

VERMONT AGENCY OF TRANSPORTATION

**Materials & Research Section
Research Report**



**CENTERLINE RUMBLE-STRIPES
CAMBRIDGE, VERMONT**

Report 2014 – 03

March 2014

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STATE OF VERMONT
AGENCY OF TRANSPORTATION

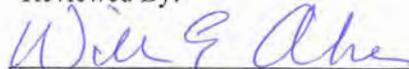
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16. Abstract <p>Centerline Rumble Stripes (CLRS) are a proven strategy for reducing head-on and opposite direction sideswipe crashes. They are also expected to be effective in run-off-road crashes where vehicles cross centerline prior to leaving the roadway, reducing lane drift due to distracted/fatigued driving and in reducing speed and off tracking in curved sections. CLRS are also expected to improve centerline visibility in wet pavement conditions and provide enhanced guidance during snow events.</p> <p>Throughout the state of Vermont, the Vermont Agency of Transportation (VTrans) has successfully implemented CLRS as a means to reduce roadway hazards as listed, particularly in roadway sections where there are a record number of crashes, where there are higher speeds and where the daily traffic is moderately high. This has resulted in an emerging standard for rumble strips.</p> <p>On VT 104 in Cambridge, VT., VTrans installed rumble stripes as part of a highway-resurfacing project. The revised pattern was a series of closely spaced depressions with equal lengths of smooth and rutted surface. Due to a series of factors during construction, the typical rumble strip pattern was changed.</p> <p>The resulting sounds coming from the stripes proved to be unacceptable to the neighboring community. VTrans confirmed that sound levels were increased with the revised pattern. As a result, the Agency chose to remove the rumbles first by patching a certain number of rumbles to approximate the standard pattern; then when that proved unacceptable, the Agency completed the work by completely milling out the rumbles and repaving. This paper summarizes the field activities and observations.</p>			
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ABSTRACT

Centerline Rumble Stripes (CLRS) are a proven strategy for reducing head-on and opposite direction sideswipe crashes. They are also expected to be effective in run-off-road crashes where vehicles cross centerline prior to leaving the roadway, reducing lane drift due to distracted/fatigued driving and in reducing speed and off tracking in curved sections. CLRS are also expected to improve centerline visibility in wet pavement conditions and provide enhanced guidance during snow events.

Throughout the state of Vermont, the Vermont Agency of Transportation (VTrans) has successfully implemented CLRS as a means to reduce roadway hazards as listed, particularly in roadway sections where there are a record number of crashes, where there are higher speeds and where the daily traffic is moderately high. This has resulted in an emerging standard for rumble strips.

On VT 104 in Cambridge, VT., VTrans installed rumble stripes as part of a highway-resurfacing project. The revised pattern was a series of closely spaced depressions with equal lengths of smooth and rutted surface. Due to a series of factors during construction, the typical rumble strip pattern was changed.

The resulting sounds coming from the stripes proved to be unacceptable to the neighboring community. VTrans confirmed that sound levels were increased with the revised pattern. As a result, the Agency chose to remove the rumbles first by patching a certain number of rumbles to approximate the standard pattern; then when that proved unacceptable, the Agency completed the work by completely milling out the rumbles and repaving. This paper summarizes the field activities and observations.

INTRODUCTION

According to the Federal Highway Administration, “run-off-road crashes cause one-third of all fatalities and two-thirds of those crashes occur in rural areas.” The main causes of run-off-the road crashes are generally attributed to drowsiness furtherer compounded by speeding and/or the use of drugs and alcohol. In recent years, there has been an effort to reduce crashes along these roadways through the implementation of rumble strips, a road safety feature that alerts drivers of potential danger by causing a tactile vibration and audible rumbling, transmitted through the wheels and through the car body. While research has shown rumble strips installed along the shoulder of a roadway are highly effective at reducing drift off the road crashes, the use of centerline rumble stripes, intended to alert drivers that they have crossed into the path of oncoming traffic, is still considered experimental. (1)

PROJECT LOCATION AND SUMMARY

Centerline rumble stripes and shoulder rumble strips were installed by change order along VT Route 104 and at the intersection of VT Route 104 and VT Route 15 in Cambridge, Vermont in conjunction with the Cambridge-Fairfax project, STP 2713. (3) According to the original plans, the work to be performed included cold planing, resurfacing with a leveling course and wearing course, pavement markings, guardrail improvements, drainage improvements, and miscellaneous items. (2)

According to the change order (Change Order #004), the addition of the rumble strips was requested by the Highway and Traffic Section. The necessity to add shoulder rumble strips were, “In order to modify the alignment of the VT Route 15 and VT Route 104 intersection so that VT Route 104 becomes more perpendicular to VT Route 15. This in theory will provide a safer intersection.” The unit price for the rumble stripes was \$0.45 per linear foot, totaling \$4,639.95 for a distance of 10,311 linear feet. Mobilization/demobilization, traffic control, type A traffic signs, and sign posts costs totaled \$19,338.50 for a total cost of \$23,978.45. A copy of the change order is in the Appendix. (3)

VTrans determined that a repair was needed to help calm the noise produced by the rumble stripes when driven over due to numerous noise complaints from area residents after installation and sound testing results conducted by Research personnel. The first repair method, which included filling every third rumble with an asphalt repair material, did not produce sufficient improvements and VTrans chose to remove the rumble stripes entirely by milling and filling the areas where the stripes were originally placed. All sound test results, construction, and repair methods and results are summarized below.

