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14. Supplementary Notes

15. Abstract

Purpose and Need

Water on the surface of pavement markings typically reduces the marking's retroreflectivity and may cause pavement markings to become nearly invisible during wet conditions at night. Water on the surface of pavement markings reflects light away from its source and doesn't allow the beads in the pavement marking to reflect light back towards its source. This condition is referred to as "wet-night" and the retroreflectivity during this condition is referred to as "wet-night retroreflectivity". To improve a marking's wet-night retroreflectivity, some states have experimented with placing markings on rumble strips. This may improve wet-night retroreflectivity by providing a slanted surface that quickly drains water off the surface of the marking. The placement of pavement markings on rumble strips has been referred to as "rumble stripes".

Objective

The objective is to determine if placing pavement markings on rumble strips will improve the marking's wet-night retroreflectivity.

Scope

To test the effectiveness of rumble stripes, the NDDOT has constructed a test section as part of project AC-NH-2-281(025)049. This project was a rehabilitation of a two-lane US Highway that serves as an interregional corridor across North Dakota. The rehabilitation consisted of a new asphalt surface constructed on a blended base. The entire project had rumble strips ground into both shoulders. A three mile test section was selected by the Valley City District. The test section was constructed using a modified location of the rumble strips on both shoulders. The edge lines were placed on the rumble strips.

Summary

The position of the markings on the rumble strip doesn't appear to greatly affect the day-time appearance of the marking. The application of marking paint on incompletely cured fog seal material may have caused adhesion and durability problems. Materials and Research personnel have observed that rumble stripes appear to have better visibility than the usual edge marking in both wet and dry conditions. Comments collected from Jamestown Section personnel support Materials and Research observations. Wet-night retroreflectivity readings were mostly inconclusive in showing improvement in retroreflectivity. Further research is needed to make definite statements based on retroreflective data.

It is recommended to further evaluate rumble stripes by placing markings within the rumble strips of an existing roadway. This could be used to do a side-by-side comparison of rumble stripes with the usual edge markings and to evaluate if this configuration may be used on existing roadways. Chip seal projects are a good opportunity to install the replacement edge line striping in a rumble strip, thereby creating a rumble stripe.

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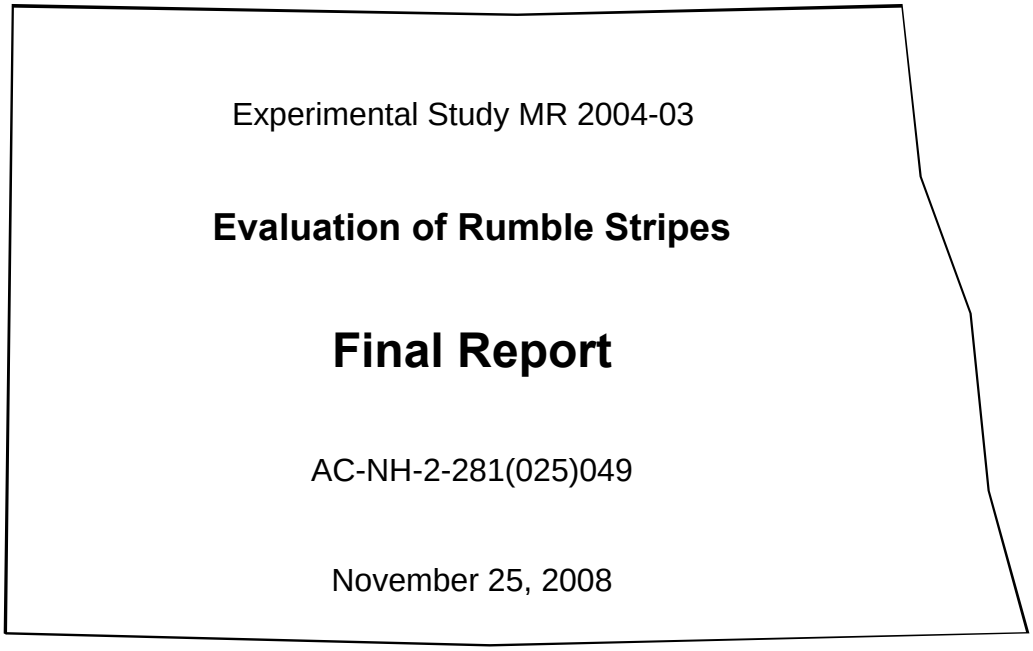
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study MR 2004-03

Evaluation of Rumble Stripes

Final Report

AC-NH-2-281(025)049

November 25, 2008

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Location

Project AC-NH-2-281(025)049 is located on US 281 south of Jamestown and is classified as an interregional corridor. The project limits were from RP 49.707 to RP 66.860. The test section is from RP 59.8803 to RP 62.8832. The location of the project and the test section is shown in Figure 1.

