Seal Coat and Rumble Strip Guidelines

Predicting Rumble Strip Noise Performance

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INTRODUCTION

The application of seal coat, or chip seal, on pavements will partially fill existing rumble strips (Figure 1) and can reduce the performance of rumble strips to alert drivers of possible lane departure. If the reduction is severe enough, the seal coat treatment can undermine the ability of the rumble strip to serve its intended function (*1*).

Figure 1. Rumble Strip before and after a Seal Coat Application.

In TxDOT research project 0-7029, the research team at the Texas A&M Transportation Institute investigated the impact of sequential seal coats, seal coat grade type, and other factors on rumble strip performance. The key recommendations from of the study, presented in this document, can guide TxDOT engineers about whether seal coat should be placed over an existing rumble strip.

DESIRED NOISE PERFORMANCE

Rumble strips function by generating noise and vibration inside the vehicle, and it is primarily noise that elicits driver response. More specifically, the noise performance of a rumble strip is the <u>change</u> in noise when driving in the wheel path to driving over the rumble strip. Noise level is measured in decibels which is a logarithmic scaling of sound pressure. A change of 5 or 6 dB is clearly perceptible, and an increase of 10 dB by most listeners is “twice as loud” (*2*). Consequently, the research defined an increase in noise level more than 10 dB as high performance, from 6 to 10 dB as moderate, and less than 6 dB as low performance (Table 1). Note, however, that these thresholds are based on general perception and not actual safety or driver behavior data.

Rumble strips also produce a distinct change in the noise pitch or frequency, which is not captured in the noise level calculation. In practice, the change in pitch also plays a significant role in rumble strip effectiveness. The models shown later in the guidelines predict a custom noise performance score that also accounts for the change in pitch, still in units of dB. The data were scaled so that the same thresholds of 6 dB and 10 dB could be used.

Table 1. Performance Thresholds.

Noise Performance Score, dB	Performance Rating
≥ 10	High
≥ 6 and <10	Moderate
>6	Low

QUICK RULES

The following are quick rules of thumb, supported by the research findings, for making decisions about applying seal coat over rumble strips. The details in the next section are better applied on a case-by-case scenario.

1. The number of seal coats covering a rumble strip, alone, is a poor indicator of noise performance. Rather, the best predictor is knowing the noise performance before the new seal coat.
2. If the existing noise performance is Δ15 dB and the depth is 0.5 inches or greater, it is acceptable to seal over the rumble strip.
3. It is acceptable to seal over a rumble strip milled into either asphalt or seal coat if using Grade 4 or 5. Using a Grade 3 seal requires more information.
4. Do not apply seal coat over an already covered rumble strip without first checking the performance using the Level I or II models (below). Otherwise, the agency should plan to reinstall or avoid covering the rumble strip.
5. Districts that typically use Grade 3 seal coats could consider installing new rumble strips deeper (5/8 inches) to avoid needing to reinstall rumble strips as often, or apply Grade 4 seal coat on the shoulders and/or lanes instead.

PREDICTING RUMBLE STRIP PERFORMANCE

The tools in this document can help TxDOT engineers decide when it is acceptable to apply a seal coat over an existing rumble strip. Three models (equations) for predicting the noise performance of a rumble strip after seal coat are shown in Table 2. The models have different levels of accuracy depending on what data the engineer can collect.

- **Level I.** Highest accuracy. Requires two field measurements: noise performance *before* the seal coat, and rumble strip depth.
- **Level II.** Moderate accuracy. Only field measurement needed is rumble strip depth.
- **Level III.** Low accuracy. No field measurements needed.

All models include the seal coat grade type and the speed limit.

For design purposes, the models include a one-tailed prediction interval at 75 and 95 percent confidence to better ensure that the rumble strip performance will be above the design thresholds in Table 1. Using a 75 percent interval means that the actual rumble strip performance value will be greater than or equal the calculated value 75 percent of the time. Also note that the higher accuracy models have tighter prediction intervals, and therefore, will not be overly conservative. The 75 percent prediction confidence is recommended for general purpose designs. For critical infrastructure, for high accident locations, or for a more conservative design, 95percent can be used.

Table 2. Summary of Design-Focused Rumble Strip Performance Prediction Models.