CONSTRUCTION

According to the daily work comments report, both the centerline rumble stripes and shoulder rumble strips were installed on Friday, July 20, 2012 by Costello Industries of Newington, CT.

In Vermont, centerline rumble stripes are typically installed in a repeating pattern shown in Figure 1 with sets of two rumbles spaced at 12" on center with each set spaced 36" on center. According to the Resident Engineer, it was determined that the centerline rumble stripes were installed in a different pattern where the rumbles were placed continuously at 12" on center as shown in Figure 2 below. This change was due to equipment availability and time constraints.
(4)

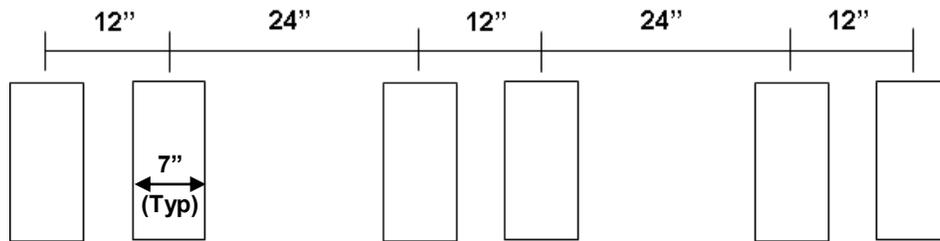


Figure 1 Standard Vermont Centerline Rumble stripe Pattern

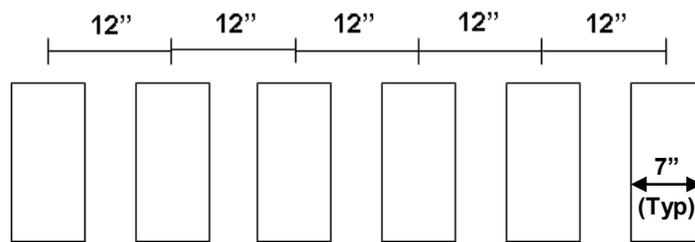


Figure 2 Altered Rumble Stripe Pattern as Placed in Cambridge-Fairfax

REPAIR

Initial Repair Method

According to the change order (#7), the contractor was to fill every third rumble along the stretch of centerline rumble stripes for approximately two miles along VT Route 104. Figure 3 shows the repair. The order also called for filling the rumbles in the shoulder rumble strip at the northern corner of the VT 104 and VT 15 intersection. Lastly, the order called for filling every rumble in the centerline stripe in front of the Boyden Farm for a distance of 75 feet.



Figure 3 Initial Repair Pattern - Patched every third rumble to approximate standard.

The anticipated cost of the repair was \$4,620.00 for the material alone. With the additional mobilization/demobilization, traffic control, mechanical grinding, crew labor, sand blasting, and flaggers, the total repair cost was \$44,190.75. (5)

Nicom Coatings Corporation of Berlin, VT was hired to complete the initial repair of the rumble stripes. The repair material used was PolyPatch, manufactured by Crafcro Inc. of

Chandler, AZ. According to the manufacturer, the product is specifically designed for cracks too large for crack sealing and distressed surfaces that are too small for repaving. It is a versatile, hot-applied, pourable, self-adhesive polymer modified asphalt binder containing selected aggregate to ensure good load bearing and skid resistant characteristics. The manufacturer claims the product is cost effective, easy to apply, lightweight, load bearing, flexible, prevents moisture penetration, and can be used in all seasons. (6)

According to the daily work comments report, the initial repair work began on Thursday, November 15, 2012. The first of attempt of filling the rumbles failed due to lack of bonding and thin edges. The second failed attempt involved heating the in-place pavement to a higher temperature. The third attempt appeared to work well which involved using angle grinders to cut vertical edges and using duct tape to mask the area to keep the hot rubber material within the limits of the rumble. The method was selected to continue the repair. The contractor repaired 232 shoulder rumbles the remainder of the first day. The remaining shoulder rumbles were filled the next day along with filling the 75-foot section of centerline rumble stripes in front of the Boyden Farm. The following Monday, November 19, 2012, the contractor attempted to install the material without vertical cut edges. It appeared that there were moisture bubbles coming through the material to the surface. Regardless of the bubbles, when the material was pulled up, stones also came up, indicating a strong bond. Although the bond appeared to be good, the Resident Engineer requested that the contractor continue the repair using the method used on the first day. Work continued though the next week, however due to slow progress, cold temperatures, and escalating costs, the decision was made by VTrans to halt the repair after 1500', of repair (about 15% of the total distance needing repair.) With slow work progress when the work was halted the cost resulted in \$42,000, almost at the total original estimated repair cost. (4)