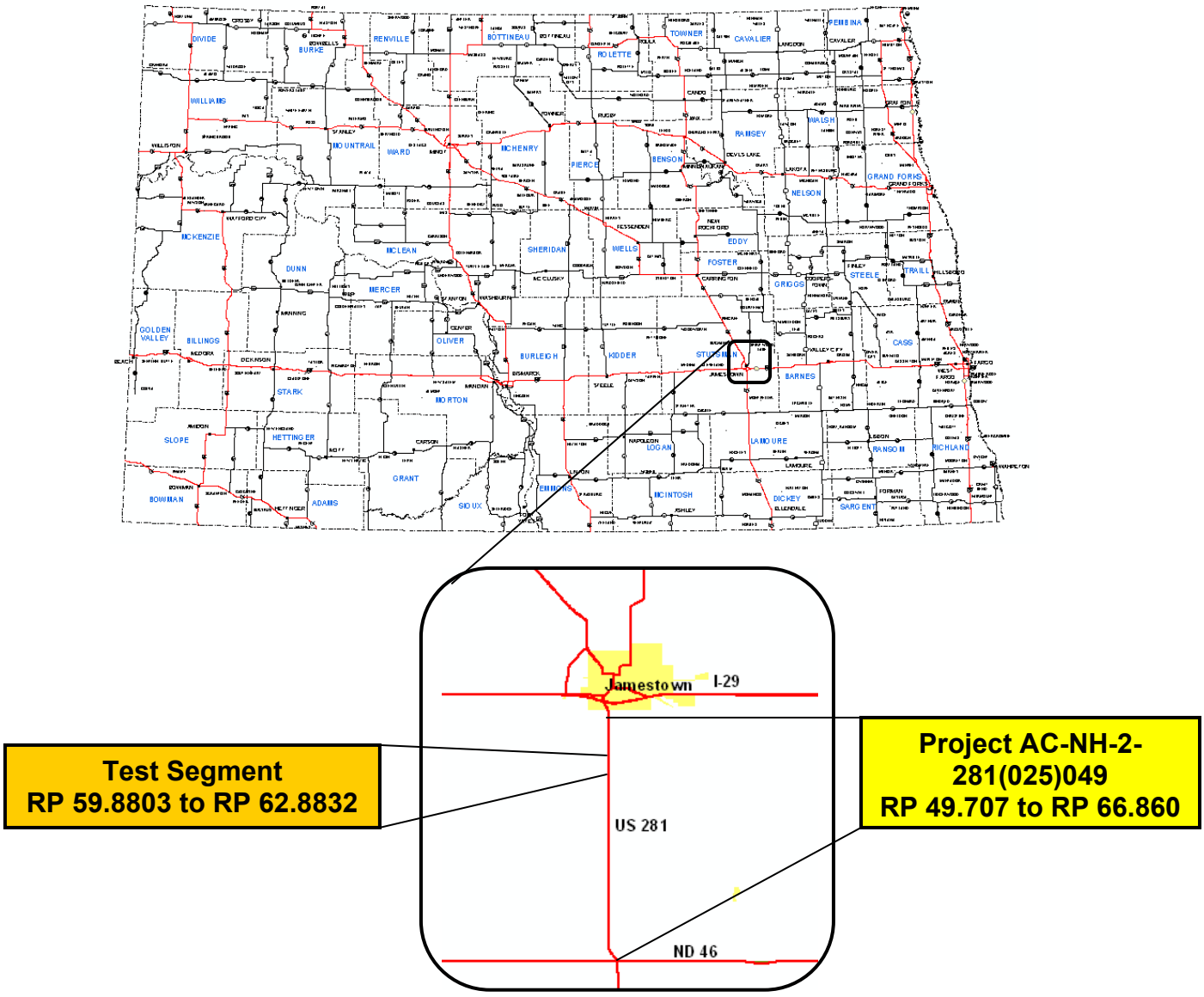

Figure 1 – Location of project and test section.

Traffic

Table 1 shows the one-way traffic used for the design of Project AC-NH-2-281(025)049.

Year	Passenger Cars	Trucks	Total	Max Hour
1998	1,945	265	2,210	225

Table 1

Design

To produce the rumble stripe section, each rumble strip was moved 6” closer to the centerline than it is typically placed, and each edge line was moved 6” further away from centerline. A drawing of the section is provided in Figure 2.

