to SR 44	8+18	12+57	Sinusoidal		16	12	
SR 252	RS-40941-A	7/23/2020	8/9/2022	0.42 mi E of US 52 (Bridge over Whitewater River) to District Line	37+5	47+83	Sinusoidal		16	12	
SR 9	R-39909-A	2/18/2021	3/1/2022	4.09 mi N of East Intersection SR 46 over Horse Creek	11+3	11+3	Sinusoidal		16	12	
SR 46	B-40058-A	11/20/2019	4/8/2021	1.24 mi E of W JCT of SR 135 over North Fork Salt Creek	74+29	74+29	Sinusoidal		16	12	
SR 3	R-40426-A	11/29/2021	2/20/2023	At 16.17 mi N of SR 7	60+37	60+37	Sinusoidal		16	12	
US 421	R-42997-A	12/16/2021	**ACTIVE**	4.93 mi S of SR 229 Jac-Cen-Del School Dr) to 0.16 mi N of SR 229	31+97	36+103	Sinusoidal		16	12	
SR 7	RS-36125-A	7/17/2019	7/21/2020	From N JCT of SR 3 to US 31	26+16	40+19	Sinusoidal		16	12	
SR 203	RS-40062-A	4/17/2020	5/27/2021	E JCT of SR 356 to SR 3	4+53	7+101	Sinusoidal		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
SR 45	RS-40072-A	2/26/2020	3/18/2021	From SR 445 to I-69 O & M Limits	23+84	34+102	Sinusoidal		16	12	
US 50	T-41021-A	9/10/2020	**ACTIVE**	From SR 3 to US 50	113+128	117+53	Sinusoidal		16	12	
SR 46	RS-40946-A	10/15/2020	7/26/2022	0.83 mi E of E JCT US 421 Base Rd.) to 0.29 mi W of SR 229	120+16	133+43	Sinusoidal		16	12	
US 52	R-41868-A	11/29/2021	4/11/2023	0.7 mi E of SR 252 Blue Creek Rd) to E JCT of SR 1	155+81.3	160+29	Sinusoidal		16	12	
SR 3	RS-40945-A	7/23/2020	4/25/2022	0.49 mi N of I-74 to 6.26 mi N of I-74 District Line	73+70	79+45	Sinusoidal		16	12	
SR 446	RS-40947-A	4/17/2020	6/18/2021	7.83 mi N of SR 58 Chapel Hill Rd) to 0.98 mi S of SR 46 E. Moores Pike	12+6	22+62	Sinusoidal		16	12	
SR 46	R-42147-A	11/29/2021	4/10/2023	SR 7 to 0.21 mi E of SR 9	94+89.7	100+83.8	Sinusoidal		16	12	
SR 7	RS-39151-B	9/18/2019	12/4/2020	From 0.27 mi N of SR 62 (Industrial Dr) to 1.61 mi S of SR 250	3+40	6+27	Sinusoidal		16	12	
PR 69	R-33541-A	2/5/2020	12/16/2022	Morgan Co from 1 mi N of Henderson Ford Rd via SR 37 to 1 mi S of SR 144. S-lines only S6.3)	123+49	128+90	Sinusoidal		16	12	
SR 111	R-40707-A	2/18/2021	1/27/2023	SR 211 to 3.25 mi N of SR 211 Knob Creek Bridge	12+54	16+25	Sinusoidal		16	12	
SR 135	R-42096-A	12/16/2021	12/21/2022	0.37 mi N of W JCT SR 252 Morgantown ECL) to E SR 252	112+69.1	118+63.7	Sinusoidal		16	12	
SR 446	RS-40947-A	4/17/2020	6/18/2021	US 50 to 7.83 mi N of SR 58 Chapel Hill Rd	1+-99	12+6	Sinusoidal		16	12	
SR 129	RS-40940-A	10/13/2020	8/8/2022	SR 48 to SR 46	36+18	42+89	Sinusoidal		16	12	
SR 60	R-40699-A	9/10/2020	4/22/2022	Intersection of Salem Bypass	35+2	35+16	Sinusoidal		16	12	
SR 135	R-40951-A	7/21/2021	12/29/2022	US 50 to S JCT of SR 58	68+16	75+36	Sinusoidal		16	12	