Final Repair Method

After the difficulty and associated costs, VTrans chose a different repair method, which included removing all rumble stripes by milling the center of the roadway and repaving the milled area, as shown in Figure 4. This was completed by ST Paving and VTrans District 8 personnel during the following construction season. The repair including equipment rental, labor, pavement mix, and traffic control totaled \$61,186.29. (7) The repair was completed between August 19 and 20, 2013.



Figure 4 Roadway centerline after milling.

PERFORMANCE AND OBSERVATIONS

Research personnel along with District 8 assistance conducted Pass-by sound measurements to evaluate the rumble stripe noise. To conduct the test a passenger car, pickup truck, and one of the Districts' tandem plow trucks was used (See Figure 5). Each vehicle made four passes at 30mph, 40mph, and 50mph. For each speed, an initial pass was made within the travel lane without encountering the rumble stripe, and then three subsequent passes were made with the vehicle's wheels riding on the rumble stripe. While the vehicles were driving by, two Agency Researchers were standing 25 feet and 50 feet away from the stripes on the side of the road taking respective sound readings at each distance. In the analysis, for each speed and distance away from the rumble stripe, the three readings from the vehicle riding on the rumble stripes were averaged, and then compared to the initial reading of the vehicle within the travel lane.

This testing was conducted before the repair on October 26, 2012, after the repair on December 6, 2012, and after the winter on April 24, 2013. All sound measurements were

recorded in decibels (dB) during the testing. Readings taken on October 26, 2012 were from a pull off area along VT Route 104. Readings taken on December 6, 2012 were from the repaired section. Readings taken on April 24, 2013 were from both locations. Readings were compared to two previously constructed centerline rumble stripe projects, Mendon-Killington constructed in 2009 along US Route 4, and Sheldon-Enosburg constructed in 2010 along VT Route 105. A summary of results from the testing and comparative results are included in this report. Tables 1-4 show comparative decibel and intensity increases between projects and Tables A1-A3 in the appendix are comparative results in Cambridge from the different testing days.



Figure 5 Test Vehicles: A passenger car, a pickup truck and a district plow truck.

The increase ratio of intensity from both Mendon-Killington and Sheldon-Enosburg to Cambridge-Fairfax showed substantial differences as summarized in Table 1. The most evident difference is 121, the increase from Sheldon-Enosburg at 50 mph in a pickup truck.

According to Cutnell and Johnson (8),

“The main application of the decibel concept is for comparing two sound intensities. The simplest method of comparison would be to compute the ratio of the intensities. However, because of the way in which the human hearing mechanism responds to intensity, it is more appropriate to us a logarithmic scale for the comparison. When a sound wave reaches a listener’s ear, the sound is interpreted by the brain as loud or soft, depending on the intensity of the wave. Greater intensities give rise to louder sounds. However, the relation between intensity and loudness is not a simple proportionality, for doubling the intensity does not double the loudness. To double the loudness of a sound, the intensity must be increased by more than a factor of two. If the intensity level increases by 10 dB, the new sound seems approximately twice as loud as the original sound.”

Table 1 Intensity Increase Ratios from Previous Projects to Cambridge-Fairfax

Vehicle Type	Trial #	Speed (miles/hr)					
		30		40		50	
		25ft	50ft	25ft	50ft	25ft	50ft
Car	Mendon Killington	1	0	3	1	7	3
	Sheldon Enosburg	4	1	9	2	20	5
Pick-up Truck	Mendon Killington	9	4	9	2	27	6
	Sheldon Enosburg	11	7	24	8	121	35
Tandem Truck	Mendon Killington	1	1	1	1	1	0
	Sheldon Enosburg	5	3	5	3	6	2

Table 2 Rumble Stripe Decibel and Intensity Increase Values at 30mph.

Vehicle Type	Trial #	Speed (miles/hr)					
		30mph					
		25ft			50ft		
		Cambridge Fairfax	Mendon Killington	Sheldon Enosburg	Cambridge Fairfax	Mendon Killington	Sheldon Enosburg
Car	dB Increase	10	5	5	8	2	6
	Intensity Increase	9	3	3	6	1	4
Pickup Truck	dB Increase	15	5	4	13	5	2
	Intensity Increase	34	3	2	22	3	2
Tandem Dump Truck	dB Increase	4	4	0	4	3	-1
	Intensity Increase	3	2	1	3	2	1

Table 3 Rumble Stripe Decibel and Intensity Increase Values at 40mph.