Model	$\boldsymbol{Noise\ Performance\ Score_{AfterSC}} =$
Level I	$5.56 + 0.39 \times \Delta Noise_{BeforeSC} + 4.86 \times Depth_{RS} + \begin{cases} -1.16 & if\ Grade\ 3 \\ -0.01 & if\ Grade\ 4 \\ 1.17 & if\ Grade\ 5 \end{cases} - 0.082 \times SpeedLimit - \begin{cases} 0 & if\ 50\%\ (Average) \\ \mathbf{1.25} & \boldsymbol{if\ 75\%\ (Recommended)} \\ 3.06 & if\ 95\%\ (Conservative) \end{cases}$ (Prediction Confidence)
Level II	$11.02 + 9.06 \times Depth_{RS} + \begin{cases} +0.91 & if\ Asphalt \\ -0.91 & if\ Seal\ coat \end{cases} + \begin{cases} -1.40 & if\ Grade\ 3 \\ -0.27 & if\ Grade\ 4 \\ 1.66 & if\ Grade\ 5 \end{cases} - 0.125 \times SpeedLimit - \begin{cases} 0 & if\ 50\%\ (Average) \\ \mathbf{1.34} & \boldsymbol{if\ 75\%\ (Recommended)} \\ 3.28 & if\ 95\%\ (Conservative) \end{cases}$
Level III	$14.30 + \begin{cases} 0.83 & if\ Asphalt \\ 0.41 & if\ Seal\ Coat, RS\ not\ covered \\ -1.24 & if\ Seal\ Coat, RS\ covered \end{cases} + \begin{cases} -1.66 & if\ Grade\ 3 \\ -0.23 & if\ Grade\ 4 \\ 1.88 & if\ Grade\ 5 \end{cases} - 0.109 \times SpeedLimit - \begin{cases} 0 & if\ 50\%\ (Average) \\ \mathbf{1.57} & \boldsymbol{if\ 75\%\ (Recommended)} \\ 3.84 & if\ 95\%\ (Conservative) \end{cases}$

where $\Delta Noise_{BeforeSC}$ = Change in overall noise level (rumble strip – wheel path) before seal coat, dBA

$Depth_{RS}$ = Rumble strip depth before seal coat, inches

The Level I through Level III models are illustrated in Figure 2 through Figure 4, respectively. Details on how to measure rumble strip noise performance ($\Delta Noise_{BeforeSC}$) and rumble strip depth ($Depth_{RS}$) are discussed after the figures.

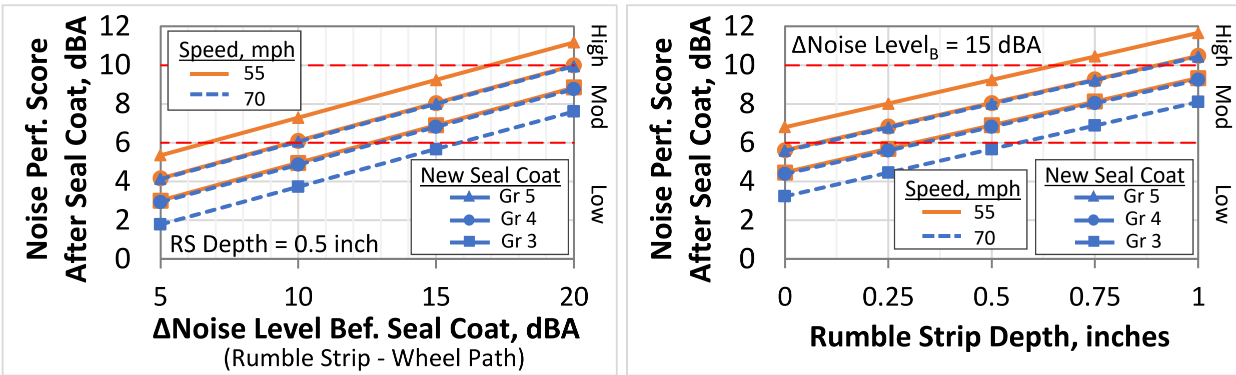

Figure 2. Level I Prediction Model @ 75% Prediction Confidence. (Highest Accuracy, R^2 = 0.72).

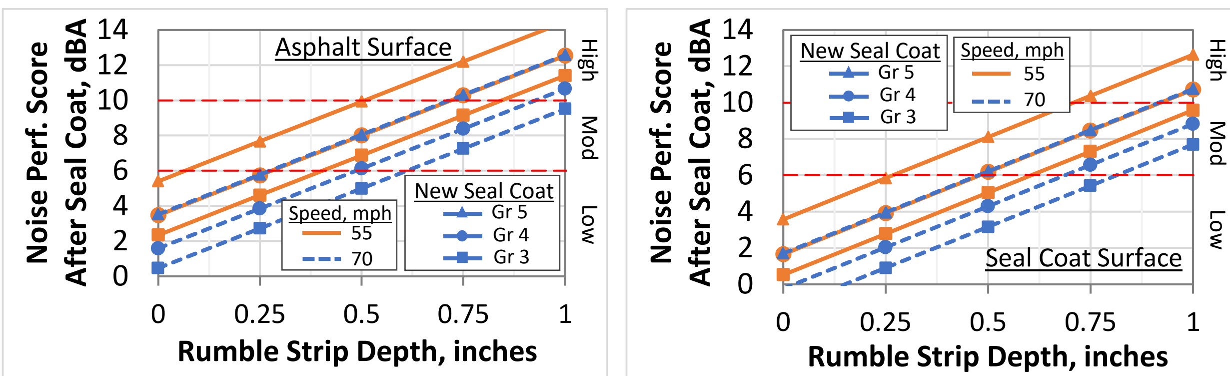

Figure 3. Level II Prediction Model @ 75% Prediction Confidence (Moderate Accuracy, R^2 = 0.53).