US 50	31980	8/16/2013	3/17/2016	US 50, Dutch Hollow Road to SR 350	158+3	160+44	Sinusoidal		16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From	To	Rumble Stripe Type	Width	Placement		
					Route or MM	Route or MM			Center	Edge	Shoulder
SR 111	34687	1/1014	12/18/2014	SR 111, SR 7, SR 46, US 50	**N/A**	**N/A**	Conventional		16	16	16
SR 46	34687	1/1014	12/18/2014	SR 111, SR 7, SR 46, US 50	**N/A**	**N/A**	Conventional		16	16	16
SR 46	34687	1/1014	12/18/2014	SR 111, SR 7, SR 46, US 50	**N/A**	**N/A**	Conventional		16	16	16
SR 7	34687	1/1014	12/18/2014	SR 111, SR 7, SR 46, US 50	**N/A**	**N/A**	Conventional		16	16	16
US 50	34687	1/1014	12/18/2014	SR 111, SR 7, SR 46, US 50	**N/A**	**N/A**	Conventional		16	16	16
US 50	35414	8/13/2014	8/21/2015	VA VARI, various locations throughout the Seymour District	**N/A**	**N/A**	Conventional		16	16	16
SR 60	35414	8/13/2014	8/21/2015	VA VARI, various locations throughout the Seymour District	**N/A**	**N/A**	Conventional		16	16	16
SR 62	35414	8/13/2014	8/21/2015	VA VARI, various locations throughout the Seymour District	**N/A**	**N/A**	Conventional		16	16	16
SR 44	30599	1/16/2015	11/15/2017	SR 44, at Centerline Road	17+0	17+45	Conventional		16	16	16
US 150	35320	4/10/2015	5/26/2015	US 150, from SR 335 to Buck Creek Road	163+22	168+78	Conventional		16	16	16
SR 44	37865	4/21/2015	20/7/17	SR 44, various safety work from SR 135 to SR 144 see log notes	13+63	18+61	Conventional		16	16	16
SR 11	34893	9/10/2015	4/21/2017	SR 11, from US 50 to I-65	37+12	43+7	Conventional		16	16	16
SR 7	37860	2/11/2016	2/16/2018	Locations in Seymour District on SR 7 and SR 135	**N/A**	**N/A**	Conventional		16	12	
SR 60	38378	3/8/2016	6/7/2017	SR 60, from SR 335 in Washington County to US 31 in Clark County	43+4	60+	Conventional		16	16	16
SR 252	30312	7/21/2016	9/18/2019	SR 252, from I-65 to Flatrock	30+39	36+58	Conventional		16	12	
SR 7	36125	7/17/2019	7/21/2020	SR 7, from N JCT of SR 3 to US 31	26+16	40+19			16	12	
SR 56	37949	5/12/2016	5/10/2017	SR 56, from SR 39 to Beechwood Avenue	112+27	117+67	Conventional		16	16	16
US 50	38640	3/28/2018	4/11/2019	US 50, from US 31 to just W of SR 750	105+90	114+20	Conventional		16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Width	Placement		
									Center	Edge	Shoulder
US 50	38641	10/19/2017	6/18/2019	US 50, from Jennings/Ripley County Line to SR 101	128+91	146+34	Conventional		16	12	
SR 135	39147	1/25/2017	10/3/2017	Locations on SR 135, SR 9, and US 31	**N/A**	**N/A**	Conventional		16	16	16
US 231	39149	4/20/2018	6/6/2019	US 231, from the E JCT of SR 46 to SR 67 District Line	122+95	128+33	Conventional		16	12	
