
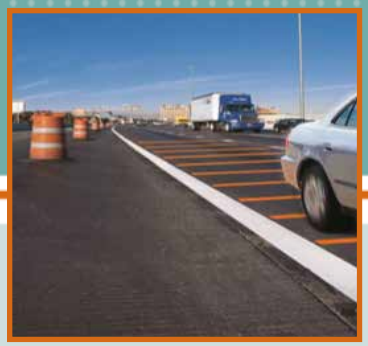

Guidance for the Use of **Temporary Rumble Strips in Work Zones**

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Unless otherwise indicated, all artwork in this document is original.

INTRODUCTION

In 2011, there were 1114 total injuries reported in work zones, 587 of which were fatal. Crash occurrence in work zones may be impacted by a variety of work zone parameters such a layout, speed limit, reduced lane width, visual obstructions, and the use of a temporary traffic lane (El-Rayes, Liu, and Elghamrawy 2013). A survey conducted by the Illinois Department of Transportation (IDOT) showed that approximately 69 percent of work zone crashes were caused by improper driving, and 40 percent of fatal and injury-related work zone crashes occurred in work zones that had no traffic signals or rigorous restrictions at the scene of the crash.

This indicates that temporary traffic control (TTC) countermeasures should be used to increase drivers' alertness and to provide advance warning of changing conditions within the work zone (El-Rayes, Liu, and Elghamrawy 2013). Even though other warning devices such as warning signs, portable changeable message signs, arrow panels, temporary pavement markings, etc. may be sufficient to guide drivers through work zones, a stronger and timelier response can be achieved by combining audible and tactile stimuli to improve driver compliance; this would be a useful addition to other TTC devices when drivers may be inattentive or misperceive the upcoming conditions (Sun, Edara, and Ervin 2011).

Rumble strips are a countermeasure that provides both an audible warning and physical vibration to alert motorists as the vehicle tires traverse the rumble strips. Because there is no specific message associated with rumble strips, they can be used to alert motorists to a variety of conditions. The *Manual on Uniform Traffic Control Devices* (MUTCD) indicates that transverse rumble strips, which extend across the travel lanes, are intended to notify road users of upcoming hazards or changes in roadway features, such as unexpected changes in alignment, and conditions requiring a reduction in speed and/or a stop (FHWA 2009). This could encompass a variety of situations such as lane closures, speed reductions, changes in alignment, new merge patterns, visual obstructions, nighttime work zones, and more. The circumstances and restrictions of work zones can vary greatly, and transverse rumble strips can alert drivers to the changing conditions and information being provided by TTC devices.

Due to the temporary nature of work zones, a need exists for rumble strips that can be installed and removed quickly and efficiently while providing the same auditory and tactile warnings to drivers as permanent rumble strips. This guidance document provides practitioners with information on the use of temporary rumble strips to increase the safety of work zones.

OBJECTIVES OF THIS DOCUMENT

The objectives of this document are as follows:

- To provide information on the use of temporary rumble strip types and configurations for work zones and their benefits and limitations;
- To discuss when and how to implement temporary rumble strips in work zones;
- To present other key aspects to consider before and during implementation; and
- To provide a list of reference materials.

TEMPORARY RUMBLE STRIPS IN WORK ZONES

ADVANTAGES

Permanent rumble strips are recessed below the pavement by milling or rolling, while temporary rumble strips consist of a raised surface that is placed on, or temporarily adhered to, the pavement. As a result, temporary rumble strips are much easier to install and remove compared to permanent rumble strips, and some forms are even reusable; this makes them particularly useful for deployment in work zones. Ease of installation, removal, and reusability vary based on the type of temporary rumble strip (please see Table 1 for a description of different types of rumble strips). Figure 1 shows temporary portable reusable rumble strips applied on the approach to a work zone (Plastic Safety Systems 2013).

Advantages of Temporary Rumble Strips

- Ease of installation and removal compared to permanent rumble strips
- Potential for reuse of rumble strips
- Increased driver awareness of upcoming conditions and compliance to other traffic control devices
- Increased braking and reduced speeds

The primary benefit of temporary rumble strips is their effectiveness in alerting drivers to other traffic control devices and upcoming circumstances such as lane changes, detours, or other hazardous conditions (Morgan 2003). The audible and vibratory stimuli produced by rumble strips can increase awareness among drivers as they travel through work zones, which can be particularly helpful for inattentive, fatigued, or sleepy drivers (Maryland SHA 2011). An increase in driver awareness can lead to positive behavior modification in terms of speed reduction, braking, and increased compliance withwarning signs and devices, all of which are behaviors that can reduce crashes in work zones. It has also been found that the application of rumble strips can improve traffic flow in cases where additional warning signs and changeable message signs (CMS) do not reduce late merges and when there is excessive congestion (Pigman and Agent 1988).

Figure 1. Temporary rumble strips applied on the approach to a work zone.
(Source: Plastic Safety Systems 2013)

Permanent rumble strips have proven to be effective in producing levels of auditory and tactile stimuli required to alert motorists; therefore, the effectiveness of temporary rumble strips in alerting motorists is often evaluated by comparing sound levels to those of permanent rumble strips. El-Rayes, Liu, and Elghamrawy (2013) measured the effectiveness of an adhesive rumble strip, a manually adhesive rumble strip, and a portable reusable rumble strip in generating adequate sound levels to alert inattentive drivers and found that all three types of temporary rumble strips generated

adequate sound levels compared to those produced by permanent rumble strips. A sample of the sound measurements collected can be found in Appendix B.

Braking is one indication of driver awareness of unusual or changing road conditions, and thus can be used to investigate the effectiveness of temporary rumble strips in work zones. Studies have shown that temporary rumble strips in work zones can result in braking by 10 to 80 percent of vehicles (Sun, Edara, and Ervin 2011; Wang et al. 2011a).

Vehicle speed reductions are the most common measurement for determining the effectiveness of temporary rumble strips in work zones. For example, The California Department of Transportation (2012) tested rumble strips in areas leading up to work zones and found that 46 percent of traffic slowed down, with nearly half of all vehicles slowing down by an average speed of 8 mph (Richards, 2012). Several research studies have examined temporary rumble strips at work zones and have found positive effects in terms of vehicle speed reduction (Fontaine and Carlson 2001; Fontaine, Carlson and Hawkins 2000; McAvoy n.d.; Meyer 2000; Sun, Edara, and Ervin 2011a; Sun, Edara, and Ervin 2011b; Wang et al. 2011a; Wang et al. 2011b), though the strength of the speed reduction results are mixed. Some of the studies show significant speed reductions of 4.6 – 11.4 mph for cars (Wang et al. 2011a) and 3.5 – 11.7 mph for trucks (Fontaine and Carlson 2001; Fontaine, Carlson, and Hawkins 2000; Wang et al. 2011a), while other studies report smaller speed reductions of 1.1 – 2.2 mph for cars (Fontaine and Carlson 2001; Fontaine, Carlson, and Hawkins 2000; Horowitz and Notbohm 2002; Meyer 2000) and 0.9 – 2.3 mph for trucks (Meyer 2000). Additionally, the effectiveness of rumble strips is influenced by a variety of factors, such as rumble strip size, configuration, and type of rumble strip, which may account for variability in the results.

Though some of the smaller speed reductions may not be practically significant, temporary rumble stripscan still alert inattentive drivers to visual information that they otherwise may not have noticed and thus have the potential for reducing accidents or intrusions in the work areas.

DISADVANTAGES

Although there are many benefits to the application of temporary rumble strips at work zones, there are potential negative effects which should also be considered.

Disadvantages of Temporary Rumble Strips

- Potential for erratic or avoidance maneuvers by drivers
- Potential rough ride or hazard for motorcycles or bicyclists
- Potential for movement of rumble strips due to inadequate installation
- Noise complaints by nearby residents

Inattentive drivers may be surprised when they inadvertently cross rumble strips, which could lead to erratic maneuvers such as hard braking or swerving. Several documents have indicated that transverse rumble strips do not appear to induce erratic maneuvers (Miles, Pratt, and Carlson 2006) and can have positive effects on the brake patterns of sleep-deprived drivers at stop-controlled intersections (Harder and Bloomfield 2005), although little research has documented or reported erratic maneuvers in work zones specifically.

Avoidance maneuvers are more frequent, although theoretically less severe, than erratic maneuvers. Avoidance maneuvers include driver attempts to straddle the rumble strips or to avoid the rumble strips completely by crossing into an opposing lane. Fontaine, Carlson, and Hawkins (2000) reported observing 2.9 maneuvers per 1000 vehicles (approximately .3 percent) where a vehicle moved into an oncoming traffic lane to go around the temporary rumble strips. The rumble strips were located in a passing zone and no oncoming traffic was observed when the maneuvers were made; however, such maneuvers could be more dangerous in locations with high traffic volumes or limited site distance (Fontaine, Carlson, and Hawkins 2000). A field test by Wang, et al. (2011b) found that when drivers approached the first set of rumble strips at a site, the majority of drivers braked, but rarely changed lanes to avoid them; however, roughly 5 percent of drivers maneuvered to avoid the rumble strips. Sun, Edara, and Ervin (2011a) found that the number of lane crossovers (crossing the centerline) increased by 8.79 percent after the installation of rumble strips in work zones, though partial crossovers could have been due todrivers avoiding the rumble strips, or due to the narrow 10 foot lanes on the bridgewhere the study occurred.

Riding surface is an important consideration for the safety of motorcyclists. Adequate warning signs should be provided to alert motorcyclists of the presence of rumble strips in the work zones; some States require that these be included in the temporary traffic control plan (Michigan Department of Transportation 2010). One research study (Horowitz and Notbohm 2002) tested rumble strips that had been spaced 7 feet apart so that motorcycles would not hit more than one strip at a time, but the rumble strips only yielded speed reductions of less than 1.4 mph at this spacing. Other researchers (Meyer 2000) suggest that placing rumble strips in the wheel path only allows for an opening in the center of the lane for motorcycles. A representative of Plastic Safety Systems provided information on portable reusable rumble strips (.81 inch thick), extending across the entire lane, that were implemented during the 2012 Bikers Against Local Diabetes (BALD) charity motorcycle run in Ohio. Approximately 150 motorcycles crossed the rumble strips traveling 25 – 45 mph with no incidents occurring. Motorcyclists were interviewed at the post-run picnic, and no complaints about the rumble strips were reported; many indicated that the rumble strips were effective in providing vibration and sound alerts.

Figure 2. Motorcycles crossing Portable Reusable Rumble Strips at the BALD charity motorcycle run.
(Source: Plastic Safety Systems 2013)

Bicyclists may also be influenced by riding surface, and therefore should be considered when implementing temporary rumble strips. The MUTCD states that transverse rumble strips should not be placed on roadways used by bicyclists unless a

minimum clear path of 4 feet is provided at each edge of the roadway or on each paved shoulder as described in AASHTO's "Guide for the Development of Bicycle Facilities" (FHWA 2009).

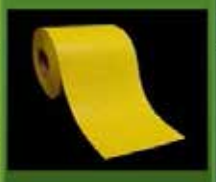
Failing to properly clean the roadway prior to installation of rumble strips can cause the strips to shift or become dislodged from the pavement. For example, researchers have found that adhesive rumble strips may lose adhesion or detach from the pavement if there is debris present on the pavement (Meyer 2000), or if the strips were installed shortly after a light rain (Shaik, Sanford Bernhardt, and Virkler 2000); however, if installed properly, and according to manufacturer installation recommendations, the strips should not move under traffic once they have been put in place (Fontaine, Carlson, and Hawkins 2000). Most manufacturers of temporary rumble strips provide specific instructions for preparing the roadway prior to the installation of rumble strips; these instructions should be followed strictly.

The potential also exists for the temporary rumble strips to cause noise disturbances to nearby residents; however, this is more likely to be an issue for long-term or night-time work zones. When these types of work zones are located directly next to or within residential areas, outreach to local residents may be required to notify them of the work, duration of the work, and potential for noise caused by the rumble strips.

Types of Temporary Rumble Strips

Table 1 provides an overview of different types of temporary rumble strips and a sample of information regarding various rumble strip characteristics.

Table 1. Types of Temporary Rumble Strips used in Work Zones

	Preformed Thermoplastic	Pavement Marking Tape	Adhesive	Manually Adhesive	Portable Reusable
	 Source: Ennis-Flint, 2013	 Source: Swarco Industries, Inc., 2013	 Source: Advanced Traffic Markings, 2013	 Source: Swarco Industries, Inc., 2013	 Source: Plastic Safety Systems, 2013
Adhesive	Polymer materials that are melted and fused to the pavement	Manufactured with a pre-applied adhesive	Manufactured with a removable adhesive backing	Require the application of a bonding/fastening agent such as adhesive cement, glues, or screws	Stay in place under their own weight; require no adhesives or fasteners
Assembly	Pre-cut strips manufactured in a two-part system: base layer & rumble bar	Pavement marking tapes come in manufactured rolls	Manufactured plastic strips come in 50 ft. rolls	Manufactured plastic rumble strips in pre-cut lengths	Modular plastic strips manufactured in 45 in. long sections of 35 lbs. each
Typical Size	3 ft. long Base– .125 in. thick; 4, 6, or 8 in. wide Bar – .25 in. thick; 2 in. wide	Can be layered and built up to the desired thickness	0.25 in. thick 4 in. wide Cut to desired length	4-6 ft. long 6 in. wide 0.25 in. thick	3 sections connect to form an 11 ft. rumble strip (105 lbs. total); 13 in. wide; .75 in. thick
Color	Black White Yellow Orange	White Black Yellow Others	Orange Black White	White (reflective available) Orange (reflective available) Black	Black
Installation					
Manpower	3 workers	2 to 3 workers	2 to 5 workers	4 workers	2 workers
Time	2 – 3 days	Varies based on thickness	30 – 40min.	45 – 75 min.	25min.
Equipment*	Industrial heat torch Propane Sealer (concrete) Paint Roller (concrete) Utility knife	Tamper cart	Saw Tamper Cart	Adhesive Cement Tamper Cart	None
Road/Ambient Temperature Requirements	None ≥32° F	≥40° – 50° F	≥40° F	≥50° F	0° – 180° F
Removal					
Manpower	2 to 3 workers	2 to 3 workers	1 to 2 workers	1 to 2 workers	1 to 2 workers
Time	A couple of hours	Variable	A few minutes	A few – 10 min.	A few minutes
Equipment	Torch or blaster	None	Utility Knife	Shovel	None
Reusable	No	No	Yes	No	Yes
Additional Features					
Speed Ratings	Max unknown	Max unknown	Max unknown	Max unknown	70 mph or less
Shelf Life	1 – 2 years	1 year	1 year	unknown	3 – 5 years

*Additional equipment may be required for cleaning or marking the roadway prior to rumble strip installation.

Effectiveness of Temporary Rumble Strips

The use of preformed thermoplastic and pavement marking tapes are techniques that agencies have used for many years; they have become widely accepted practices that practitioners are generally familiar with.

Preformed thermoplastic rumble strips are easier to install than traditional hot applied thermoplastic, but have the same benefits of flexibility and conforming to the roadway making them very durable.