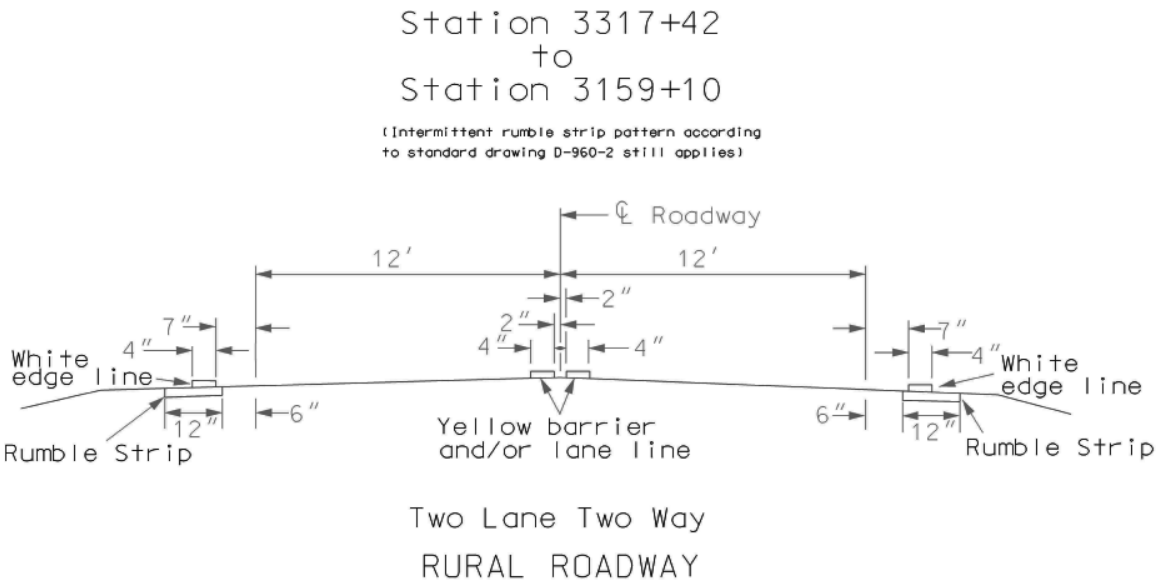

Figure 2 – Drawing of the placement of edge lines and rumble strips in the test section.

Construction

The rumble strips were ground on August 22, 2004. The first rumble strips ground on the project were the northbound rumble strips of the test section. Approximately 8,000’ of the northbound portion of the test section were constructed with continuous rumble strips. The rest of the test section consisted of intermittent rumble strips. Intermittent rumble strips have a 10’ break for every 40’ of rumble strips.

On the same day that the rumble strips were ground, they were fog sealed with an emulsified asphalt. The fog seal was sprayed continuously, over both the rumble strips and the intermittent area.

On August 23, 2004 a second layer of fog seal was observed being placed on the rumble strips in the experimental section. Later that day, water-based pavement markings, with glass beads for retroreflectivity, were applied. Photo 1 shows the completed test section.

Photo 1 – Completed test section.

First Evaluation

Materials and Research personnel evaluated the completed test section in the daylight on September 2, 2004. The change in location of the edge line did not appear to be a distraction. The edge line showed up well and its appearance wasn't much different from any other edge line. On closer inspection, some isolated spots of thick fog seal had bled through to the surface of the water-based paint, see Photo 2. On later inspections, these areas appeared to be cracking and some pieces of paint had flaked-off, indicating a failure of the pavement marking to bond to the pavement surface. This appeared to occur only in the areas with unusually thick fog seal material, see Photo 3.

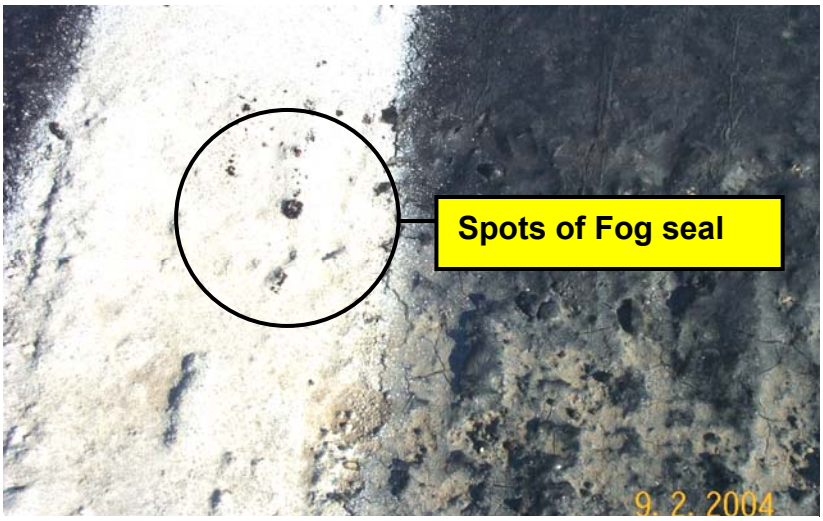

Photo 2 – Spot of fog seal that bled through to the surface of the marking.