Vehicle Type	Trial #	Speed (miles/hr) 40mph					
		25ft			50ft		
		Cambridge Fairfax	Mendon Killington	Sheldon Enosburg	Cambridge Fairfax	Mendon Killington	Sheldon Enosburg
Car	dB Increase	15	4	2	11	3	3
	Intensity Increase	32	3	2	13	2	2
Pickup Truck	dB Increase	12	6	5	11	5	2
	Intensity Increase	17	4	3	13	3	2
Tandem Dump Truck	dB Increase	5	4	1	5	3	-1
	Intensity Increase	3	2	1	3	2	1

Table 4 Rumble Stripe Decibel and Intensity Increase Values at 50mph.

Vehicle Type	Trial #	Speed (miles/hr) 50mph					
		25ft			50ft		
		Cambridge Fairfax	Mendon Killington	Sheldon Enosburg	Cambridge Fairfax	Mendon Killington	Sheldon Enosburg
Car	dB Increase	18	4	3	18	3	2
	Intensity Increase	58	3	2	63	2	2
Pickup Truck	dB Increase	17	7	4	17	9	3
	Intensity Increase	54	5	2	50	8	2
Tandem Dump Truck	dB Increase	6	3	3	7	5	2
	Intensity Increase	4	2	2	5	3	2

The United States Code of Federal Regulations 23 CFR 772, “Procedures for Abatement of Highway Traffic Noise and Construction Noise” establishes design standards for mitigating highway traffic noise. The document purposefully provides the State Highway Administrations (SHAs) with flexibility to establish their own definition of "substantial increase." A 10-dBA increase in noise levels is a doubling of the perceived loudness. A 15-dBA increase in noise levels represents more than a doubling of the loudness. Factors such as available resources, the public's attitudes toward highway traffic noise, and the absolute noise levels may influence a State's definition. The FHWA will accept a well-reasoned definition that is applied uniformly and consistently. Several SHA have evolved their definitions of what a substantial increase of noise represents. When the decibel readings in Tables A1-A3, in the appendix are compared to the Table 5, most of the increases can be described as a substantial increase in loudness.

**Table 5 Noise Abatement Criteria (NAC)
Hourly A-Weighted Sound Level in Decibels (dBA)* (10)**

Activity Category	L_{eq}(h)	L₁₀(h)	Description of Activity Category
A	57 (Exterior)	60 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (Exterior)	75 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	None	None	Undeveloped lands.
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.
* Either L _{eq} (h) or L ₁₀ (h) (But not both) may be used on a project.			
Note: These sound levels are only to be used to determine if there is impact. These are the absolute levels where abatement must be considered. Noise abatement should be designed to achieve a substantial noise reduction - not the noise abatement criteria.			
Definitions:			
L _{eq} : the equivalent steady-state sound level which in a stated period of time contains the same acoustic energy as a time-varying sound level during the same period.			
L _{eq} (h): the hourly value of L _{eq} .			
L ₁₀ : the sound level that is exceeded 10% of the time (the 90th percentile for the period under consideration).			
L ₁₀ (h): the hourly value of L ₁₀ .			

When traffic noise impacts are producing substantially higher intensity values, a SHA may choose to reference the noise abatement criteria shown in Table 5. Please note that these values are directly dependent upon the length of time the noise exists. The values in Table 5 are based on an hour-long period and the values shown in Tables A1-A2 cannot directly be compared. In future evaluations this table should be referenced if sound is monitored and collected at the noise sensitive areas.

COST ANALYSIS

The cost of the repair of the rumble stripes in Cambridge-Fairfax VT 104 was substantial. Though the initial estimates of the initial rumble patching was low, applying the patch material proved to be a highly involved process. The costs rose from \$44,190.75 for the entire project to \$42,000 for repairing critical areas and 1,500 feet of centerline stripes. Had the entire 10,311 feet been repaired, the costs were projected to increase to over \$280,000. Because of the high projected costs, the repair was abandoned. According to the data collected, the repair either marginally reduced the sound or increased the sounds substantially, depending on the vehicle and the speed of the vehicle.

The cost of the final repair method of milling and filling the rumbles was \$61,186.29. Though this proved to be a higher cost than the original estimate of the patching, it did prove to provide about \$220,000 savings over the patching had the Agency continued with that approach.

In total, the cost of placing and removing the rumbles in Cambridge-Fairfax VT Route 104 was \$127,164.74.