The primary benefit of ***preformed thermoplastic rumble strips*** is that they commonly come in pre-cut strips and do not require the roadway to be pre-heated to a certain temperature—as with traditionally preheated thermoplastic—but have the same benefits of flexibility and conforming to the surface of the roadway. Due to the nature of thermoplastic, these strips will be very durable and resistant to movement on the roadway.

The primary benefit of ***pavement marking tape*** is that it can be layered and built up to achieve the desired thickness. Morgan (2003) compared various heights of tape rumble strips and found that the most effective (in terms of noise generated and tactile sensation) were between 8 – 10 mm thick. The 4 – 5 mm thick strips were not noticeably different from the 5 – 6 mm strips, and none were as loud as the 8 – 10 mm thick strips. The other strips gave the sensation of riding over pavement joints. Additionally, strips that taper along the edges (i.e. taper up to highest area, then taper back down) may be more audible, although the tactile sensation may not be as pronounced (Morgan 2003). While the tape rumble strips generally had good adhesion with minimal tearing, one test site experienced a significant loss of adhesion. Morgan (2003) attributed this to four factors: (1) the asphalt cement pavement was old and dried out, (2) the pavement surface was rough and pitted, (3) the road had a high AADT (>25,000) with heavy truck traffic, and (4) the strips were placed on a downgrade with a traffic light at the bottom, which caused drivers to apply their brakes on the strips.

Pavement marking tape can be layered and built up to achieve the desired thickness.

Although the use of thermoplastic and pavement marking tapes are commonly accepted practices, there has been a trend in recent years toward more removable and portable rumble strip alternatives. Manufacturers are providing more options that are increasingly flexible to use, don't require a lot of specialized equipment, and arereusable in some cases. With the increase in new rumble strip alternatives, there has also been a rise in research regarding their effectiveness.

Adhesive Rumble Strips

Meyer (2000) evaluated temporary adhesive rumble strips at a rural bridge repair site in Kansas and found a significant change in average speeds and 85th percentile speeds downstream of the removable rumble strips for both passenger cars and trucks. One set of six rumble strips (0.125 inch thick) was installed with 1 foot between strips, which elicited average speed reductions of 1.7 – 2.2 mph for

passenger cars, and 0.9 – 2.3 mph for trucks. Although subjective reports indicate that the rumble strips installed in this study only produced a slight audible effect, and little to no tactile effect (Meyer 2000), El-Rayes, Liu, and Elghamrawy (2013) tested adhesive rumble strips (0.25 in. thick) in sets of four, six, or eight strips, each at a spacing of 12, 24, and 36 inches between strips; the results indicate that the sound levels produced by traversing the strips are comparable to those of permanent rumble strips and are sufficient to alert drivers.

Adhesive rumble strips are manufactured with a removable adhesive backing and can be cut to the desired length. Redressing adhesives are also available for up to four uses.

In an attempt to increase audible and tactile effects of the 0.125 inch thick strips tested in Kansas (Meyer 2000), researchers (Fontaine, Carlson, and Hawkins 2000; Fontaine and Carlson 2001) doubled the height of the strips by adhering one on top of another, although adhering multiple strips together is not recommended by manufacturers (Advanced Traffic Markings n.d.). At the increased thickness (0.25 inch), a set of six strips with 18 inches between each strip had little impact on passenger car speeds (speed reductions of less than 2 mph), but reduced truck speeds by 3 – 5 mph. Additionally, the percentage of vehicles exceeding the speed limit in the advanced warning area tends to be reduced following the rumble strip installations (Fontaine, Carlson, and Hawkins 2000; Fontaine and Carlson 2001).

Redressing adhesives are available, and can be applied to the rumble strips up to four times (for a total of five uses) (Advanced Traffic Markings n.d.). Some studies have shown that the strips were not reusable when there was debris or degradation to the backing due to the initial use (Fontaine, Carlson, and Hawkins 2000; Meyer 2000). One study found that the application of supplemental adhesive layers (as per manufacturer recommendations) makes the strips more difficult to remove but increases the strips' resistance to vertical loading (Meyer 2006).

Manually Adhesive Rumble Strips

Horowitz and Notbohm (2002) tested manually adhesive rumble strips at a rural intersection in Wisconsin where a temporary signal had been installed. A set of 6 strips (0.25 inches thick) were placed 7 feet apart. Only small changes in speeds were found (1.1 – 1.3 mph) after the installation of the rumble strips. They also examined average changes in speed from one point in the work zone to another, and found that there was no significant change in vehicle speed before and after installation of the rumble strips. The sound levels produced by the strips were approximately 77.3 a-weighted decibels (dBA), as compared to approximately 85.0 dBA for the tested conventional rumble strips, although a narrowing spacing, as recommended by the manufacturer, should produce higher sound levels (Horowitz and Notbohm 2002). Other research has shown that these rumble strips produce sound levels comparable to permanent rumble strips and higher than adhesive

Manually adhesive rumble strips are available in reflective versions, which give the strips potential to provide visual cues in both daytime and nighttime operations.

rumble strips in most cases, although not as high as portable reusable rumble strips (El-Rayes, Liu, and Elghamrawy 2013).

In the Wisconsin study, the strips were left on the road for seven weeks and remained in good condition, except for a single strip that had dislodged sometime after five weeks (Horowitz and Notbohm 2002), suggesting that the strips are reasonably durable. However, the application of multiple layers of contact cement and tamping adds a considerable amount of time to the installation process as compared to some other types of temporary rumble strips. The availability of multiple colors and reflective versions give the strips the potential to provide visual cues in both daytime and nighttime operations, although no research regarding the reflectivity benefit of the strips has been identified.

Portable Reusable Rumble Strips

Portable reusable rumble strips can be set out and removed with relatively little time or effort. This makes them especially useful for flagging operations, traffic safety check-points, lane closures, routine maintenance operations, paving operations, or other situations where daily installation and removal may be required. An additional benefit of the portability and reusability is that the strips could be used in a variety of scenarios at work zones, such as for temporary three-way stops, temporary changes in traffic control, use on alternative routes, etc.

Portable reusable rumble strips require no adhesives, making them ideal in situations where daily installation and removal may be required.

These rumble strips are being implemented in many areas throughout the State of Texas to reduce speeds through work zones (Brown 2013; Parr n.d.; KBTX 2013) and are even being used at Border Patrol checkpoints in an attempt to reduce speeds and improve merging patterns, reducing near-miss accidents (Jamieson 2012). Figure 3 highlights other States that are known to have experience with portable reusable rumble strips.

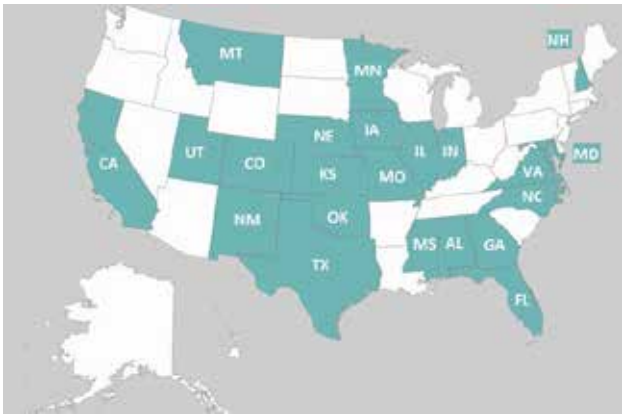


Figure 3. State use of portable reusable rumble strips.

A closed-course test conducted by Schrock et al. (2010) showed that portable reusable rumble strips (0.83 inch thick, tested in six different configurations with varying numbers of strips and spacing) can provide improved vibration and sound performance relative to the tested adhesive rumble strip and comparable performance to the tested permanent cut-in-place rumble strips. Other research by El-Rayes, Liu, and Elghamrawy (2013) shows that three tested types of temporary rumble strips provide adequate sound levels compared to permanent rumble strips. Furthermore, the portable reusable rumble strips

generated higher sound levels than the tested manual adhesive rumble strip and tested adhesive rumble strip at all speeds (30, 40, and 50 mph) and with all vehicle types (sedan, van, 26 ft. truck) (El-Rayes, Liu, and Elghamrawy 2013).

McAvoy's (n.d.) tests in Ohio found that multiple arrays of portable reusable rumble strips (.8125 inches thick) placed in advance of construction work zones reduced driving speeds by 4 – 6mph. Wang, et al. (2011a) also installed portable reusable rumble strips (.83 inches thick, in sets of four strips, with 36 inches between each strip) in advance of flagger-controlled work zones in Kansas. The results showed that the rumble strips' effect on speed reduction was more significant for cars than it was for trucks, reducing car speeds by 4.6 – 11.4 mph. Truck speeds at two of the three sites were also reduced by 5.0 – 11.7 mph. It was also observed that 30 – 80 percent of truck drivers activated their brakes when they approached the rumble strips. Sun, Edara, and Ervin (2011a) conducted a study in Missouri evaluating portable reusable rumble strips (.8125 inch thick, installed in sets of two strips, with 36 inches between strips) to determine the effects on safety in an elevated-risk work zone; the test site contained curves, a bridge approach, and a pavement transitions. The number of vehicles that braked due to the rumble strips was more than 10 percent, with an average decrease in speed of up to 3.71 mph for braking vehicles. There was also an increase in speed compliance of 2.9 percent. This study also reported minimal movement of the rumble strips when placed perpendicular to the roadway; the strips had a vertical movement of 0 inches per 100 vehicle impacts, and a horizontal movement of .28 inches per 100 vehicle impacts.

Various field test reports indicate large speed reductions due to the installation of portable reusable rumble strips. In a Missouri field test (2009), a set of four to five strips (.8125 inch thick) were installed in a work zone. The Missouri DOT measured speed reductions of 5 – 10 mph after drivers crossed the rumble strips (Plastic Safety Systems 2009a). An Indiana field test (Plastic Safety Systems 2010) involved the installation of two sets of rumble strips (.8125 inch thick) with three strips per set spaced 3 feet apart. The strips were placed on a curve on I-465 where drivers occasionally exceed the 70 mph speed limit and destroy the guardrail; the rumble strips were installed to help protect the guardrail crews. During the test hours, it was observed that drivers slowed to a steady 35 – 40 mph.

WHEN AND HOW TO IMPLEMENT TEMPORARY RUMBLE STRIPS IN WORK ZONES

DURATION OF WORK ZONE

The duration of the work zone is a key variable in deciding whether or not the use of rumble strips would be beneficial and, if so, which type of rumble strip would be ideal for a given work zone. The different types of temporary rumble strips that are available allow for the use of rumble strips in stationary, slow-moving, and long- and short-duration work zones, as shown in Figure 4.

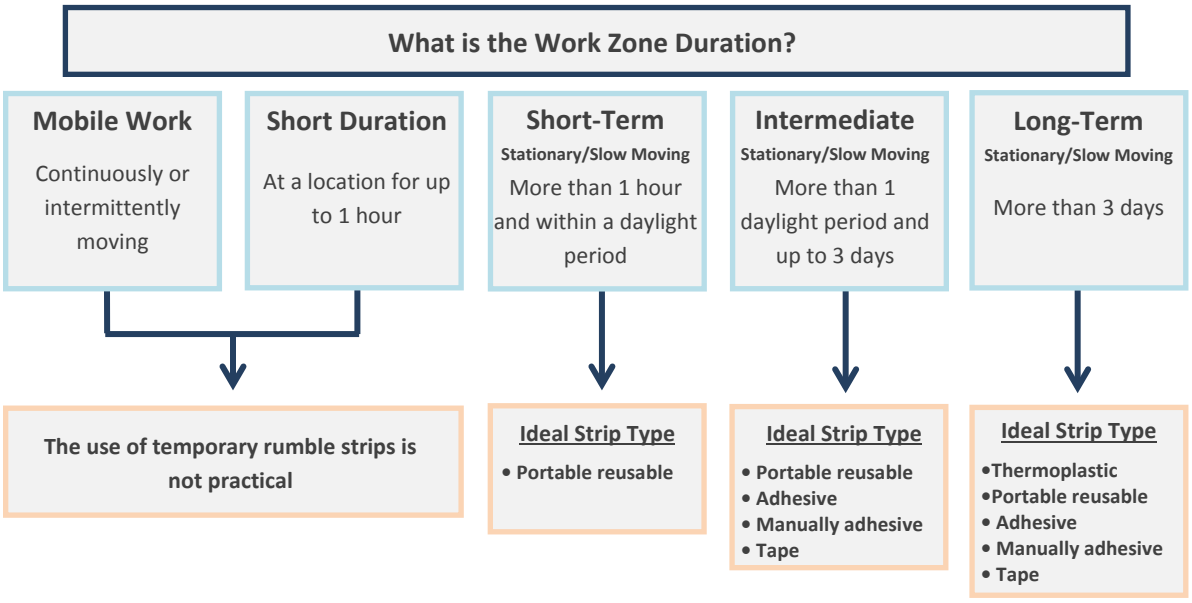


Figure 4. Recommended rumble strip types based on work zone duration.

CONFIGURATION OF RUMBLE STRIPS

The configuration of rumble strips includes a variety of interrelated factors such as placement of the rumble strips within the work zone, number of arrays (or sets) of rumble strips used at a work zone location, number of strips in a set, spacing of strips in the set, and size of the rumble strips. The effectiveness of temporary rumble strips is dependent on the auditory and vibratory stimuli produced by vehicles traversing the rumble strips. El-Rayes, Liu, and Elghamrawy (2013) conducted a correlation analysis that indicated that sound level readings representing the effectiveness of rumble strips were correlated with four parameters: spacing of rumble strips, type of rumble strips, type of vehicle, and vehicle speed; sound levels were not correlated with the number of strips in a set of rumble strips. Therefore, when determining the overall configuration of temporary rumble strips placed prior to

and within work zones, it is important to consider the design characteristics, such as rumble strip height, width, and spacing.

Array of Rumble Strips

An array refers to a single group, or set, of rumble strips. Multiple arrays of rumble strips spaced several hundred feet apart (Bryden and Mace 2002) can be used to provide repeated warnings. McAvoy (n.d.) evaluated rumble strips (.8125 inches thick) installed prior to construction work zones and found speed reductions of 2 mph with one group of rumble strips, and 4 – 6 mph with two groups of rumble strips. This indicates that, although one array of temporary rumble strips can be effective, the use of multiple arrays may be even more effective.

Pattern of Rumble Strips in an Array

Rumble strips are often deployed in sets of 3, 4, 6, or 10 strips.

The pattern of rumble strips primarily refers to the number of strips within the array. The pattern should be adequate enough to alert drivers without being so dramatic that they make drivers or motorcyclists uncomfortable or promote evasive or unsafe maneuvers to avoid the rumble strips. Temporary rumble strips have been deployed and/or tested for use in work zones in patterns ranging from 1 to 25 rumble strips, with 6 strips being a frequently used pattern in evaluations. The Maryland State Highway Administration Standard Specifications for Construction and Materials indicates that a pattern of at least 10 strips, but not more than 12, should be used per array.