SR 7	39151	9/18/2019	12/4/2020	SR 7, from 0.27 mi N of SR 62 (Industrial Dr) to 1.61 mi S of SR 250	3+40	6+27			16	12	
US 50	39224	6/21/2016	5/8/2017	US 50, from SR 446 to 0.41 mi W of E JCT of SR 135 CSX RR)	75+55	91+22	Conventional		16	16	16
SR 256	40020	9/19/2018	**ACTIVE**	SR 256, from .50 E of US 31 to 1200 feet E of SR 203	7+71	12+41	Conventional		16	12	
US 50	40073	5/15/2019	6/10/2020	US 50, 1.82 mi E of SR 3 (Deer Creek Rd) to 9.02 mi W of W JCT of US 421	119+65	129+35			16	12	
SR 46	40297	3/21/2018	8/13/2019	SR 46, W JCT SR 135 to 1.08 mi W of I-65	73+8	88+3	Conventional		16	12	
SR 39	40675	4/11/2019	3/24/2020	SR 39, N JCT SR 67 to SR 142 District Line	12+41	23+52			16	12	
SR 445	38962	4/12/2017	5/20/2020	SR 445, from SR 54 to 0.40 mi W of SR 45	0+0	1+0	Conventional		16	16	16
SR 67	40944	1/25/2019	8/8/2022	SR 67, from N JCT of SR 39 to 2.57 mi S of SR 144 Hancel Pike	86+0	93+48			16	12	
SR 67	40944	1/25/2019	8/8/2022	SR 67, 1.06 mi S of S JCT of SR 39 to S JCT of SR 39	81+47	82+48			16	12	
SR 144	40944	1/25/2019	8/8/2022	SR 144, from SR 67 to SR 37	0+0	7+23			16	12	
SR 67	40944	1/25/2019	8/8/2022	SR 67, 2.57 mi S of SR 144 Hancel Pike) to SR 144	93+37	95+109			16	12	

Table 10.6 Vincennes rumble strip's survey

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Placement Center	Placement Edge	Placement Shoulder
SR 57	RS-40640-A	7/16/2020	9/9/2021	From SR 58 to 5.91 mi N of SR 58	66+79	72+70	Sinusoidal	16	12	
SR 161	RS-39380-A	5/15/2020	12/29/2021	From E JCT with SR 62 to W JCT with SR 68 RP 15+71 to 27+12)	16+29	27+12	Sinusoidal	16	12	
US 50	RS-41130-A	5/19/2020	6/22/2021	From SR 60 to SR 37	53+38	63+12	Sinusoidal	16	12	
I 69	RS-39090-B	7/17/2019	5/3/2021	From I-64 to US 231	21+50	87+15	Sinusoidal	16	12	
SR 60	RS-39385-A	11/18/2020	10/28/2021	From SR 37 to Orange/Washington County Line	10+0	20+83	Sinusoidal	16	12	
SR 64	RS-41157-A	10/15/2020	12/28/2021	From W JCT SR 145 Birdseye) to W JCT SR 37	61+34	66+82	Sinusoidal	16	12	
SR 48	R-42120-A	3/18/2022	3/29/2023	From SR 63 to US 41	0+0	6+98	Sinusoidal	16	12	
SR 162	R-41128-A	1/21/2021	4/25/2022	From E JCT SR 245 to I-64	6+86	14+14	Sinusoidal	16	12	
SR 57	R-41163-A	4/15/2021	3/8/2022	From N Corp. limits of Washington to S JCT SR 58	50+74	66+81	Sinusoidal	16	12	
SR 69	RS-40042-A	1/22/2020	2/19/2021	From 3.90 mi N of SR 62 to 0.5 mi N of SR 269	17+37	26+55	Sinusoidal	16	12	
SR 66	RS-39357-A	5/15/2020	8/16/2022	From 2.2 mi E of SR 61 to E JCT SR 161 Reo	43+0	53+71	Sinusoidal	16	12	
SR 64	R-42121-A	3/18/2022	**ACTIVE**	2.45 mi W I-69 ECL of Francisco) to SR 57	18+99	22+94	Sinusoidal	16	12	
SR 37	RS-42626-A	12/17/2020	3/17/2022	From W JCT SR 64 to E JCT SR 64/ SR 237	29+42	38+46	Sinusoidal	16	12	