SUMMARY AND RECOMMENDATIONS

During construction, alternatives to specified solutions in project plans may be necessary when unforeseen hindrances arise or when advantageous technology becomes available. In the case of the Cambridge-Fairfax VT Route 104, rumble stripes were added to the project to enhance safety. The Agency supplied its current details for the rumble stripes as an amendment to the project plans. The details were subsequently modified to accommodate the equipment that was available to the contractor. This change resulted with rumble stripes that emanated measurably louder ambient sounds than what was customary from other locations throughout the state. Due to public dissatisfaction, the Agency decided to remove the stripes.

It was found that rather than patch individual rumbles, the most cost effective approach to repairing rumbles was to mill the rumbles out and then repave with new asphalt mix. Individual patching proved to be slow and more expensive. Patching did not provide an adequate solution for sound reduction. Milling and filling proved to remove the rumble pattern quickly and effectively while at the same time provide a fresh new surface in which to place a different rumble pattern.

From what has been gained from this research effort, it is recommended that rumble stripes be placed according to current Agency details, with no alternatives. Until further research provides adequate alternatives that optimize the overall reduction of ambient exterior sounds while, providing an effective interior warning indicator for the driver, the current pattern as shown in Figure 1 should not be altered.

It is also recommended that if rumble stripes are placed incorrectly or are in need of repair over long distances, that a milling and filling process is employed. Patching may prove to be effective for either small repairs or where minimal adjustments are necessary for the rumble pattern within short distances.

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APPENDIX A

Table A1 Sound Testing data near the pull off, 50' from the rumble-stripe – Unrepaired Section

Location:		Cambridge-Fairfax VT Route 104 Pull Off								
Distance from Rumble-stripe		50 feet								
Vehicle Type	Trial #	Speed (mph)								
		30			40			50		
		10/26/2012	4/24/2013	Difference	10/26/2012	4/24/2013	Difference	10/26/2012	4/24/2013	Difference
Car	Off Rumble Stripe	57	64	---	62	66	---	62	70	---
	Average On Rumbles	64.7	68.3	-3.7	73.0	74.3	-1.3	80.0	77.7	2.3
	Intensity Increase	5.8	2.7	-3.1	12.6	6.8	-5.8	63.1	5.8	-57.3
	dB Increase	7.7	4.3	-3.3	11.0	8.3	-2.7	18.0	7.7	-10.3
Pickup Truck	Off Rumble Stripe	62	65	---	68	70	---	72	75	---
	Average On Rumbles	75.3	78.7	-3.3	79.0	84.7	-5.7	89.0	91.0	-2.0
	Intensity Increase	21.5	23.3	1.7	12.6	29.3	16.7	50.1	39.8	-10.3
	dB Increase	13.3	13.7	0.3	11.0	14.7	3.7	17.0	16.0	-1.0
Tandem Dump Truck	Off Rumble Stripe	71	76	---	73	76	---	74	79	---
	Average On Rumbles	75.5	83.5	-8.0	77.5	88.0	-10.5	81.3	93.7	-12.3
	Intensity Increase	1.1	1.8	0.7	2.8	15.8	13.0	5.4	29.3	23.9
	dB Increase	0.5	2.5	2.0	4.5	12.0	7.5	7.3	14.7	7.3

Table A2 Sound Testing data near Boyden Valley Winery, 25' from the rumble-stripe – Repaired Section

Location:		Cambridge-Fairfax VT Route 104 Winery								
Distance from Rumble-stripe		25 feet								
Vehicle Type	Trial #	Speed (mph)								
		30			40			50		
		12/6/2012	4/24/2013	Difference	12/6/2012	4/24/2013	Difference	12/6/2012	4/24/2013	Difference
Car	Off Rumble Stripe	67	69	---	71	70	---	75	74	---
	Average On Rumbles	78.0	73.0	5.0	83.3	76.7	6.7	86.7	80.0	6.7
	Intensity Increase	12.6	2.5	-10.1	17.1	4.6	-12.5	14.7	4.0	-10.7
	dB Increase	11.0	4.0	-7.0	12.3	6.7	-5.7	11.7	6.0	-5.7
Pickup Truck	Off Rumble Stripe	73	70	---	79	74	---	80	77	---
	Average On Rumbles	86.0	81.3	4.7	87.7	84.7	3.0	93.0	91.0	2.0
	Intensity Increase	20.0	13.6	-6.4	7.4	11.7	4.3	20.0	25.1	5.2
	dB Increase	13.0	11.3	-1.7	8.7	10.7	2.0	13.0	14.0	1.0
Tandem Dump Truck	Off Rumble Stripe	85	79	---	86	81	---	88	83	---
	Average On Rumbles	90.0	84.0	6.0	93.0	89.3	3.7	97.3	92.3	5.0
	Intensity Increase	3.2	3.2	0.0	5.0	6.8	1.8	8.6	8.6	0.0
	dB Increase	5.0	5.0	0.0	7.0	8.3	1.3	9.3	9.3	0.0