An array with only 1 or 2 rumble strips will not likely have a significant effect on speed reductions (McAvoy n.d.). Sun, Edara, and Ervin (2011a) tested patterns of 2 strips (contrary to the manufacturer's recommendation of 4 strips) and agreed with the manufacturer that the rumble strips should be deployed in greater numbers than two.

Schrock et al. (2010) tested 4, 5, 6 and 25 temporary rumble strips and found that in most cases, the configurations with 6 plastic rumble strips tended to generate the largest in-vehicle sound level for both cars and trucks, though the configuration of 4 plastic rumble strips was sufficient to generate a comparable level of vibration and sound as the permanent rumble strips. El-Rayes, Liu, and Elghamrawy (2013) tested three types of temporary rumble strips with patterns of 4, 6, or 8 strips and found that the patterns of rumble strips was not statistically correlated with the increase in sound levels, though all three patterns produced sufficient sound levels.

Patterns containing between 3 and 10 rumble strips would presumably be enough that they would not be mistaken for distresses in pavement or pavement joints, but not too much that they would become a nuisance to drivers.

Spacing of Rumble Strips in an Array

Literature suggests that a narrower spacing (the amount of space between strips within a pattern/array) should produce higher sound levels (El-Rayes, Liu, and Elghamrawy 2013; Horowitz and Notbohm 2002). Additionally, the spacing of temporary rumble strips is dependent on the speed within the work zone; lower speeds require less spacing between strips, whereas higher speeds require more spacing. Refer to Figure 5 for a sample of spacing recommendations based on posted speed limits. The MUTCD recommends that the spacing of rumble strips may be reduced as the distance to the approaching condition decreases in order to convey that an action is imminent and/or give the impression that the driving speed is too fast (FHWA 2009).

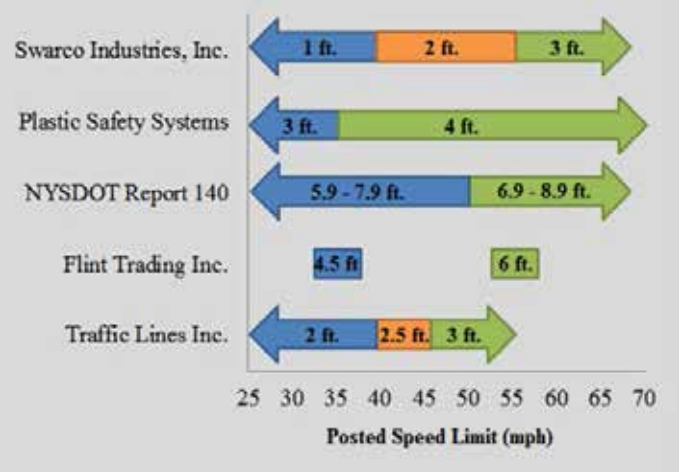


Figure 5. Sample of rumble strip spacing recommendations based on posted speed limits.

New York State DOT requires that rumble strips be spaced 9.84 feet (3.0 meters) apart, though researchers subjectively evaluated temporary rumble strips to determine their effectiveness at different spacing and speeds (Morgan 2003). When vehicles traversed the strips (of varying thickness) at 40 mph, the rumble strips spaced at 5.91 feet (1.8 meters) gave a "rumbling" effect and were more pronounced than the sets spaced at 7.87 feet (2.4 meters) and 9.84 feet (3.0 meters), which gave the feel and sound of closely spaced pavement joints. At 65 mph, the 5.91 foot (1.8 meters) spacing was more noticeable than the 7.87 foot (2.4 meters) spacing as well. At 45 mph, 4.59 foot (1.4 meters) spacing is driven over too quickly to feel the full effect, although having spacing within a pattern that ranged between 7.87 - 8.86 feet (2.4 - 2.7 meters) took away the feel and sound of driving over regularly spaced pavement joints (Morgan 2003). In addition, 3.94 feet (1.2 meters), 1.96 feet (0.6 meter), and 1.48 feet (0.45 meter) spacing were also evaluated, although all were too close to be considered effective. Additionally, it was hard to distinguish between the rumble strips spaced at 3.94 feet (1.2 meters) and the rough pavement conditions (Morgan 2003).

> The spacing of rumble strips may be reduced as the distance to the approaching condition decreases in order to convey that an action is imminent and/or give the impression that the driving speed is too fast.

Figure 6 provides a range of acceptable rumble strip spacing based on the speed limit of the work zone; these numbers are based on a compilation of various research and manufacturer recommendations. Variability in recommended spacing may be due in part to the height (and thus the type) of temporary rumble strip that is used. The wider spacing within an acceptable range may be better suited for thicker rumble strips, whereas the narrower spacing may be more appropriate for thinner rumble strips.

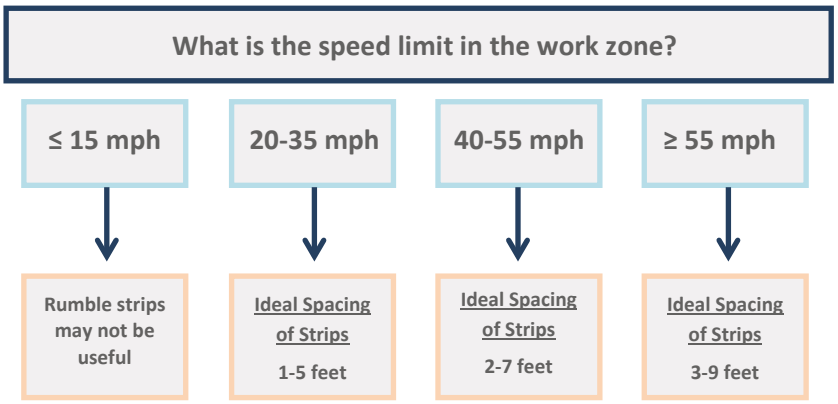


Figure 6. Recommended spacing of rumble strips based on work zone speed limit.

Height of Rumble Strips

The size of temporary rumble strips refers to the geometric characteristics of the rumble strips that include height (vertical distance from top to bottom of rumble strip), length (distance of the side that runs perpendicular to traffic), and width (distance of the side that runs parallel to traffic). Height, or thickness, in particular can have a large impact on the sound and vibration levels generated by crossing over the rumble strips. When comparing various heights of tape rumble strips, Morgan (2003) found that the most effective strips tested were between 8 mm and 10 mm thick; the 4 – 5 mm thick strips were not noticeably different from the 5 – 6 mm strips, and none were as loud as the 8 – 10 mm thick strips. The type (including height and composition) of rumble strip may also influence the height required to achieve the desired effects. For example, a manually adhesive rumble strip that is 6.35 mm thick can produce sounds as loud, and with the same tactile sensation, as tape rumble strips of 8 mm – 10 mm thick (Morgan 2003). Temporary rumble strips with heights ranging from .25 in. – .81 in. thick have proven to be effective.

Acceptable heights of temporary rumble strips range from around .25 in. to .81 in.

Location of Rumble Strips

Rumble strip arrays should be selectively located with respect to the potential hazard so as to maximize their effectiveness (Government of Saskatchewan 2009). McAvoy (n.d.) conducted a research review that summarized the upstream location of rumble strips relative to the work zone, the location where speed data was collected, and the average speed reductions resulting from the installation of the rumble strips. This research synthesis indicated that as the location of the rumble strips in relation to the taper diminished, the effect in terms of speed reductions generally increased (McAvoy n.d.). The results of this research are shown in Table 2; the state in which the data was collected is also indicated.

Table 2. Location of Rumble Strips Relative to Work Zone and Resulting Speed Reductions (McAvoy n.d.)

State	Rumble Strip Distance Upstream from Taper (feet)	Speed Data Collection Location Upstream from Taper (feet)	Reported Speed Reductions (mph)
Missouri	3,727	3,029	3.2-4.1
Kansas	3,000	3,500	0.8-1.7
Texas	2,120	2,120	0.3-2.1
Florida	1,400	1,100	8.7
Texas	1,090	1,090	3.0-3.3
Missouri	433	0	1.2-12.8

Note: The roadways all had posted speed limits prior to the work zone of 55 miles per hour or greater

McAvoy (n.d.) also identified previous research that evaluated various configurations in terms of array and spacing between groups of rumble strips:

- Spacing of 500-ft, 250-ft either side of an advanced warning sign 300-ft, 500-ft, 700-ft and 1,000-ft ahead of the taper;
- Spacing of 300-ft from the work zone and then at intervals of 200-ft, 230-ft, 320-ft or 290-ft;
- Spacing of 656-ft from the work zone and then at intervals of 984-ft, 1,312-ft, and1,640-ft;
- Spacing of 500-ft to 1000-ft; and
- Spacing of 433-ft, 1,416-ft and 3,029-ft from the work zone.

Based on the resulting speed reductions in previous research, McAvoy conducted a regression analysis including a trend line indicating the anticipated speed reduction based on the location of the rumble strips; the trend line was highest (representing greater speed reductions) at 500 feet upstream from the work zone. The Maryland State Highway Administration (2011) also recommends that the closest set of rumble strips should be placed 300 – 500 feet in advance of the work zone location, though placement within the work zone may ultimately be dictated by the signing plan. The ideal circumstance is to have drivers traverse the rumble strips at the same time that the driver is exposed to the advance warning signs, as the intent is to make inattentive drivers aware of approaching conditions. In an Illinois survey (El-Rayes, Liu, and Elghamrawy 2013), resident engineers were asked to identify possible locations to place temporary rumble strips within work zone layouts. Table 3 presents the recommended locations and the number of resident engineers supporting these locations.

Table 3. Placement of Temporary Rumble Strips within Work Zones (as identified in El-Rayes et al. 2013)

Placement of Temporary Rumble Strips within Work Zone Layout	No. of Recommendations
1. As close to the work zone as possible, 500 feet prior to the flagger	26
2. Prior to the “Road Construction Ahead” warning sign (current IDOT standard)	24
3. By the “Work Zone Speed Limit” sign	14
4. 1500 feet before lane closure taper at “Lane Merge” sign	12
5. Along tapers at the edge of work zones	5
6. 500 feet past the farthest estimated queue of stopped or slowed vehicles	3
7. At “Road Construction 1 Mile Ahead”	2
8. Use a note signaling to motorists that there is a hazard ahead	2
9. At “Road Construction 0.5 Mile Ahead”	1

The results show that 30 percent of resident engineers recommended placing a set of strips as close to the work zone as possible, and 27 percent recommended following the IDOT standard by placing sets in advance of the work zone prior to the Road Construction Ahead sign. Figure 7 provides a sample traffic control layout when temporary rumble strips are used for a lane closure on a two-lane road using flaggers (Plastic Safety Systems 2013).

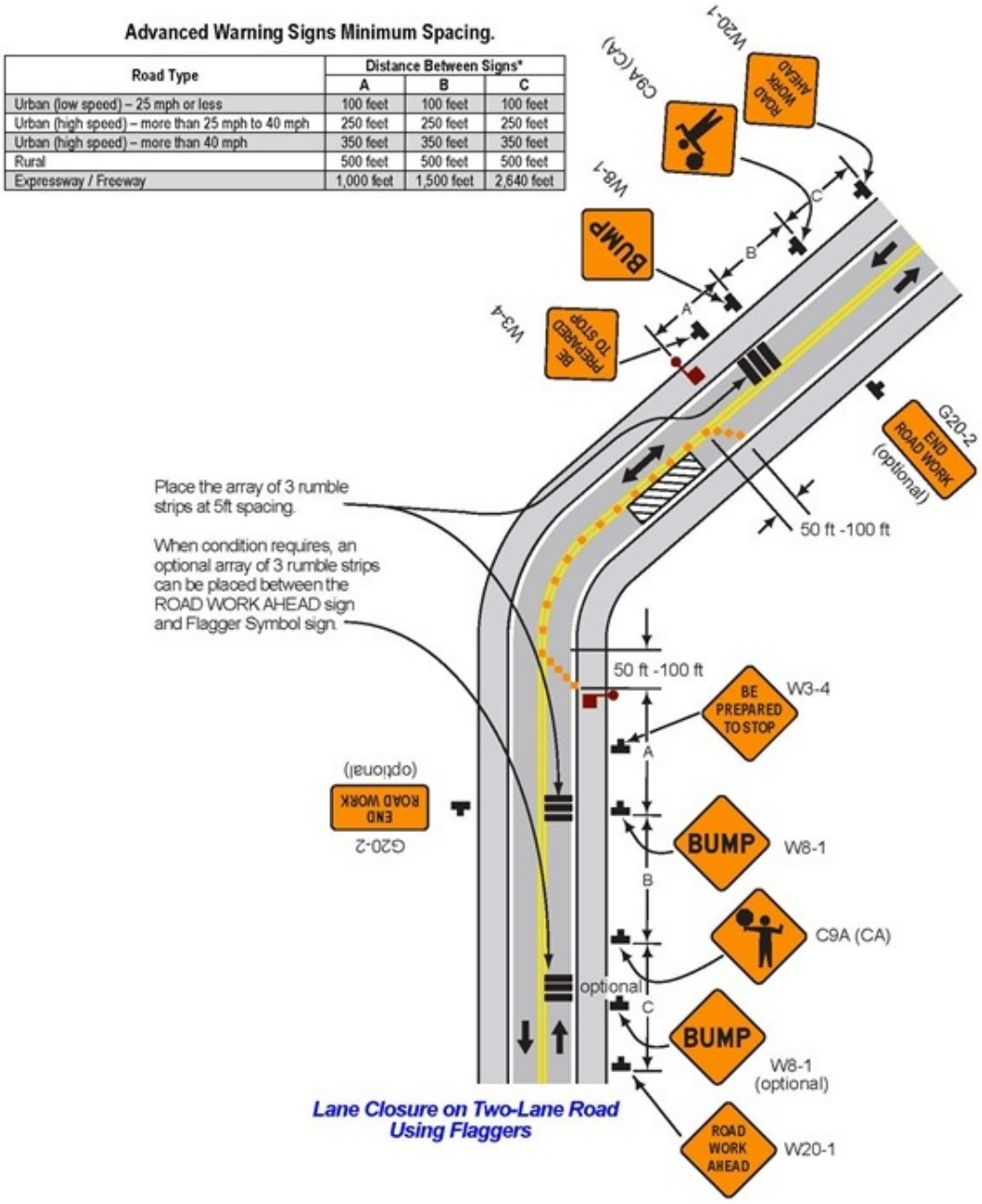


Figure 7. Typical Traffic Control Layout When Portable Temporary Rumble Strips Are Used
(Plastic Safety Systems, 2013)

CONFIGURATION OVERVIEW

All of the factors discussed above should be considered when implementing temporary rumble strips, as they play an interrelated role in the effectiveness of the rumble strips. Table 4 provides a sample of rumble strip configurations that have been tested in work zones and the resulting speed reductions; only studies that reported speed reductions were included.

Table 4. Sample of Tested Configurations of Temporary Rumble Strips and Reported Effects.