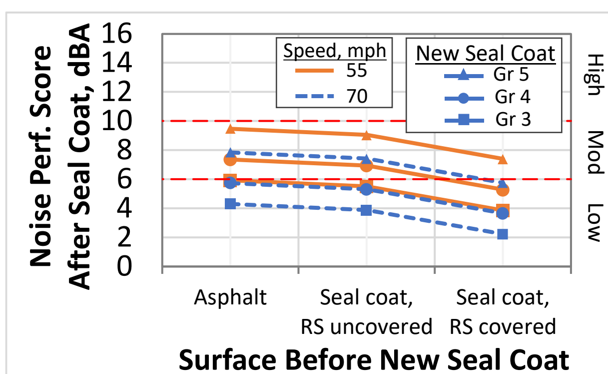

Figure 4. Level III Prediction Model @ 75% Prediction Confidence (Low Accuracy, R^2 = 0.33).

HOW TO MEASURE

Noise Performance

Equipment/Personnel:

- Noise level meter (ANSI Class II or better) with data logging capabilities.
- One driver and one equipment operator recommended on roadways with high traffic volumes and when testing centerline rumble strips.

Method:

1. Identify a 1000-ft roadway segment that is straight, relatively flat, and has a continuous rumble strip (i.e., no drive-way gaps).
2. If testing centerline rumble strips, ample sight distance and low traffic volumes are necessary for safety, otherwise testing should not be performed.
3. Enable A-weighted filtering on the noise level meter and set the device to measure in a time-average mode.
4. Position the meter in the center of the passenger cabin at head-height.
5. Maintain the desired driving speed using the cruise control. Traffic should be free-flowing and not overly crowded.
6. Measure noise in the wheel path for a minimum of 5 seconds.
7. Position one set of tires over the rumble strip, and make another measurement for a minimum of 5 seconds.
8. Calculated rumble strip performance using Equation 1:

$$\Delta L_{eq} = L_{eq,Rumble\ strip} - L_{eq,Wheel\ path} \quad (1)$$

where L_{eq} = Equivalent continuous sound level, or overall sound level. May be labeled L_{Aeq}. (A-weighted decibel, dBA).

Rumble Strip Depth

Equipment/Personnel:

- Option 1: Straight edge (24 or 36-inch length) and measuring tape.
- Option 2: Contour gage (10-inch minimum) (Figure 5) and measuring template.
- Based on conditions, have a spotter for added safety.

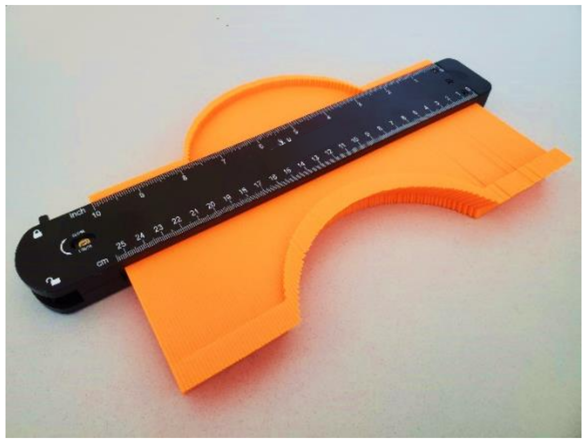

Figure 5. Contour Gage.

Method:

1. Option 1: Place straightedge across the length of the rumble strip, and measure depth from the bottom of the trough to the straightedge. Measure to nearest 1/8 inch.
2. Option 2: Place contour gage into trough lengthwise to capture the trough shape. Using grid paper or similar template, measure distance from the contoured pavement surface to bottom of trough. Measure to nearest 1/8 inch.
3. If the depth across the width of the rumble strip varies, approximate where the average depth is located and take measurement there.
4. Measure three rumble strip troughs and calculate the average depth.

WHEN NOISE PERFORMANCE IS COMPROMISED

If performance will drop below 6 dB based on a Level II or Level III model, the engineer is encouraged to evaluate with the Level I model. If the Level I model also predicts less than 6dB, then strong consideration should be given to the following:

- Option 1: Reinstall the rumble strip.
- Option 2: If the site conditions allow, the seal coat can be placed up to, but not covering, the rumble strip.

SEAL COAT AND RUMBLE STRIP DURABILITY

Some agencies have found that rumble strips milled into seal coat or microsurfacing can cause premature failure of the treatment (Figure 6). Moisture can penetrate underneath the treatment and cause debonding followed by delamination. The researchers at TTI did observe rumble strips with this issue, but most sites were in good condition. If this is a concern, then avoid milling into seal coat; instead, plan on milling rumble strips deeper, at 5/8-inch, prior to covering them with seal coat.

Figure 6. Rumble Strip Pavement Distress.

REFERENCES

1. *Pike, A. M., B. T. Wilson, E. S. Park, S. R. Geedipally, and L. Wu. Evaluation of Audible Lane Departure Warning Treatments for Seal Coat Road Surfaces. FHWA/TX-19/0-6888-1. Texas Department of Transportation, Austin, TX, 2019.*

2. *Hansen, C. H. Fundamentals of Acoustics. In Occupational exposure to noise: Evaluation, prevention and control, World Health Organization.*