Table A3 Sound Testing data near Boyden Valley Winery, 50' from the rumble-stripe – Repaired Section

Location:		Cambridge-Fairfax VT Route 104 Winery								
Distance from Rumble-stripe		50 feet								
Vehicle Type	Trial #	Speed (mph)								
		30			40			50		
		12/6/12	4/24/13	Difference	12/6/12	4/24/13	Difference	12/6/12	4/24/13	Difference
Car	Off Rumble Stripe	67	67	---	71	65	---	75	68	---
	Average On Rumbles	78.0	78.7	-0.7	83.3	73.3	10.0	86.7	77.3	9.3
	Intensity Increase	12.6	14.7	2.1	17.1	6.8	-10.3	14.7	8.6	-6.1
	dB Increase	11.0	11.7	0.7	12.3	8.3	-4.0	11.7	9.3	-2.3
Pickup Truck	Off Rumble Stripe	73	67	---	79	70	---	80	74	---
	Average On Rumbles	86.0	78.7	7.3	87.7	82.7	5.0	93.0	89.0	4.0
	Intensity Increase	20.0	14.7	-5.3	7.4	18.5	11.1	20.0	31.6	11.7
	dB Increase	13.0	11.7	-1.3	8.7	12.7	4.0	13.0	15.0	2.0
Tandem Dump Truck	Off Rumble Stripe	85	76	---	86	78	---	88	81	---
	Average On Rumbles	90.0	79.5	10.5	93.0	86.3	6.7	97.3	91.0	6.3
	Intensity Increase	3.2	0.6	-2.6	5.0	6.8	1.8	8.6	10.0	1.4
	dB Increase	5.0	3.5	-1.5	7.0	8.3	1.3	9.3	10.0	0.7

APPENDIX B

Project Change Orders related to Centerline Rumble Stripes.

- Change Order #04 – Adding Centerline Rumble Stripes to Project
- Change Order #07 – Using PolyPatch to Patch Every Third Rumble

Vermont
Agency of Transportation
CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401
Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)
Change Order: 004 SUPPLEMENTAL AGREEMENT

Date: 08/06/2012

Extra Work Order: Y

TO: PIKE INDUSTRIES, INCORPORATED- You are hereby notified to perform the following work in accordance with the Provisions of your Contract with the Agency of Transportation dated **11/08/2011** and as modified by this document and in accordance with the 2006 Standard Specifications for Highway and Bridge Construction and Supplements thereto.

REVISION: Introduction of the following items to the Contract; 213.10 - Milled Rumbled Strips, 635.11 - Mobilization/Demobilization (Rumble Strip Work), 641.10 - Traffic Control (Rumble Strip Work), 675.20 - Traffic Signs, Type A (Rumble Strip Signs) and 675.341 - Square Tube Sign Post and Anchor (Rumble Strip Signs).

NECESSITY FOR REVISION: Per the recommendation of the Highway & Traffic Safety Section, milled rumbled strips were installed on the project in order to modify the alignment of the VT Rte 15 & VT Rte 104 intersection so that VT Rte 104 becomes more perpendicular to VT Rte 15. This in theory will provide a safer intersection. In addition to the milled rumble strips, advance warning signage and modified lane markings were also used.

One (1) additional day was requested for this extra work, resulting in an adjusted Contract Completion Date of 8/11/12.

This change order received verbal approval from, Project Manager, **Mike Fowler** on **06/22/2012**.
 This change order received verbal approval from, Federal Highway Administrator, **N/A** on **N/A**.

NEW ITEMS NOT IN CONTRACT: Item 213.10 - Milled Rumble Strips at Zero Dollars and Forty Five Cents (\$0.45) per Linear Foot (LF). Item 635.11 - Mobilization/Demobilization (Rumble Strip Work) at Fifteen Thousand Dollars and Zero Cents (\$15,000.00) per Lump Sum (LS). Item 641.10 - Traffic Control (Rumble Strip Work) at Two Thousand Dollars and Zero Cents (\$2,000.00) per Lump Sum (LS). Item 675.20 - Traffic Signs, Type A (Rumble Strip Signs) at Seventeen Dollars and Fifty Cents (\$17.50) per Square Foot (SF). Item 675.341 - Square Tube Sign Post and Anchor at Eleven Dollars and Fifty Cents (\$11.50) per Linear Foot (LF). These unit prices are full and final compensation for all specialized equipment, materials, labor, tools, and any incidentals required to perform this extra work to the satisfaction of the Engineer. A time extension was granted for this extra work and the Adjusted Contract Completion date is 8/11/12.