Reference	State	Number of Arrays/Sets	Number of Strips per Set	Spacing between Strips (feet)	Height of Strips (inches)	Width of Strips (inches)
McAvoy (n.d.)	Ohio	1	2	4	0.81	12
McAvoy (n.d.)	Ohio	1	3	4	0.81	12
McAvoy (n.d.)	Ohio	1	3	4	0.81	12
Plastic Safety Systems (2009a)	Missouri	1	4-5	3	0.81	12
Meyer (2000)	Kansas	1	6	1	0.125	4
Fontaine and Carlson (2001)	Texas	1	6	1.5	0.25	4
Horowitz and Notbohm (2002)	Wisconsin	1	6	7	0.25	6
Sun, Edara, and Ervin (2011)	Missouri	2	2	3	0.25	12
Plastic Safety Systems (2010)	Indiana	2	3	3	0.81	12
McAvoy (n.d.)	Ohio	2	3	4	0.81	12
McAvoy (n.d.)	Ohio	2	3	4	0.81	12
Fontaine, Carlson, and Hawkins (2000)	Texas	2	6	1.5	.25	4
Wang et al. (2011a)	Kansas	2-3	4	3	0.83	12
Shaik, Sanford Bernhardt, and Virkler (2000)	Missouri	6	6	1^{st} - 10 2^{nd} - 5 4^{th}-6^{th} - 2	0.15	4

As Figure 8 shows, there are a variety of practices or recommendations regarding the configuration of temporary rumble strips. Practitioners should ultimately follow State DOT specifications, traffic control plans, and manufacturer recommendations, when available. Please see Appendix C for various State guidelines, best practices, and/or specifications regarding the use of temporary rumble strips.

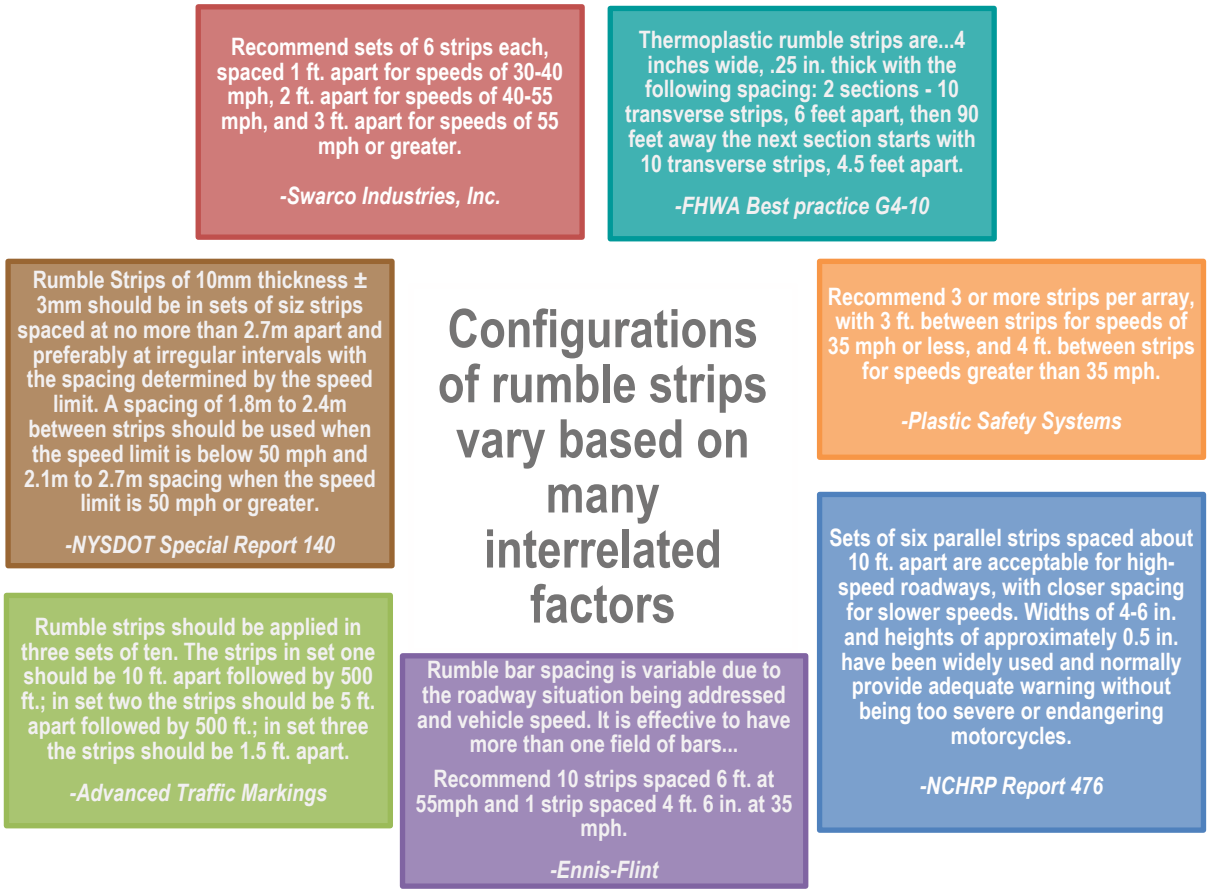


Figure 8. Sample of recommendations on the configuration of temporary rumble strips.

Additional Rumble Strip Parameters

Color of Rumble Strips

MUTCD Section 6F, Temporary Traffic Control Zone Devices, states that if the color of the transverse rumble strips used is not the same color as the pavement, then they must be black, white, or orange. Additionally, if a longitudinal rumble strip is not the same color as the pavement, it must be the same color as the longitudinal line that it supplements (FHWA 2009).

Opinions vary on whether it is more advantageous for temporary transverse rumble strips to be black (and better match the pavement) or to be colored (i.e. white or orange); colored strips may help by providing additional visual cues, or hinder by allowing drivers to see them early and avoid them.

For example, Meyer (2006) found significant speed reductions despite weak audible and tactile effects of the tested strips due to their low 3.2 mm (1/8 inch) thickness, indicating that the orange color of rumble strips was sufficient alone to have a positive effect. On the other hand, strips of different colors could confuse motorists and/or cause them to move into the adjacent lane to try and avoid the strips (Morgan 2003), although research has shown that avoidance maneuvers of rumble strips have occurred at both orange (Fontaine, Carlson, and Hawkins 2000) and black (Sun, Edara, and Ervin 2011a; Wang et al. 2011a) temporary rumble strips. Regardless of what rumble strips are used, it is best to ensure that the strips generate sufficient stimuli so that the effectiveness of the strips is not reliant on color.

Figure 9. Orange adhesive rumble strips.
(Source: Advanced Traffic Markings, 2013)

Continuous vs. Wheel Path Only

While some types of rumble strips (such as thermoplastic or tape) can be applied or cut to specific lengths, a rumble strip that does not need to be manipulated (i.e., cut or layered) before placement may also be preferable as it allows for quick and easy placement. Depending on the length of the rumble strips, they may be placed either continuously across the lane (also referred to as "full-coverage"), or placed in wheel paths only. Figure 10 shows an example of rumble strips placed only in the wheel paths, and an example of rumble strips extending continuously across each lane.

Figure 10. Wheel path rumble strips (left) and continuous rumble strips (right).
(Source: Matt Myers 2013 [left] and Plastic Safety Systems 2013 [right])

Some researchers and practitioners claim that when strips run across an entire lane, drivers may travel in the opposing lane to avoid them, whereas with wheel path rumble strips, drivers who are intent on avoiding the strips can move partly onto the shoulder, straddling the right side of the strips (Carlson and

Miles 2005). Others may take the stance that drivers may be more likely to avoid the strips if they are given the opportunity to by leaving open spaces in the strips. The Maryland State Highway Administration Work Zone Safety Toolbox (2011) indicates that temporary rumble strips should extend onto the shoulder, if possible, to discourage drivers from making maneuvers to avoid the strips (Maryland State Highway Administration 2011). Miles et al. (2005) says that research results reveal that drivers brake earlier with full coverage rumble strips than with wheel track only rumble strips.

Vehicle Parameters

Vehicle-related factors, such as vehicle type and speed, can also influence the sound generated by crossing rumble strips.

Vehicle Type

El-Rayes, Liu, and Elghamrawy (2013) found that a van commonly generated sound level changes higher than a sedan. A sample of the sound measurements collected for a sedan, van, and 26-foot truck prior to work zones can be found in Appendix B.

Vehicle Speed

The speeds of the vehicles traversing the rumble strips may also influence their effectiveness. The speed limit of the work zone will help to determine variables such as ideal spacing of the rumble strips. Lower speeds will typically require less spacing between the rumble strips, whereas higher speeds will require more spacing. When strips are spaced properly, speeds of 30 mph can generate higher sound-level changes than speeds of 40 or 50 mph (El-Rayes, Liu, and Elghamrawy 2013). Conversely, strips crossed at 45 mph can lose their effect if spaced too tightly (Morgan 2003). McAvoy (n.d.) tested rumble strips prior to a pedestrian crossing within a work zone and found that the rumble strips were not effective; this may be due to the crosswalk. The average driving speed in the vicinity of the crosswalk was 15 mph, indicating that rumble strips will not likely be effective at such low speeds.

Challenges and Special Considerations

Signing and Messaging

The importance of signing in addition to the use of temporary rumble strips is two-fold. First, the primary purpose of rumble strips is to alert drivers to approaching conditions; therefore, signs must be present in order to provide the appropriate information to drivers, and rumble strips should be strategically placed relative to the signs in order to maximize their effectiveness. Second, the MUTCD indicates that a sign may be placed in advance of the rumble strips to warn drivers of the onset

of rumble strips (FHWA 2009). This could decrease the possibility that drivers will be startled by the rumble strips and/or make erratic maneuvers.

A "RUMBLE STRIPS AHEAD" sign (see Figure 11) is often recommended for use in advance of temporary rumble strips (Maryland State Highway Administration 2011; Plastic Safety Systems 2013). The Colorado DOT provides dimensions for a "RUMBLE STRIPS AHEAD" sign, which can be found in Appendix C. For example, Horowitz and Notbohm (2002) used temporary rumble strips at an intersection that had been given temporary signals. The location of the rumble strips were dictated by a pair of "signal ahead" signs located 906 feet from the stop line. The strips were placed in advance of the warning signs, and an additional warning sign reading "rumble strips ahead" was placed approximately 200 feet upstream of the rumble strips.

Figure 11. "Rumble Strips Ahead" advanced warning sign for temporary rumble strips.
(Source: Colorado DOT, 2011)

In addition to signing for the upcoming hazard or conditions, and signing for the rumble strips themselves, additional measures can be taken to maximize the effectiveness of rumble strips. For example, Zwahlen and Oner (2006) recommend that speed limit signs on both sides of the road should be spaced more closely throughout work zones and used in conjunction with transverse rumble strips in order to emphasize the reduced speed limit message in work zones.

Meyer (2000) indicates that a typical traffic control plan for a Kansas Department of Transportation (KDOT) bridge maintenance project consists of a temporary traffic signal, a sequence of warning and regulatory signs, and two sets of rumble strips. Table 5 summarizes the typical signage and locations identified by this resource.

Table 5.Work Zone Signs and Locations (as identified in Meyer 2000)

Distance Upstream of Work Zone (feet)	Sign	Type	With Flashing Light
2442	Give 'Em a Brake	Warning	No
2097	ROAD WORK AHEAD	Warning	Yes
1297	REDUCED SPEED 30 AHEAD	Warning	No
1077	ONE LANE ROAD AHEAD	Warning	Yes
797	SPEED LIMIT 30	Regulatory	No
654	NO PASSING ZONE	Warning	No
546	[Traffic Signal Ahead Symbol]	Warning	No
419	NO PASSING ZONE	Warning	No
49	STOP HERE ON RED	Regulatory	No

Weather

Various weather conditions can influence the effectiveness of some adhesives. Some manufacturers do not recommend the installation of rumble strips if it has rained 24 hours prior to installation (Swarco Industries, Inc. 2013) or if rain is expected within 24 hours after installation (Advanced Traffic Markings 2013). Additionally, tape, adhesive, and manually adhesive rumble strips typically require that air and surface temperatures be at least 40 – 50 degrees Fahrenheit for installation (Advanced Traffic Markings 2013; Swarco Industries, Inc. 2013). The MUTCD also indicates that rumble strips should not adversely affect overall pavement skid resistance under wet or dry conditions (FHWA 2009).

Edge Line Rumble Strips

Though rumble strips are typically applied transversely in work zones, temporary rumble strips can also be used at the edge of work zones or along centerlines where traffic is flowing in opposite directions, although this usage is not commonly practiced nor is it included in the MUTCD (FHWA 2009). By applying strips between two and four feet long at the edge of work zones, the strips have potential to alert drivers if they encroach in the work area, just as permanent rumble strips alert drivers when they leave the roadway or cross into another lane (El-Rayes, Liu, and Elghamrawy 2013). El-Rayes, Liu, and Elghamrawy (2013) tested the effectiveness of two types of temporary rumble strips (adhesive and manually adhesive) at the edge of a hypothetical work zone by measuring the sound levels generated by traversing the strips. The researchers applied three sets of rumble strips with varying factors such as number of strips in a set (4, 6, or 9), spacing between strips (12, 24, or 36 inches), and vehicle speed (30, 40, or 50 mph) and found that in all cases the strips were effective in generating adequate sound levels.

Although the installation of rumble strips along the shoulders and centerlines could increase driver and worker safety (Zwahlen and Oner 2006) by warning drivers who drift out of their lanes, there are other factors to consider before deciding to install temporary rumble strips along the edge lines or centerlines of the work zone. First, the rumble strips would have to be cut and/or applied at shorter lengths; it is possible that this could increase installation time or limit the type of rumble strip that can be used. Second, even when smaller lengths are used, rumble strips along the edge line or centerline may decrease the width of the lanes. And finally, other delineation devices (e.g., cones) would need to be placed outside of the rumble strips, thus potentially intruding into the work area.

Ongoing Inspection of Work Zone Devices

To ensure appropriate use of temporary rumble strips in work zones, department or manufacturer guidelines and specifications should always be followed. Additionally, regular inspection of the rumble strips should be conducted to ensure they remain in place and in proper condition. This is especially important when using a new type of rumble strip, as the durability and grip to the road may vary depending on the type of strip that is used. Rumble strips should also be replaced per agency and/or product specifications.

In order to ensure appropriate use of temporary rumble strips in work zones, department or manufacturer guidelines and specifications should always be followed.

CONCLUSIONS

- Temporary rumble strips are much easier to install and remove compared to permanent rumble strips, and some forms are even reusable; this makes them particularly useful for deployment in work zones.

- The audible and vibratory stimuli produced by rumble strips can increase driver awareness while traveling through work zones, which can be particularly useful for inattentive, fatigued, or sleepy drivers.

- Practitioners should use caution when installing temporary rumble strips on high-volume roads as there is potential for erratic or avoidance maneuvers by drivers.

- Failing to properly clean the roadway prior to installation of rumble strips can cause the strips to shift or become dislodged from the pavement; installation instructions provided by manufacturers should be followed strictly.

- Outreach to local residents may be required to notify them of the work, duration of the work, and potential for noise caused by the rumble strips.

- The different types of temporary rumble strips that are available allow for the use of rumble strips in stationary, slow-moving, and long- and short-duration work zones.