SR 54	B-40555-A	12/16/2021	2/16/2023	4.38 mi E JCT US 41	14+34	14+34	Sinusoidal	16	12	
SR 37	31614	4/21/2011	7/6/2017	SR 37, 1.02 mi N of JCT US 150/SR 56 to 0.09 mi S of Martin St.	56+1	61+75	Conventional	16	16	16
SR 54	30732	12/19/2013	8/31/2018	SR 54, US 41 to W JCT of SR 59	10+0	22+55	Conventional	16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Placement Center	Placement Edge	Placement Shoulder
US 41	30362	3/14/2014	1/26/2017	US 41, from 3.19 mi N SR 57 (1,000 ft N of Boon/N Harm Rd) to SR 168 Coal Mine Rd	12+0	22+23	Conventional	16	16	16
SR 61	30688	7/16/2014	4/13/2016	SR 61, JCT with SR 66 to W JCT with SR 62	0+9	8+81	Conventional	16	16	16
SR 67	30731	7/16/2014	2/6/2018	SR 67, JCT with SR 54 to N JCT with SR 57 and US 231	34+62	38+58	Conventional	16	16	16
US 231	30731	7/16/2014	2/6/2018	US 231, JCT with SR 67 to 2.48 mi N SR 67 (S of Worthington	10+44	103+92	Conventional	16	16	16
PR 61	30187	1/26/2015	8/18/2016	PR 61, from SR 62 to Millersburg Road	0+0	4+0	Conventional	16	16	16
US 150	31710	7/15/2015	12/7/2017	US 150, 2.04 mi W of JCT SR 37 to JCT w/ SR 37	132+10	134+14	Conventional	16	16	16
SR 257	38469	8/12/2015	2/23/2017	SR 257, from SR 356 to US 50	16+88	29+93	Conventional	16	16	16
SR 57	34959	11/18/2015	12/8/2016	SR 57, from SR 356 to 1.65 mi N of US 50	36+45	49+53	Conventional	16	16	16
SR 56	34967	2/11/2016	2/21/2017	SR 56, N JCT of SR 61 to S JCT of SR 61	19+30	23+83	Conventional	16	16	16
SR 61	34967	2/11/2016	2/21/2017	SR 61, SR 64 to SR 56	32+26	40+33	Conventional	16	16	16
SR 67	37943	3/11/2016	1/30/2017	SR 67, from 0.50 mi North of SR 550 to 0.25 mi South of SR 159	5+55	10+8	Conventional	16	16	16
SR 54	30733	4/28/2016	2/16/2018	SR 54, JCT with SR 67 to JCT with SR 57 and US 231	31+30	33+80	Conventional	16	16	16
SR 66	33873	4/12/2017	10/16/2019	SR 66, US 231 to SR 70	5721	71+8	Conventional	16	16	16
SR 54	30733	4/28/2016	2/16/2018	SR 54, JCT with SR 67 to JCT with SR 57 and US 231	31+30	33+80	Conventional	16	16	16
SR 68	37819	4/19/2018	2/19/2019	SR 68, from SR 65 to 0.35 W I-69	14+0	26+14	Conventional	16	16	16
US 231	38589	3/14/2017	2/7/2018	US 231, from 0.95 mi N of I-64 to 1.69 mi S of SR 64	35+31	40+24	Conventional	16	16	16
SR 545	38963	10/19/2017	3/7/2019	SR 545, from 0.3 mi N of SR 66 to SR 62	0+3	13+97	Conventional	16	16	16

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Placement		
								Center	Edge	Shoulder
US 150	39202	4/12/2017	9/12/2018	US 150, from US 50 to 0.20 mi W of SR 56 RP 111.91 to RP 125.18)	112+0	125+18	Conventional	16	16	16
SR 164	39211	2/8/2017	12/11/2017	SR 164, from 0.50 mi E of US 231 to 0.40 mi E of SR 545	0+50	12+20	Conventional	16	16	16