QUANTITY AND COSTS AS PER PLANS AND/OR REVISIONS											
Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)											
Sub Item	Line Nbr	Catg	Item Code	Unit	Unit Price	Current Qty	CO Qty	Revised Qty	Current Price	CO Price	Revised Price
	9010	1011	213.10	LF	\$0.45	0.000	10,311.000	10,311.000	\$0.00	\$4,639.95	\$4,639.95
Description: MILLED RUMBLE STRIPS (VT 15 & VT 104)											
	9015	1011	635.11	LS	\$15,000.00	0.000	1.000	1.000	\$0.00	\$15,000.00	\$15,000.00
Description: MOBILIZATION/DEMobilIZATION (Rumble Strip Work)											

Vermont
 Agency of Transportation
 CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401
Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)
Change Order: 004 SUPPLEMENTAL AGREEMENT

Date: 08/06/2012

Extra Work Order: Y

	9020	1011	641.10	LS	\$2,000.00	0.000	1.000	1.000	\$0.00	\$2,000.00	\$2,000.00
Description: TRAFFIC CONTROL (Rumble Strip Work)											
	9025	1011	675.20	SF	\$17.50	0.000	39.000	39.000	\$0.00	\$682.50	\$682.50
Description: TRAFFIC SIGNS, TYPE A (Rumble Strip Signs)											
	9030	1011	675.341	LF	\$11.50	0.000	144.000	144.000	\$0.00	\$1,656.00	\$1,656.00
Description: SQUARE TUBE SIGN POST AND ANCHOR (Rumble Strip Signs)											
Totals:									\$0.00	\$23,978.45	\$23,978.45

Additional Cost: \$23,978.45 **Contract Extension Granted:** Y
Original Contract Amount: \$2,588,064.75
Revised Contract Amount: \$2,635,875.70

New Completion Date: 08/11/2012

Vermont
Agency of Transportation
CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401
 Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)
 Change Order: 004 SUPPLEMENTAL AGREEMENT

Date: 08/06/2012

Extra Work Order: Y

Change Order Approved:			
PIKE INDUSTRIES, INCORPORATED		<i>WILLIAM J. ROCHON</i>	<i>[Signature]</i> 8/26/12
Contractor		Authorized Individual (Printed)	Signature of Authorized Individual / Date
Recommended for Approval:			
Delvin Warner	Al Campo	David Hoyne	Richard Tetreault
Resident Engineer	Regional Construction Engineer	Construction Engineer	Director of Program Development
Date: 08/14/2012	Date: 08/15/2012	Date: 08/21/2012	Date: 08/21/2012

Approved for Federal Participation	
N/A	
Division Administrator, FHWA	
Date:	

Vermont
Agency of Transportation
CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401
Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)
Change Order: 007 SUPPLEMENTAL AGREEMENT

Date: 10/26/2012

Extra Work Order: Y

TO: PIKE INDUSTRIES, INCORPORATED- You are hereby notified to perform the following work in accordance with the Provisions of your Contract with the Agency of Transportation dated **11/08/2011** and as modified by this document and in accordance with the 2006 Standard Specifications for Highway and Bridge Construction and Supplements thereto.

REVISION: Introduction of the following Items to the Contract; 900.530 - Supplemental Agreement (Mobilization/Demobilization) (Rumble Strip Repairs), 900.530 - Supplemental Agreement (Traffic Control) (Rumble Strip Repairs), 900.525 - Supplemental Agreement (PolyPatch Material) (Rumble Strip Repairs), 900.530 - Supplemental Agreement (Mechanical Grinding) (Rumble Strip Repairs), 900.530 - Supplemental Agreement (PolyPatch Crew Labor) (Rumble Strip Repairs), 900.530 - Supplemental Agreement (Sand Blasting) (Rumble Strip Repairs), and 630.15 - Flaggers (Rumble Strip Repairs).

NECESSITY FOR REVISION: The rumble strips installed as part of Change of Design/Supplemental Agreement No. 4 did not include the proper spacing for a centerline application. The rumble strip spacing as installed was for use on the shoulders of a roadway and not along the centerline of a roadway. As a result, excessive noise complaints were received immediately after installation and corrective measures were required.

The corrective measures developed involve the following:

Filling every third (3rd) rumble strip along a two-mile stretch of VT Rte 104 heading west from the intersection of VT Rte 15 to approximately STA 103+00 +/- on VT Rte 104 in the Town of Cambridge.

Filling every shoulder rumble strip at the northern corner of intersection of VT Rte 15 and VT Rte 104 West.

Filling every centerline rumble strip in front of the Boyden Farm for a distance of 75 feet from the intersection of VT Rte 15 and VT Rte 104 heading toward Fairfax.

This change order received verbal approval from, Project Manager, **Mike Fowler** on **10/22/2012**.

This change order received verbal approval from, Federal Highway Administrator, **N/A** on **N/A**.