- Many factors influence the stimuli created by the rumble strips, such as pattern, spacing, size, and type of rumble strips, as well as vehicle-related factors such as speed and type of vehicle.

- Temporary rumble strips should be selectively located with respect to the potential hazard so as to maximize their effectiveness; placement within the work zone may ultimately be dictated by the signing plan.

- Multiple arrays (sets) of rumble strips spaced several hundred feet apart can be used to provide repeated warnings.

- The pattern (number of rumble strips) should be adequate enough to alert drivers, without being so dramatic that they make motorists uncomfortable or promote unsafe maneuvers to avoid the rumble strips; rumble strips are often deployed in sets of 3, 4, 6, or 10 strips.

- The spacing of temporary rumble strips is dependent on the speed within the work zone; lower speeds require less spacing between strips, whereas higher speeds require more spacing.

- The spacing of rumble strips may be reduced as the distance to the approaching condition decreases in order to convey that an action is imminent and/or give the impression that the driving speed is too fast.

- Acceptable heights of temporary rumble strips range from around 0.25 - 0.81 inches.

- Practitioners should follow State DOT specifications, traffic control plans, and manufacturer recommendations, when available.

- If the color of transverse rumble strips used is not the same color as the pavement they should be black, white, or orange.

- Transverse temporary rumble strips may be placed continuously across the entire lane or in the wheel paths only.

- Additional warning signs may be placed in advance of the rumble strips in order to warn drivers and motorcyclists of the onset of rumble strips.

- Temporary rumble strips can also be utilized at the edge of work zones or along centerlines where traffic is flowing in opposite directions in order to alert drivers if they encroach in the work area, although this is not commonly practiced.

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APPENDIX B. SAMPLE OF SOUND MEASUREMENTS (EL-RAYES, ET AL., 2013) OF RUMBLE STRIPS PRIOR TO WORK ZONES (6 STRIPS/SET)

Vehicle Type	Rumble Strip	Speed Limit	Spacing (inch)	Sound Readings		
				Ambient	Rumble	Effect* (dBA)
Sedan	ATM	50	12	70.14	82.4	12.26
			24	70.14	79.4	9.26
			36	70.14	79.8	9.66
		40	12	68.24	77.1	8.86
			24	68.24	78.3	10.06
			36	68.24	76.9	8.66
		30	12	65.01	77.7	12.69
			24	65.01	74.9	9.89
			36	65.01	73.7	8.69
	Swarco	50	12	70.14	83.9	13.76
			24	70.14	82	11.86
			36	70.14	82.3	12.16
		40	12	68.24	80.7	12.46
			24	68.24	79	10.76
			36	68.24	79.4	11.16
		30	12	65.01	77.3	12.29
			24	65.01	77.1	12.09
			36	65.01	74.5	9.49
	Road Quake	50	36	70.14	84.7	14.56
		40	36	68.24	83.1	14.86
		30	36	65.01	86.8	21.79
26' Truck	ATM	50	12	69.27	76.7	7.43
			24	69.27	76.7	7.43
			36	69.27	78.2	8.93
		40	12	67.98	72.7	4.72
			24	67.98	73.6	5.62
			36	67.98	75.9	7.92
		30	12	64.25	74.3	10.05
			24	64.25	80.9	16.65
			36	64.25	82	17.75
	Swarco	50	12	69.27	78.3	9.03
			24	69.27	81.6	12.33
			36	69.27	75.7	6.43
		40	12	67.98	79.5	11.52
			24	67.98	79.8	11.82
			36	67.98	82	14.02
		30	12	64.25	73.7	9.45
			24	64.25	74.9	10.65
			36	64.25	76.8	12.55
	Road Quake	50	36	69.27	87.2	17.93
		40	36	67.98	85.1	17.12
		30	36	64.25	92.7	28.45

*The report indicated that a sound level change ranging from 4 to 12 dB can be considered adequate to alert motorists of the upcoming work zone, with an upper limit of 20dB due to risks of excessive vibration.

Colorado Department of Transportation

May 5, 2011

REVISION OF SECTION 630
TEMPORARY PORTABLE RUMBLE STRIP

NOTICE

This is a standard special provision that revises or modifies CDOT's *Standard Specifications for Road and Bridge Construction*. It has gone through a formal review and approval process and has been issued by CDOT's Project Development Branch with formal instructions for its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by CDOT's Standards and Specifications Unit. The instructions for use on CDOT construction projects appear below.

Other agencies which use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

Instructions for use on CDOT construction projects:

Use this standard special provision having rumble strips. The Designer shall coordinate with the Region Traffic Engineer on the use of this special provision.

This special shall be used in conjunction with Standard Plan S-630-5.

May 5, 2011

REVISION OF SECTION 630
TEMPORARY PORTABLE RUMBLE STRIPS

Section 630 of the Standard Specifications is hereby revised for this project as follows:

Subsection 630.01 shall include the following:

This work includes the placement, maintenance, and removal of temporary portable rumble strips at locations as shown on the plans.

Subsection 630.07 shall include the following:

(c) *Temporary Portable Rumble Strips*. Temporary portable rumble strips shall be made of Thermoset Cast Urethane. The Contractor shall submit documentation from the manufacturer showing that the product meets all ATSSA and FHWA criteria for temporary portable rumble strips. The rumble strip shall capable of being installed without adhesives or bolts, and shall have a minimum weight of 105 pounds. The face of the rumble strip shall be a non-slip textured surface.

Subsection 630.142 is added following subsection 630.14 as follows:

630.142 Temporary Portable Rumble Strip Installation. Temporary portable rumble strips shall be placed in locations shown in the traffic control plans, and shall be removed at the end of each work day, or as approved by the Engineer.

Prior to placement of the rumble strip, the roadway shall be cleaned to be free of dust, sand, and other materials that may cause slippage. The minimum roadway temperature at the time of installation shall be in accordance with manufacturer recommendations.

If the strip slides, it shall be thoroughly cleaned on both sides, and reset on to a clean roadway surface.

A minimum of three temporary portable rumble strips shall be arranged in an array, as shown on the plans. The actual number of temporary portable rumble strips in each array shall be as recommended by the manufacturer. The spacing between temporary portable rumble strips in each array shall be as recommended by the manufacturer.

Use temporary portable rumble strips on roadways with posted speed limits of 60 MPH or less.

Subsection 630.15 shall include the following:

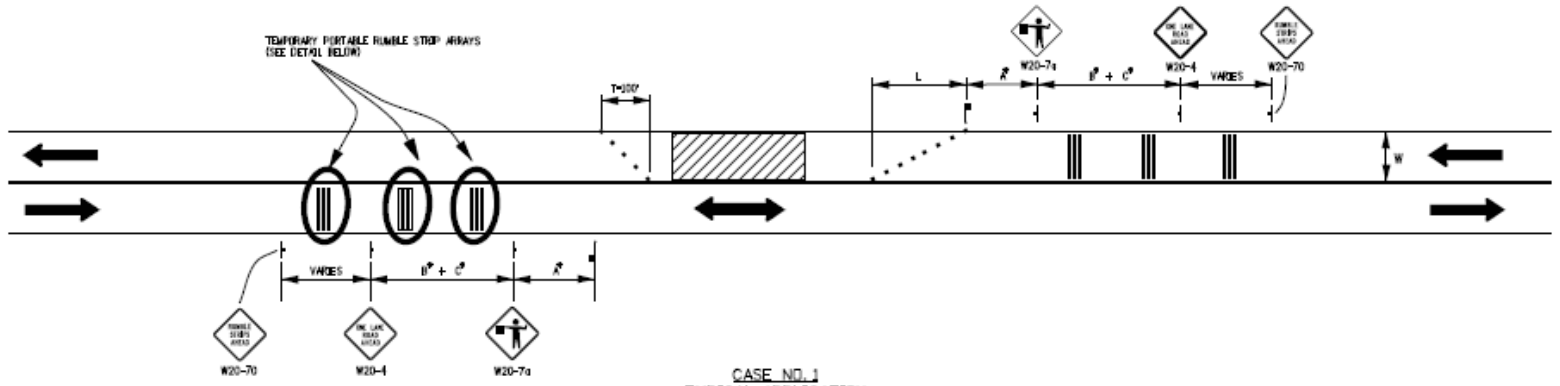
Temporary Portable Rumble Strips will be measured as the actual number of strips that are used in this project.

Subsection 630.16 shall include the following:

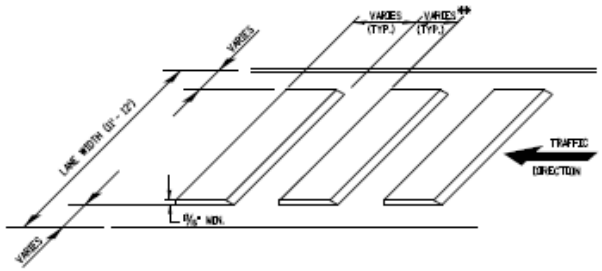
Pay Item	**Pay Unit**
Temporary Portable Rumble Strips	Each

Payment will be full compensation for cleaning the roadway surface, installing the rumble strip, maintaining the strip through the duration of each day's use (including cleaning and resetting of the strip if it slides), removal at the end of each work day, and final removal.

Signing required for the rumble strip will be measured and paid for under the construction signing items.



CASE NO. 1
TYPICAL APPLICATION
TWO-LANE UNDIVIDED HIGHWAY



DETAIL - TEMPORARY PORTABLE RUMBLE STRIP ARRAY

GENERAL NOTES

1. TEMPORARY PORTABLE RUMBLE STRIP ARRAYS SHALL BE PLACED IN ADVANCE OF EACH FLAGGING STATION WHEN CALLED FOR IN THE PLANS.
2. TEMPORARY PORTABLE RUMBLE STRIP ARRAYS ARE USED TO SUPPLEMENT A SERIES OF ADVANCED WARNING SIGNS AND SHALL BE INSTALLED AND REMOVED WHEN THE SIGNS ARE INSTALLED AND REMOVED.
3. REMOVE THE TEMPORARY PORTABLE RUMBLE STRIPS PRIOR TO REMOVING THE ADVANCED WARNING SIGNS.
4. LANE WIDTHS SHOULD BE MAINTAINED THROUGH WORK ZONE TRAVEL LANES WHENEVER PRACTICAL.
5. DO NOT USE TEMPORARY PORTABLE RUMBLE STRIPS ON SLIPPERY SURFACES, SUCH AS WET OR SANDY PAVEMENT.
6. DO NOT USE TEMPORARY PORTABLE RUMBLE STRIPS ON HORIZONTAL CURVES.
7. USE TEMPORARY PORTABLE RUMBLE STRIPS ON ROADWAYS WITH POSTED WORK ZONE SPEED LIMITS OF 60 MPH OR LESS.
8. FOR THE LOWEST AIR TEMPERATURE TO APPLY THE TEMPORARY PORTABLE RUMBLE STRIPS ON ROAD PAVEMENTS, CONTACT THE TEMPORARY PORTABLE RUMBLE STRIP MANUFACTURER.
9. INSTALL PER MANUFACTURER'S RECOMMENDATIONS.

LEGEND

- CHANNELIZING DEVICE: FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED IN PLANS.
- DIRECTION OF TRAVEL
- FLAGGER
- WORK AREA

T = TERMINATION TAPER = 100'
S = WORK ZONE SPEED LIMIT
W = LANE WIDTH
L = MERGING TAPER (S > 45 MPH) = WxS
L = MERGING TAPER (S ≤ 45 MPH) = (WxS²)/60
N = NUMBER OF DEVICES (L/S) + 1
N = NUMBER OF DEVICES AT TERMINATION TAPER = S (MIN.)

KEY TO ADVANCE SIGNING DISTANCES

ROAD TYPE	DISTANCE BETWEEN SIGNS (FT.)		
	A	B	C
URBAN (S < 45 MPH)	100	100	100
URBAN (S ≥ 45 MPH)	350	350	350
RURAL	500	500	500

++ FOR RUMBLE STRIP SPACING DISTANCE, USE MANUFACTURER'S RECOMMENDATIONS.

Computer File Information			Sheet Revisions	
Creation Date: 07/04/12	Initials: KEN		Date:	Comments
Last Modification Date:	Initials:			
Full Path: www.coloradodot.info/library/traffic/traffic-standards-plans				
Drawing File Name: S-630-05_1of2.dgn				
CAD Ver.: MicroStation V8 Scale: Not to Scale	Units: English			

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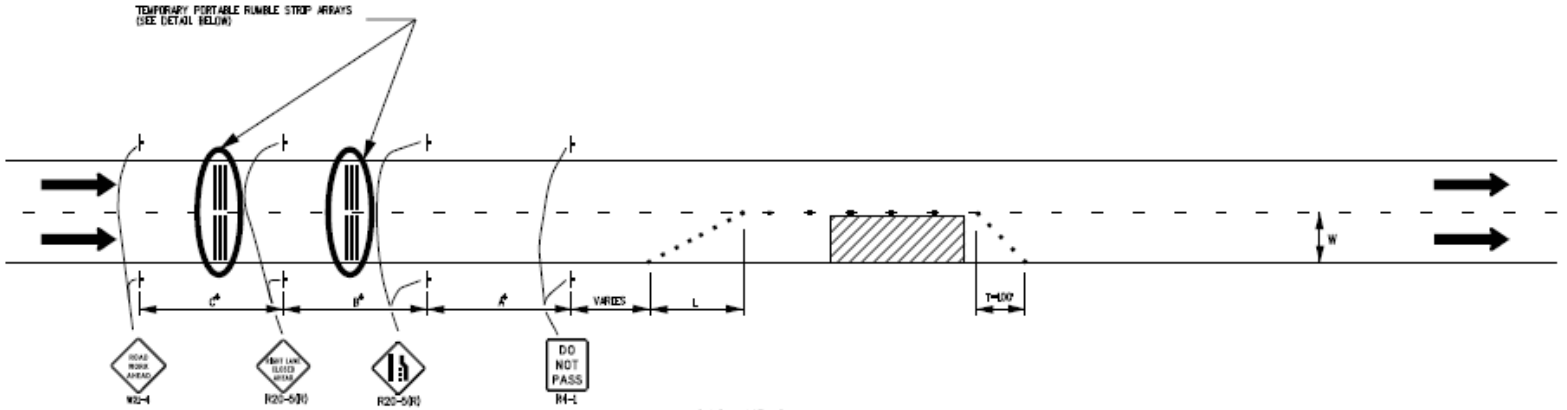
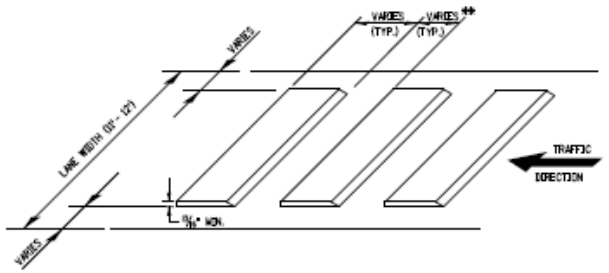
PORTABLE RUMBLE STRIPS (TEMPORARY)

Issued By: Safety & Traffic Engineering Branch July 4, 2012

STANDARD PLAN NO.
S-630-5
Sheet No. 1 of 2



CASE NO. 2
TYPICAL APPLICATION
MULTI-LANE DIVIDED HIGHWAY WITH RIGHT LANE CLOSED



DETAIL – TEMPORARY PORTABLE RUMBLE STRIP ARRAY

GENERAL NOTES

1. TEMPORARY PORTABLE RUMBLE STRIP ARRAYS ARE USED TO SUPPLEMENT A SERIES OF ADVANCED WARNING SIGNS AND SHALL BE INSTALLED AND REMOVED WHEN THE SIGNS ARE INSTALLED AND REMOVED.
2. REMOVE THE TEMPORARY PORTABLE RUMBLE STRIPS PRIOR TO REMOVING THE ADVANCED WARNING SIGNS.
3. LANE WIDTHS SHOULD BE MAINTAINED THROUGH WORK ZONE TRAVEL LANES WHEREVER PRACTICAL.
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5. DO NOT USE TEMPORARY PORTABLE RUMBLE STRIPS ON HORIZONTAL CURVES.
6. USE TEMPORARY PORTABLE RUMBLE STRIPS ON ROADWAYS WITH POSTED WORK ZONE SPEED LIMITS OF 60 MPH OR LESS.
7. FOR THE LOWEST AIR TEMPERATURE TO APPLY THE TEMPORARY PORTABLE RUMBLE STRIPS ON ROAD PAVEMENTS, CONTACT THE TEMPORARY PORTABLE RUMBLE STRIP MANUFACTURER.
8. INSTALL PER MANUFACTURER'S RECOMMENDATIONS.