Photo 3 – Area of thick fog seal with paint flaking-off.

Wet-night retroreflectivity readings were taken, during daylight hours, on October 4, 2004, following ASTM E-2177 “Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness”. This two-part test is performed by taking initial retroreflectivity readings on dry markings. Then, the markings are sprayed with water, and retroreflectivity readings are taken again on the wet markings.

Wet-night retroreflectivity readings were taken at four test areas. Three of the test areas were in the intermittent rumble strip section, and one was in the continuous rumble strip section. Readings were taken on a rumble stripe and on a nearby flat marking for comparison. Readings taken on the rumble stripe were taken approximately 1" apart to determine if retroreflectivity varied with the markings position in the milled groove of the rumble strip. For the first three test areas, flat readings were taken in the 10' space in-between intermittent rumble strips. For the fourth test area, flat readings were taken in the control section immediately to the south of the continuous rumble strips.

There were no obvious patterns to the variations in retroreflectivity readings of the rumble stripes, and no area of the rumble stripe appeared to have unusually high retroreflectivity. The average readings of the test areas, and the percent of retroreflectivity retained when wet, are shown in the following table.

Location Number	Rumble Stripe			Flat Marking		
	Dry We	t	Retroreflectivity Retained	Dry We	t	Retroreflectivity Retained
1	314.3	70.6	22.5%	332.2	53.2	16.0%
2	375.0	77.7	20.7%	398.2	98.8	24.8%
3	373.1	86.4	23.2%	356.0	45.2	12.7%
4	302.2	110.4	36.5%	258.2	29.8	11.5%
Average	341.2	86.3	25.7%	336.2	56.8	16.3%

Table 2

Second Evaluation

The test section was observed again on April 13, 2005. The marking paint was peeling away from the rumble stripes in both the grind and non-grind areas. It is a possibility that the fog seal was not fully cured when the pavement marking was placed. As noted in the first evaluation, the bond of the pavement marking immediately failed in areas of thick fog seal. Photos 4 and 5 show that the most extensive failure, to date, is located in the non-grind areas. The most likely explanation is that the entire marking is suffering from an unsatisfactory bond; and when combined with the abrasiveness of

snow plow activity, the pavement marking is detaching from the surface. The markings in the control section and the centerline skips, both of which did not receive a second fog seal, were much more intact.

Photo 4 – A "rumble stripe" with peeling pavement marking.

Photo 5 - -An overview of the "rumble stripes".

Dry retroreflectivity readings were taken on June 21, 2005. The average of the readings taken in the test section was 152. The average retroreflectivity reading from the flat areas within the test section was 197. The average from within the control section was 202.

The test section was visually observed in a dry condition on the night of March 24, 2005, and in a wet condition in the early-morning hours of November 19th, 2005. In

both conditions, rumble stripes appeared more retroreflective than flat markings in the control section and the 10' space in between intermittent rumble strips. Jamestown Section personnel report that the rumble stripes appear to have better visibility than the typical edge marking in wet and dry conditions.

Final Evaluation

In the summer of 2007, a chip seal project on US 281 went through the rumble stripe research section. A mistake was made during construction that resulted in the obliteration of the rumble stripes. When the striping crew came to re-stripe the roadway following the chip seal in the driving lanes, they thought the rumble stripes were a mistake and moved the edge lines inside the rumble strips. Then the shoulders and rumble strips were fog sealed, obliterating the original striping through the rumble strips, effectively ending the research project.

Summary & Recommendations

The position of the markings on the rumble strip doesn't appear to greatly affect the day-time appearance of the marking. The application of marking paint on incompletely cured fog seal material may have caused adhesion and durability problems. Materials and Research personnel have observed that rumble stripes appear to have better visibility than the usual edge marking in both wet and dry conditions. Comments collected from Jamestown Section personnel support Materials and Research observations. Wet-night retroreflectivity readings were mostly inconclusive in showing improvement in retroreflectivity. Further research is needed to make definite statements based on retroreflective data.

It is recommended to further evaluate rumble stripes by placing markings within the rumble strips of an existing roadway. This could be used to do a side-by-side comparison of rumble stripes with the usual edge markings and to evaluate if this configuration may be used on existing roadways. Chip seal projects are a good opportunity to install the replacement edge line striping in a rumble strip, thereby creating a rumble stripe.