NEW ITEMS NOT IN CONTRACT: Item 900.530 - Supplemental Agreement (Mobilization/Demobilization) (Rumble Strip Repairs) at Ninety Dollars and Zero Cents (\$90.00) per Hour (HR), Item 900.530 - Supplemental Agreement (Traffic Control) (Rumble Strip Repairs) at One Hundred Dollars and Zero Cents (\$100.00) per Hour (HR), 900.525 - Supplemental Agreement (PolyPatch Material) (Rumble Strip Repairs) at Twenty Eight Dollars and Twenty Five Cents (\$28.25) per Gallon (GAL), 900.530 - Supplemental Agreement (Mechanical Grinding) (Rumble Strip Repairs) at Two Hundred Ten Dollars and Zero Cents (\$210.00) per Hour (HR), 900.530 - Supplemental Agreement (PolyPatch Crew Labor) (Rumble Strip Repairs) at Three Hundred Seventy Dollars and Zero Cents (\$370.00) per Hour (HR), 900.530 - Supplemental Agreement (Sand Blasting) (Rumble Strip Repairs) at Four Hundred Twenty Five Dollars and Zero Cents (\$425.00) per Hour (HR), and 630.15 - Flaggers (Rumble Strip Repairs) at Thirty Dollars and Zero Cents (\$30.00) per Hour (HR). These unit prices are full and final compensation for the extra work described above, including all materials, equipment, labor, tools, and any incidentals required to complete the added work to the satisfaction of the Engineer. No additional time has been granted as part of this agreement.

Vermont
Agency of Transportation
CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401

Date: 10/26/2012

Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)

Change Order: 007 SUPPLEMENTAL AGREEMENT

Extra Work Order: Y

QUANTITY AND COSTS AS PER PLANS AND/OR REVISIONS											
Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)											
Sub Item	Line Nbr	Catg	Item Code	Unit	Unit Price	Current Qty	CO Qty	Revised Qty	Current Price	CO Price	Revised Price
	9035	1011	900.530	HR	\$90.00	0.000	49.000	49.000	\$0.00	\$4,410.00	\$4,410.00
Description: SUPPLEMENTAL AGREEMENT (Mobilization/Demobilization) (Rumble Strip Repair)											
	9040	1011	900.530	HR	\$100.00	0.000	45.000	45.000	\$0.00	\$4,500.00	\$4,500.00
Description: SUPPLEMENTAL AGREEMENT (Traffic Control) (Rumble Strip Repairs)											
	9045	1011	900.525	GAL	\$28.25	0.000	51.000	51.000	\$0.00	\$1,440.75	\$1,440.75
Description: SUPPLEMENTAL AGREEMENT (PolyPatch Material) (Rumble Strip Repairs)											
	9050	1011	900.530	HR	\$210.00	0.000	22.000	22.000	\$0.00	\$4,620.00	\$4,620.00
Description: SUPPLEMENTAL AGREEMENT (Mechanical Grinding) (Rumble Strip Repairs)											
	9055	1011	900.530	HR	\$370.00	0.000	43.000	43.000	\$0.00	\$15,910.00	\$15,910.00
Description: SUPPLEMENTAL AGREEMENT (PolyPatch Crew Labor) (Rumble Strip Repairs)											
	9060	1011	900.530	HR	\$425.00	0.000	22.000	22.000	\$0.00	\$9,350.00	\$9,350.00
Description: SUPPLEMENTAL AGREEMENT (Sand Blasting) (Rumble Strip Repairs)											
	9065	1011	630.15	HR	\$30.00	0.000	132.000	132.000	\$0.00	\$3,960.00	\$3,960.00
Description: FLAGGERS (Rumble Strip Repairs)											
Totals:									\$0.00	\$44,190.75	\$44,190.75

Additional Cost: \$44,190.75

Contract Extension Granted: N

New Completion Date:

Original Contract Amount: \$2,588,064.75

Revised Contract Amount: \$3,069,695.08

Vermont
 Agency of Transportation
 CHANGE OF DESIGN or CONSTRUCTION

Contract ID: 11101401
 Project Name: CAMBRIDGE-FAIRFAX STP 2713(1)
 Change Order: 007 SUPPLEMENTAL AGREEMENT

Date: 10/26/2012

Extra Work Order: Y

Change Order Approved:			
PIKE INDUSTRIES, INCORPORATED		<i>[Signature]</i> 1-28-2013	
Contractor		Authorized Individual (Printed)	
Signature of Authorized Individual / Date			
Recommended for Approval:			
Delvin Warner	Al Campo	David Hoyne	N/A
Resident Engineer	Regional Construction Engineer	Construction Engineer	Director of Program Development
Date: 12/04/2012	Date: 12/12/2012	Date: 12/13/2012	Date:

Approved for Federal Participation	
N/A	
Division Administrator, FHWA	
Date:	