LEGEND

■ CHANNELIZING DEVICE(FOR TYPE OF DEVICE TO BE USED, SEE THE SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES INCLUDED ON PLANS.

DIRECTION OF TRAVEL

WORK AREA

T = TERMINATION TAPER = 100'
S = WORK ZONE SPEED LIMIT
W = LANE WIDTH
L = MERGING TAPER (S ≥ 45 MPH) = WxS
L = MERGING TAPER (S < 45 MPH) = (WxS²)/60
N = NUMBER OF DEVICES (L/S) + 1
N = NUMBER OF DEVICES AT TERMINATION TAPER = 5 (MIN.)

*KEY TO ADVANCE SIGNING DISTANCES

ROAD TYPE	DISTANCE BETWEEN SIGNS (FT.)		
	A	B	C
URBAN (S < 45 MPH)	100	100	100
URBAN (S ≥ 45 MPH)	350	350	350
RURAL	500	500	500
EXPRESSWAY/FREEWAY	1,000	1,000	2,640

++ FOR RUMBLE STRIP SPACING DISTANCE, USE MANUFACTURER'S RECOMMENDATIONS.

Computer File Information			Sheet Revisions	
Creation Date: 07/04/12	Drafter: KEN		Date:	Comments
Last Modification Date:	Drafter:			
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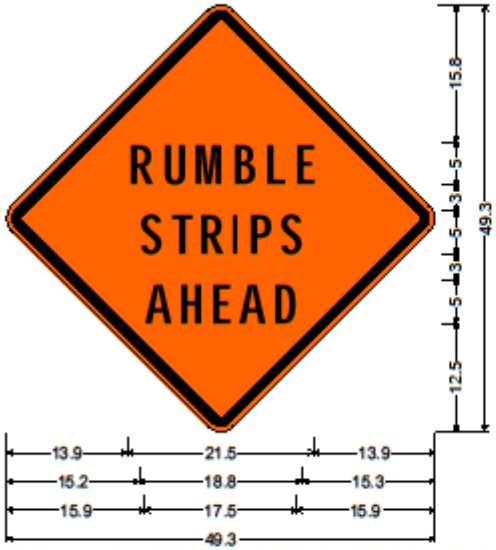
PORTABLE RUMBLE STRIPS (TEMPORARY)

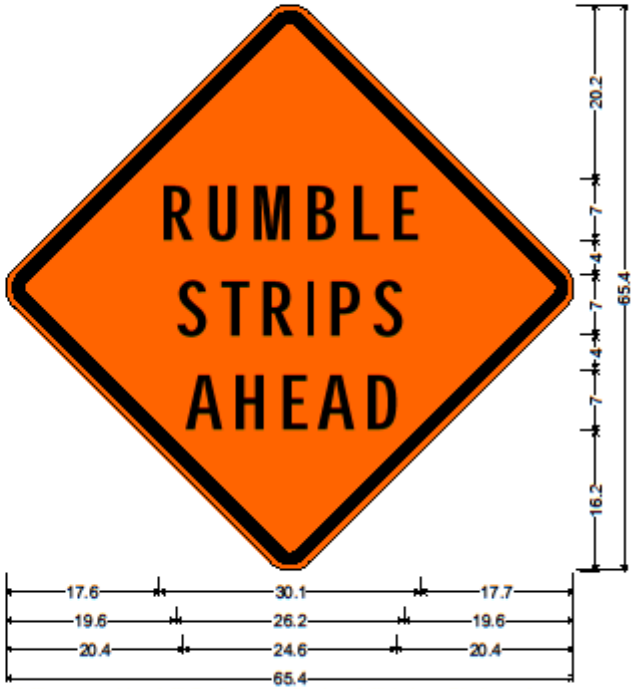
Issued By: Safety & Traffic Engineering Branch July 4, 2012

STANDARD PLAN NO.
S-630-5
Sheet No. 2 of 2



36.0" across sides 2.0" Radius, 0.9" Border, 0.6" Indent, Black on Orange;
"RUMBLE" C; "STRIPS" C; "AHEAD" C;
Table of letter and object lefts.

R 13.9	U 17.7	M 21.5	B 25.7	L 29.5	E 32.9
S 15.2	T 18.8	R 22.2	I 25.9	P 27.7	S 31.3
A 15.9	H 19.8	E 23.6	A 26.7	D 30.7	



48.0" across sides 3.0" Radius, 1.3" Border, 0.8" Indent, Black on Orange;
"RUMBLE" C; "STRIPS" C; "AHEAD" C;
Table of letter and object lefts.

R 17.6	U 22.9	M 28.3	B 34.3	L 39.6	E 44.2
S 19.6	T 24.6	R 29.2	I 34.5	P 37.0	S 42.0
A 20.4	H 26.0	E 31.3	A 35.6	D 41.1	

104.26 REMOVABLE RUMBLE STRIPS.

104.26.01 DESCRIPTION. Furnis h, install, maintain, and remove removable rumble strips.

104.26.02 MATERIALS.

Removable Rumble Strips QPL

Rumble strips shall be white in color, 4 in. wide, and 0.250 in. thick.

104.26.03 CONSTRUCTION.

104.26.03.01 Quality Assurance/Quality Control. Perfor m quality control testing using technicians certified by the Administration.

104.26.03.02 Warranty Period. Maintain the rumble strips and repair defects for a period of 180 days from the date of application. Replace a s necessary within this period as direct ed at no additional cost to the Administration. Refer to GP-5.11.

At least 90 percent of the total number of rumble strips in any lane shall be free from signs of failure due to blistering, excessive cracking, discoloration, smearing or spreading under heat, chipping, spalling, or poor adhesion to the pavement. Replace rumble strips showing wear or a thickness less than 0.20 in.

104.26.03.03 Application and Removal. The pavement surfaces shall be completely dry and free of oil, grease, sand, dirt, dust, loose aggregate, soil, salt, and other contaminants. Apply the rumble strips in accordance with the manufacturer's recommendations and the Contract Documents. Place perpendicular to the flow of traffic and located as specified.

Space the strips between 4 and 10 ft on center, with a pattern of at least 10 but not more than 12 strips per set. Decrease the spacing within each set as motorists approach the work zone. The spacing between the sets shall be as specified.

Do not place on sharp horizontal or vertical curves. Use in conjunction with other traffic control devices or visual cues that will assist drivers in identifying the appropriate action to take.

For installations where the roadway is wider than one lane in each direction, install in one-lane width segments utilizing butt joints. Do not overlap. Continue at least 1 ft onto each shoulder. Do not install over pavement seams, joints, or deteriorating markings and substrates.

When no longer required, remove rumble strips and residue. Return the pavement surface to its original condition.

104.26.04 MEASUREMENT AND PAYMENT. Removable Rumble Strips will be measured and paid for at the Contract unit price per linear foot. The payment will be full compensation for all material, labor, equipment, tools, and incidentals necessary to complete the work.

Removal and replacement required beyond the 180 day period will be measured and paid for at the Contract unit price for the Removable Rumble Strip item.

Replacements made during the service life due to plowing will be paid for at the Contract unit price for the Removable Rumble Strip item.

104.26.04.01 Removal, Replacement, and Corrective Actions. Any additional cost, including maintenance of traffic, for the removal of rumble strips that are installed inaccurately or incorrectly shall be at no additional cost to the Administration. In addition, the current road user fee will be applied when traffic disruption occurs during corrective actions.

C. Transverse Rumble Strips

Transverse rumble strips are to be applied to the pavement surface with pavement marking material. Milled or ground transverse rumble strips may be used with the concurrence of the Director, Office of Traffic and Safety and the Director, Office of Maintenance. The guidelines described herein are applicable to applied transverse rumble strips.

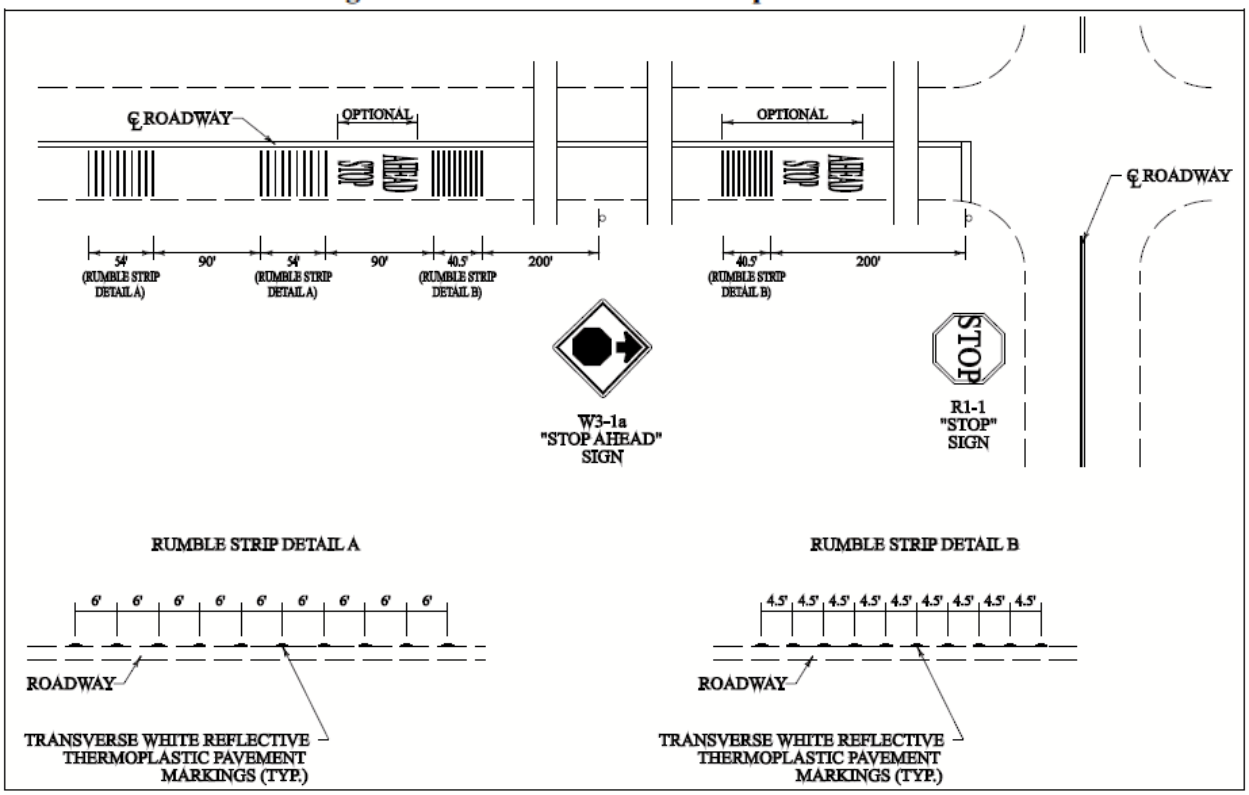
Applied transverse rumble strips are created by placing two pieces of preformed pavement marking material on top of each other to obtain the desired thickness. Options include:

- Placing a 10" pavement marking strip on the pavement and then a 5" pavement marking strip on top of the 10" pavement marking strip.
- Placing two 5" pavement marking strips on the pavement applied on top of each other (more aggressive application).

Figure 3 shows an example of the recommended placement of applied transverse rumble strips on the approach to a "Stop Ahead" sign. The "STOP AHEAD" pavement markings and the two

sets of rumble strips located after the "Stop Ahead" sign are optional. This same application could be used prior to other warning signs including "Signal Ahead", "Yield Ahead", "Roundabout Ahead", "Reduced Speed Ahead", and other traffic control devices.

Figure 3 –Transverse Rumble Strip Placement



Construction/Maintenance Materials, Methods, Practices, and Specifications → Traffic Control	G4-10

BEST PRACTICE:

Rumble Strips at the Beginning of Work Zones

DESCRIPTION:
Thermoplastic rumble strips are placed transversely across the travel lane(s) heading into a long-term work zone in order to get the attention of drivers. They are 4 inches wide, 250 mil thick with the following spacing: 2 sections – 10 transverse strips, 6 feet apart, then 90 feet away the next section starts with 10 transverse strips, 4½ feet apart.

REASON(S) FOR ADOPTING:
To alert motorists of the construction zone and to slow motorists down.

PRIMARY BENEFIT(S):
Drivers are more alert going into the work zone.

MOST APPLICABLE LOCATION(S)/PROJECT(S):
All locations. All types of work.

STATE(S) WHERE UTILIZED:
Ohio

SOURCE/CONTACT(S):
Dennis O'Neil, Work Zone Traffic Control Engineer, Ohio DOT
Telephone: (216) 581-2100, ext. 373
Email: doneil@odot.dot.ohio.gov

Joe Glinski, Safety Program Engineer, FHWA Ohio Division
Telephone: (614) 280-6844
Email: joseph.glinski@fhwa.dot.gov

Rumble strip for work zone speed control

MEMORANDUM

TO: District Engineers **DATE:** November 12, 2012

FROM: Carol T. Rawson, P.E., Director
Traffic Operations Division

SUBJECT: Work Zone Temporary Rumble Strip Standard Sheet

The Traffic Operations Division has developed the Work Zone Temporary Rumble Strip standard sheet, WZ(RS)-12, for use on temporary lane closures to enhance safety.

Temporary rumble strips are to be used on:

- one-lane, two-way flagging operations with a posted speed limit of 70 mph or less
- lane closures on conventional highways with a posted speed limit of 70 mph or less

If Portable Traffic Signals or Automated Flagger Assistance Devices are used in lieu of flaggers for lane closures, this standard sheet also applies.