SR 60	39254	7/28/2017	3/16/2018	SR 60, from US 50 to 0.03 mi West North JCT SR 37	0+0	8+80	Conventional	16	16	16
US 150	39353	5/18/2018	11/25/2019	US 150, from 0.18 mi W of E JCT of SR 56 to 0.03 mi E SR 66 - RP 148+06	134+31	148+3	Conventional	16	12	
SR 62	39376	5/18/2018	12/3/2019	SR 62, from SR 545 to SR 145	76+89	85+34	Conventional	16	12	
SR 165	39389	1/25/2019	1/6/2020	SR 165, from North JCT SR 68 to 0.47 mi West of SR 65	5+0	16+69		16	12	
SR 261	40287	2/15/2019	9/10/2019	SR 261, from 3.01 mi N of SR 66 to SR 62	3+1	7+75		16	12	
SR 357	34957	3/10/2017	8/31/2018	SR 357, JCT with SR 64 to JCT with SR 57	0+0	1+26	Conventional	16	16	16
SR 68	34957	3/10/2017	8/31/2018	SR 68, from 0.13 mi E of SR 57 to 0.02 mi W of SR 61 RP 27+14 to 36+27)	26+82	36+20	Conventional	16	16	16
SR 64	37841	4/11/2019	9/2/2021	SR 64, 1.29 mi E of W JCT SR 65 to US 41	6+0	9+56	Conventional	16	12	
US 231	38754	3/21/2018	7/17/2020	US 231, from 0.77 mi S of S JCT SR 157 to 8.27 mi S of W JCT of SR 46 See Log	103+92	113+35	Conventional	16	12	
US 231	38754	3/21/2018	7/17/2020	US 231, from SR 57 to SR 67	98+18	101+44	Conventional	16	12	
SR 64	39200	4/19/2017	10/25/2019	SR 64, from 0.35 mi E. of IL/IN East End of Bridge) to 1.36 mi E of the W JCT of SR 65	0+35	6+1	Conventional	16	16	16
SR 65	39200	4/19/2017	10/25/2019	SR 65, from SR 165 Owensville) to 0.03 mi S of SR 64	20+27	26+29	Conventional	16	16	16
SR 59	40620	12/18/2018	5/18/2020	SR 59, from W Co Rd 25 S to SR 54 Linton	10+80	11+83	Conventional	16	12	

Route	Contract	Construction Acceptance Date	Substantial Completion Date	Location Description	From Route or MM	To Route or MM	Rumble Stripe Type	Placement		
								Center	Edge	Shoulder
SR 58	40620	12/18/2018	5/18/2020	SR 58, from E JCT with SR 45 to SR 54	62+0	69+22	Conventional	16	12	
US 50	38591	5/16/2018	5/20/2020	US 50, from E JCT of US 231-to-0.03-mi E of US 150	35+63	43+26	Conventional	16	12	
US 231	38591	5/16/2018	5/20/2020	US 231, from 1.27 mi N of N JCT of SR 56 to the W JCT of US 50	56+96	68+94	Conventional	16	12	
US 231	38591	5/16/2018	5/20/2020	US 231, from 4.56 mi S of N JCT of SR 56 to 0.86 mi N of N JCT of SR 56	51+16	56+54	Conventional	16	12	
SR 54	38962	4/12/2017	5/20/2020	SR 54, from 1.1-mi E of SR 59 to SR 67	26+5	31+4	Conventional	16	16	16
SR 54	38962	4/12/2017	5/20/2020	SR 54, from 0.55-mi E of US 231 to SR 45	38+35	51+17	Conventional	16	16	16
US 231	38962	4/12/2017	5/20/2020	US 231, from 1.16 mi S of E JCT SR 54/ SR 157 to 0.03 mi S of W JCT SR 57	93+4	98+12	Conventional	16	16	16

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

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