This standard sheet is required for Construction and Maintenance let projects that meet either of the conditions listed above starting with the May 2013 letting.

The temporary rumble strip standard sheet is to be used immediately by district maintenance crews as soon as the rumble strips become available in the warehouse.

The General Services Division (GSD) has placed a one-time purchase order for the temporary rumble strips and they will be stocked at the Athens and Seguin distribution centers. Attached is a list with the total number of complete sets that has been ordered for each district. Each complete set will comprise of 36 temporary rumble units. A strip is made of 3 units. An array will have 3 strips (9 units). Four arrays will make a complete set of temporary rumble strips. GSD has also ordered 2 "RUMBLE STRIPS AHEAD" signs and portable sign stands for each complete set of rumble strips.

The DHT numbers for the items discussed above are as follows:

- Rumble Strips, RoadQuake2, DHT 166988
- Roll up Sign – 48" – "Rumble Strips Ahead", DHT 167004
- Stand, Sign, Roll-up, 7ft, adjustable, DHT 157488

Approved temporary rumble strips can be found in the Compliant Work Zone Traffic Control Device list (CWZTCD). The CWZTCD is available at the following web address: http://www.txdot.gov/txdot_library/publications/construction.htm

If you have any questions on the temporary rumble strips, please contact Michael Chacon at (512) 416-3120 or me at (512) 416-3200.

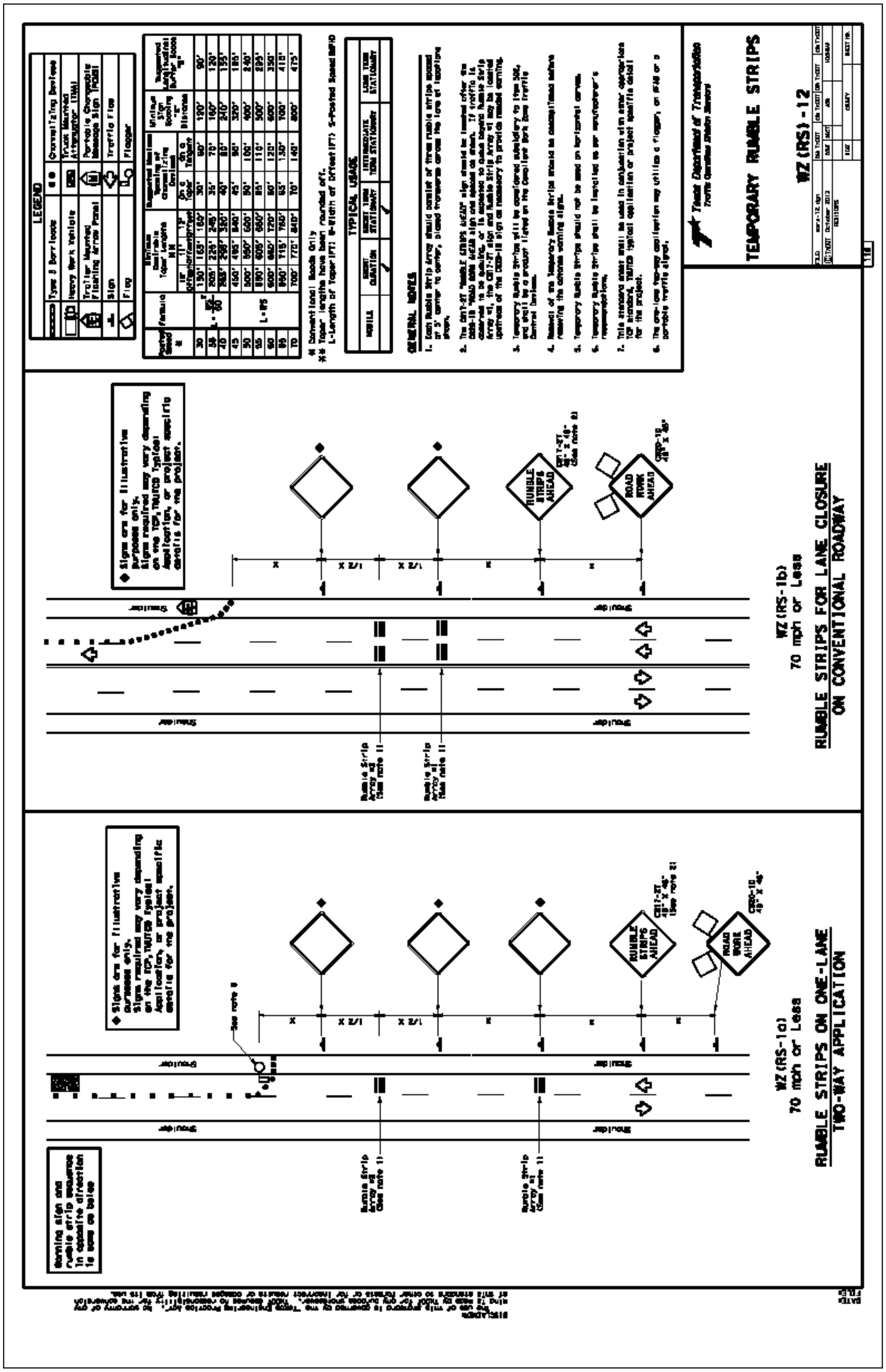
Attachments

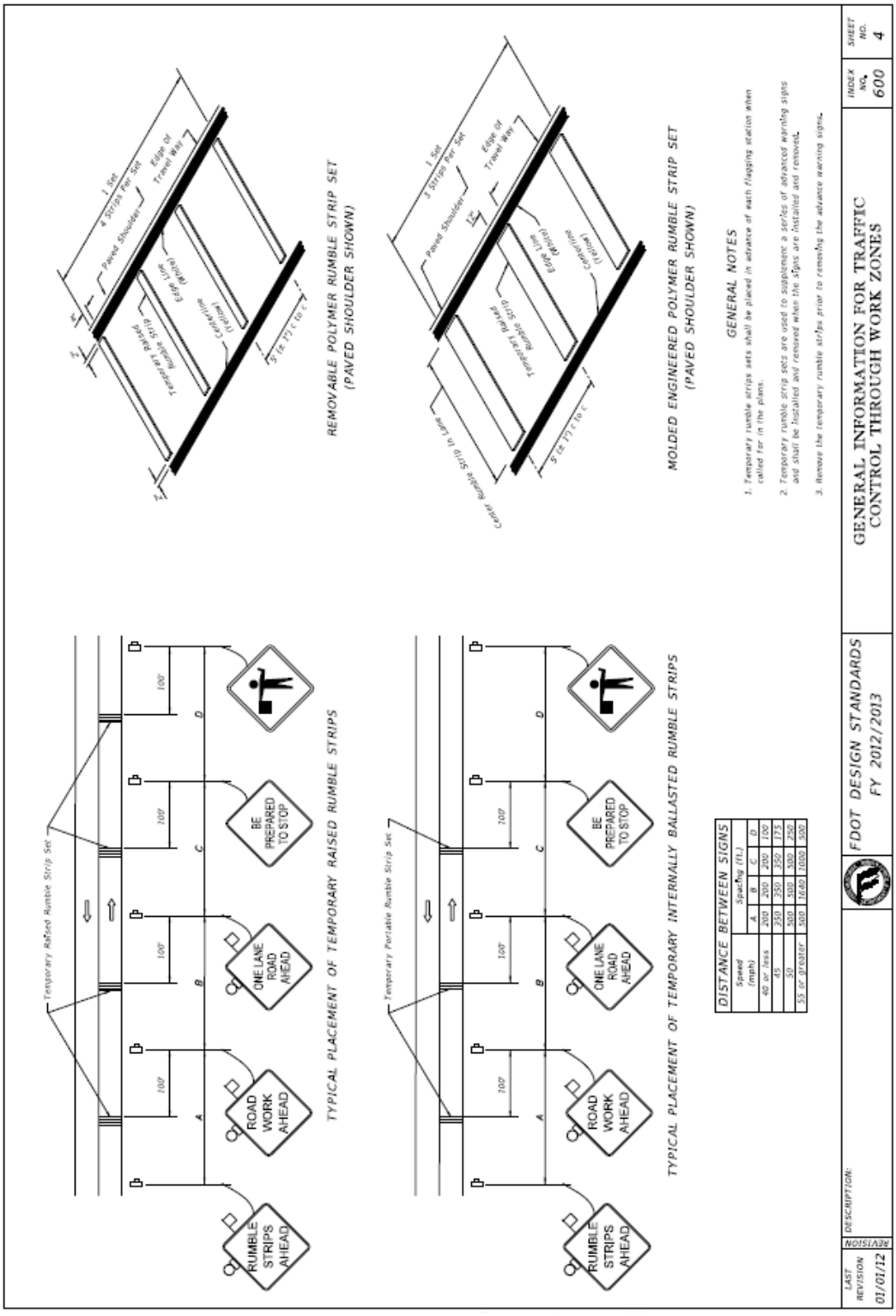
cc: ADM
AUD
CST
DES
District Traffic Engineers
GSD
LGP
MNT
SPD
A.P. Boyd, AGC
Thomas Bohuslav, P.E., AGC
Gregory Brinkmeyer, P.E., ATSSA
William R. Lowery, TEEX
Mark Olson, P.E. FHWA, Texas Division

Temporary Rumble Strips - Number of Complete Sets per District

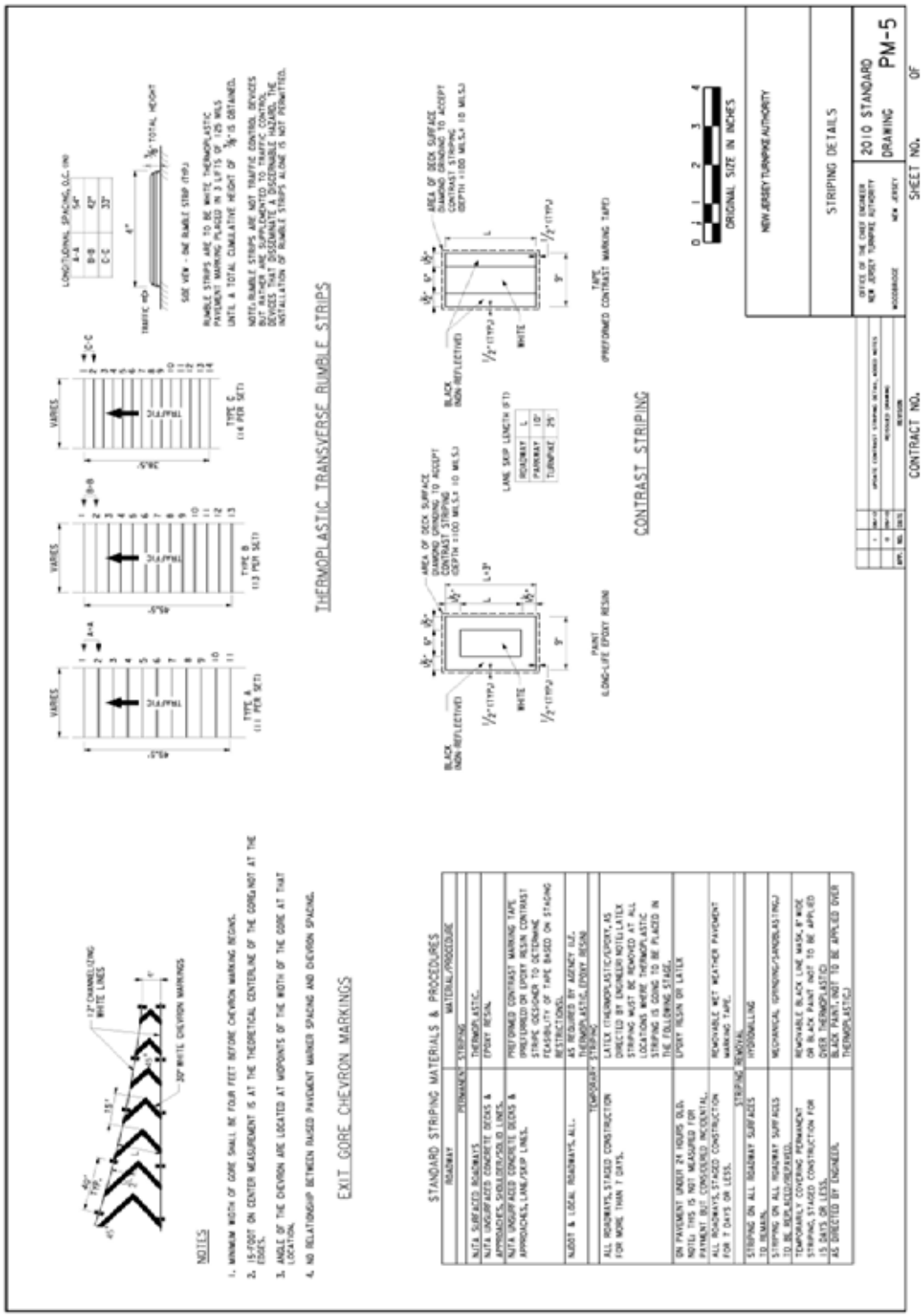
Abilene	13
Amarillo	20
Atlanta	12
Austin	15
Beaumont	15
Brownwood	15
Bryan	13
Childress	12
Corpus Christi	12
Dallas	5
El Paso	9
Fort Worth	15
Houston	10
Laredo	10
Lubbock	22
Lufkin	12
Odessa	13
Paris	9
Pharr	10
San Angelo	13
San Antonio	17
Tyler	6
Waco	10
Wichita Falls	12
Yoakum	12
TOTAL	**312**

Dario Alavarez of Plastic Safety Services has offered to provide training on the installation of the temporary rumble strips to any district. Please contact Dario at (216) 409-6032 to make arrangements for a training date.


TEMPORARY RUMBLE STRIPS
WZ (RS) -12
Texas Department of Transportation
WZ (RS-1a)
70 mph or Less
RUMBLE STRIPS ON ONE-LANE TWO-WAY APPLICATION
WZ (RS-1b)
70 mph or Less
RUMBLE STRIPS FOR LANE CLOSURE ON CONVENTIONAL ROADWAY
RUMBLE STRIPS AHEAD
ROAD WORK AHEAD
CW17-2T
CW20-1D
48" X 48"
LEGEND
TYPICAL USAGE
GENERAL NOTES


REMOVABLE POLYMER RUMBLE STRIP SET
(PAVED SHOULDER SHOWN)
MOLDED ENGINEERED POLYMER RUMBLE STRIP SET
(PAVED SHOULDER SHOWN)
GENERAL NOTES
1. Temporary rumble strips sets shall be placed in advance of each flagging station when called for in the plans.
2. Temporary rumble strip sets are used to supplement a series of advanced warning signs and shall be installed and removed when the signs are installed and removed.
3. Remove the temporary rumble strips prior to removing the advance warning signs.
TYPICAL PLACEMENT OF TEMPORARY RAISED RUMBLE STRIPS
TYPICAL PLACEMENT OF TEMPORARY INTERNALLY BALLASTED RUMBLE STRIPS
DISTANCE BETWEEN SIGNS
Speed (mph) | Spacing (ft.) A | B | C | D
40 or less | 200 | 200 | 200 | 100
45 | 350 | 350 | 350 | 175
50 | 500 | 500 | 500 | 250
55 or greater | 500 | 1640 | 1000 | 500
RUMBLE STRIPS AHEAD
ROAD WORK AHEAD
ONE LANE ROAD AHEAD
BE PREPARED TO STOP
FDOT DESIGN STANDARDS
FY 2012/2013
GENERAL INFORMATION FOR TRAFFIC CONTROL THROUGH WORK ZONES
INDEX NO. 600
SHEET NO. 4
LAST REVISION 01/01/12
REVISION
DESCRIPTION:

New Jersey Turnpike Authority
2010 Standard Drawing PM-5



New York State Department of Transportation
Engineering Instruction 03-039

To: SUPERSEDED BY EB 06-057 EFFECTIVE 05/03/07		*New York State Department of Transportation* ENGINEERING INSTRUCTION	EI 03-039
Title: **TEMPORARY RUMBLE STRIPS FOR CONSTRUCTION WORK ZONES**			
Distribution: ☐ Manufacturers (18) ☒ Main Office (30) ☒ Local Govt. (31) ☒ Regions/Agencies (32) ☐ Surveyors (33) ☒ Consultants (34) ☒ Contractors (39) ☐ _____( )		Approved: /s/ J. F. Tynan 11/6/03 James F. Tynan Director, Construction Division Date	

ADMINISTRATIVE INFORMATION:

- This Engineering Instruction is effective for projects submitted for the letting of May 6, 2004.
- This EI supersedes the Special Specifications issued by EI 96-001.
- The Standard Specifications revisions issued by this EI will be incorporated into the next update of the Standard Specifications.
- The design guidance in EI 96-001 is not superseded and will be incorporated into the next revision of Chapter 16 of the Highway Design Manual.

PURPOSE:

The purpose of this EI is to issue a standard specification for temporary rumble strips for use in construction work zones.

TECHNICAL INFORMATION:

The revised specification for temporary rumble strips for construction work zones incorporates this item into the Standard Specifications. The specification allows the use of preformed plastic strips in addition to raised asphalt strips, recessed, saw-cut or milled-in strips, and strips formed from layers of pavement-marking tape.

Experience with temporary rumble strips on Department projects confirms the effectiveness of the suggested layout pattern in EI 96-001 and thickness requirements in the specification. Some other observations follow.

1. Proper pavement surface preparation is essential for good performance of tape and preformed rumble strips. Pavement must be in good condition and clean, and rumble strips must be applied according to the manufacturer's instructions (proper air and pavement temperatures, absence of moisture, appropriate adhesive) for best results. Strips do not adhere well to pitted, deteriorated pavement and will pull away from the pavement if not properly applied.

2. Rumble strips formed from pavement-marking tape provide optimal performance when multiple layers of tape, preferably four, are placed directly on top of one another. These strips create the right level of noise and can be felt within a vehicle without causing a jarring effect.

3. Because preformed strips rely upon ridges and depressions in the strip to enhance their audible and tactile effect, they can have a slightly lower profile than strips formed of tape and still provide good warning to drivers. Therefore, a lower minimum thickness is specified. Strips higher than 13 mm are considered to be too aggressive and may not be used. The maximum thickness for preformed strips (13 mm) is the same as for tape strips and raised asphalt strips.

4. Potential locations for temporary rumble strips should be evaluated on a project-to-project basis. Generally, rumble strips are not effective in urban settings and are not appropriate for residential areas because of the noise. Some suggested locations are: when the work zone occurs on an open stretch of highway; at a detour or diversion; where the traffic pattern has been changed; where there is alternating one-way traffic with a temporary traffic signal.

IMPLEMENTATION:

The following special specifications are disapproved:

18619.6460 Temporary Rumble Strips
08619.646001 Temporary Rumble Strips

Main Office Design Quality Assurance Bureau will insert the standard specification shelf note beginning with projects submitted for the letting of May 6, 2004. Regions may use this item in contracts let before this date, and should include the specification in the proposal. This item may be added to projects under construction by order-on-contract.

BACKGROUND:

EI 96-001 provided specifications and design guidance for use of temporary rumble strips in work zones. These rumble strips had minimal use on Department projects for several years, even though they performed well in the few instances they were used. Engineering Directive ED 99-002, Work Zone Intrusion Countermeasures, listed temporary rumble strips as one of seven countermeasures to be used on selected projects to reduce the incidence of traffic intrusions into highway work areas where workers are exposed to traffic. Temporary rumble strips were included as a countermeasure because they are a low-cost, easy-to-install/remove feature that is effective in providing audible and tactile warning to drivers that they are approaching a highway work zone. While they are not generally effective in reducing speed, they can raise a driver's level of awareness and reduce risk to the traveling public as well as workers.

In 1999, the first season of the work zone intrusion initiative, temporary rumble strips were used on over fifty construction projects. Since then, temporary rumble strips have become one of the most frequently used intrusion countermeasures.

Most temporary rumble strips have been constructed of several layers of removable, preformed, black pavement-marking tape. Several products have become available that use a polymer or polycarbonate product in preformed strips manufactured specifically as temporary removable rumble strips. The Department has used preformed strips on a number of projects on an experimental basis for several years and has found that their performance is comparable to rumble strips formed from pavement-marking tape. These strips are available from several manufacturers and may now be used as raised, removable rumble strips.

CONTACT

Direct questions to the Regional Traffic Group or Chuck Riedel criedel@dot.state.ny.us. of the Traffic Engineering & Highway Safety Division at (518) 457-2185

TEMPORARY RUMBLE STRIPS FOR CONSTRUCTION WORK ZONES

Make the following changes to Volume 2 of 3 of the Standard Specifications of January 2, 2002:

Page 6-81, after line 38 **insert** the following:

619-1.16 (Vacant)

619-1.17 Temporary Rumble Strips. Work shall consist of installing, maintaining, and removing temporary rumble strips in construction work zones at the locations shown in the contract documents or as directed by the Engineer.

Page 6-86, after line 31 **insert** the following:

619-2.11 (Vacant)

619-2.12 (Vacant)

619-2.13 (Vacant)

619-2.14 (Vacant)

619-2.15 (Vacant)

619-2.16 (Vacant)

619-2.17 Temporary Rumble Strips.

A. Raised Asphalt Rumble Strips. Raised asphalt rumble strips shall be formed from Type 5 (Shim Course) or Type 7 (Top Course) hot mix asphalt (HMA) meeting the requirements of Section 403, *Hot Mix Asphalt (HMA) Pavements for Municipalities* or a 9.5 mm hot mix asphalt meeting the requirements of Section 402, *Hot Mix Asphalt (HMA) Pavements*. Asphalt Emulsion Tack Coat shall be used to adhere the rumble strip to the existing pavement. Raised asphalt rumble strips shall have a width measured in the direction of traffic of between 150 mm and 225 mm and have a final compacted thickness of 10 mm ± 3 mm.

B. Raised, Removable-Tape Rumble Strips. Removable-tape rumble strips shall be formed from black, nonreflectorized, removable pavement-marking tape. Raised, removable-tape rumble strips shall have a minimum width measured in the direction of traffic of 150 mm, with sufficient layers of tape such that each finished rumble strip has a thickness of 10 mm ± 3 mm.

C. Raised, Preformed Rumble Strips. Raised, preformed rumble strips shall be manufactured specifically as temporary rumble strips. Raised, preformed rumble strips shall have a minimum width measured in the direction of traffic of 100 mm, with a thickness of between 6 mm and 13 mm.

D. Saw-cut Rumble Strips. Saw-cut rumble strips shall have a width measured in the direction of traffic of 100 mm ± 13 mm. The depressions shall have a rectangular cross section with a depth of 10 mm ± 3 mm.

E. Milled-in Rumble Strips. Milled-in rumble strips shall have a nominal width measured in the direction of traffic of 150 mm. The depressions shall have a semicircular, concave cross section with a depth of 10 mm ± 3 mm.

F. Removing Temporary Rumble Strips. Rumble strip depressions shall be filled in with Type 5 (Shim Course) or Type 7 (Top Course) hot mix asphalt (HMA) meeting the requirements of Section 403, *Hot Mix Asphalt (HMA) Pavements for Municipalities* or a 9.5 mm hot mix asphalt meeting the requirements of Section 402, *Hot Mix Asphalt (HMA) Pavements*.

Page 6-103, after line 23 **insert** the following:

TEMPORARY RUMBLE STRIPS FOR CONSTRUCTION WORK ZONES

619-3.14 (Vacant)

619-3.15 (Vacant)

619-3.16 (Vacant)

619-3.17 Temporary Rumble Strips. Due to difficulties in patching shallow voids in hot mix asphalt pavement surfaces, saw-cut and milled-in rumble strips shall only be installed in locations where hot mix asphalt pavement will subsequently be overlaid or reconstructed.

A. Raised Asphalt Rumble Strips. The roadway surface on which the rumble strips are to be attached shall be dry, free of surface contaminants such as dust or oil, and thoroughly swept with a stiff broom. The surface temperature of the pavement shall be 8°C or greater unless otherwise authorized by the Engineer. The pavement surface shall be cleaned with compressed air just prior to tack coating and subsequent installation of the rumble strips. The strips shall be formed using a rumble strip paver (drag box) pulled transversely across the pavement, or by hand placement between forms fixed to the pavement. If forms are used, they shall be removed prior to compaction of the asphalt mixture. Compaction shall be accomplished using a plate tamper or a static roller.

B. Raised, Removable-Tape Rumble Strips. Raised removable tape rumble strips shall be formed by applying one or more layers of removable preformed pavement-marking tape. The tape shall be applied to a clean, dry pavement surface in accordance with the Manufacturer's recommendations. The pavement surface shall be swept or cleaned with compressed air just prior to application of the tape.

C. Raised, Preformed Rumble Strips. Raised preformed rumble strips shall be applied to a clean, dry pavement surface in accordance with the Manufacturer's recommendations. The pavement surface shall be swept or cleaned with compressed air just prior to application of the tape.

D. Saw-cut Rumble Strips. Saw-cut rumble strips shall be saw cut into existing pavement using wet cutting methods. The blade or blades shall be of such configuration that the desired dimensions of the saw cut can be made with one pass. No spacers between blades will be allowed.

Before a work area is reopened to traffic, the pavement shall be cleaned by sweeping, flushing, or with a stream of compressed air. Sawing slurry from the wet-sawing process shall be flushed from the pavement surface immediately.

E. Milled-In Rumble Strips. Milled-in rumble strips shall be milled into existing pavement using a rotary-type cutting head with a maximum nominal outside diameter of 600 mm. The cutting head shall be on its own suspension system, independent from that of the power unit, to allow the head to align itself with the slope of the pavement and/or any irregularities in the pavement surface. The pattern of cutting tips on the head shall be arranged to produce a relatively smooth cut with no more than 2 mm between peaks and valleys. Prior to beginning work, the Contractor shall demonstrate to the Engineer the ability to achieve the desired surface without tearing or snagging the pavement.

Before a work area is reopened to traffic, the pavement shall be cleaned by sweeping, flushing, or with a stream of compressed air.

F. Removing Temporary Rumble Strips. The Contractor shall either completely remove raised rumble strips from the pavement or fill in the depressions from saw-cut or milled-in rumble strips prior to the start of the winter plowing season, prior to the placement of successive pavement courses, or as directed by the Engineer. Any damage to the pavement surface that results from the removal of raised rumble strips shall be repaired at no additional cost to the State.

Rumble strip depressions shall be filled in with hot mix asphalt. Before they are filled, the depressions shall be cleaned by sweeping, flushing, or with a stream of compressed air, and coated with Asphalt Emulsion Tack Coat. The rumble strips shall be overfilled slightly and compacted using a plate tamper or static roller so that the final compacted surface is flush with the existing pavement.

TEMPORARY RUMBLE STRIPS FOR CONSTRUCTION WORK ZONES

Page 6-105, after line 13 **insert** the following:

619-4.15 (Vacant)

619-4.16 (Vacant)

619-4.17 Temporary Rumble Strips. The work will be measured for payment as the number of meters of individual rumble strip, measured transverse to the direction of traffic flow, satisfactorily installed.

Page 6-109, after line 20 **insert** the following:

619-5.17 Temporary Rumble Strips. The unit price bid for temporary rumble strips shall include the cost of all labor, materials and equipment necessary to complete the work. Payment will include the cost of pavement cleaning, hot mix asphalt, or other materials used to form or fill in the rumble strips, and tack coat. Progress payments will be made at the unit price bid for 75 percent of the quantity after installation. The remaining 25 percent will be paid upon removal.

Page 6-109, after line 49 **add** the following:

619.22 M	Temporary Rumble Strips	Meter

Government of Saskatchewan
Ministry of Highways & Infrastructure

TCDMWZ 903

TRAFFIC CONTROL DEVICES MANUAL FOR WORK ZONES

Section: ADDITIONAL DEVICES

Subject: PORTABLE RUMBLE STRIPS

PORTABLE RUMBLE STRIPS

Portable rumble strips are grooved or raised pavement corrugations placed perpendicular to the path of vehicles and across the full width of the shoulder and travelled lane. The purpose is to alert inattentive drivers of hazards that may not be readily apparent but which require substantial speed reduction or other cautionary manouevres. Portable rumble strips have the same effect as the rumble strips made with pavement, with the benefit of being easier to use and less expensive.

Rumble strips are practical for stationary and slow moving work zones and for short to long duration projects. If the work zone is moving quickly, the installation and removal of the rumble strips may become impractical.

Types of Rumble Strips

Rumble strips are a rubber mat device approximately 325 mm wide x 18 mm high extending across the approach lane of the highway.

Specifications

Rumble strips must:

- Generate a sufficient audible noise when traversed by the wheels of a vehicle as to alert the driver.
- Generate a distinct vibration when traversed.
- Be designed so as not to compromise the safety of the roadway for traffic.
- Be selectively located with respect to the potential hazard so as to maximize their effectiveness.
- The device's length should be adjustable in order to span the entire width of the roadway.

Date 2009-08-25

Page 1 of 2

- Be well suited for quick and efficient emergency removal and lightweight to provide maximum mobility.
- The materials used be sufficiently strong to prevent unexpected failure, as well as sufficiently durable to withstand the wear caused by traffic.

Placement of Rumble Strips

Rumble strips shall be used on all long duration construction and maintenance projects on the 1A and 1B Highways as identified in the Preservation Highways Hierarchy or as specified in the contract. The contractor may wish to consider the application of the device on other project locations to supplement their traffic accommodation plan.

Two sets of three rumble strips should be placed 15 m apart, 90 - 150 m prior t the regulatory speed sign. Additional rumble strips may be used as required.

The rumble strips shall be removed when no workers are present.

Notes

Developed by:

The American Traffic Safety Services Association

15 Riverside Parkway Suite 100

Fredericksburg, VA 22406-1022

800-272-8772

U.S. Department of Transportation

Federal Highway Administration