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Observational study on the pavement performance effects of shoulder rumble strip on shoulders

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Abstract

Rumble strip implementation has shown a constant increase with its safety benefits. Rumble strips are milled into the roadway shoulder to produce noise and vibrations when driven on. With the milling process, the pavement performance is expected to be negatively impacted by the decreased depth, though not mathematically quantified. Using methods defined by the Long-Term Pavement Performance Program, the severity of the shoulder site's distresses, with and without shoulder rumble strips, will be quantified. The quantification would permit the design to compensate for the impact. This design compensation allows the implementation of hard shoulder running, the use of shoulder as a travel lane during congestion, and retains the shoulder rumble strip safety instead of removing, as suggested by some proposed projects. While hard shoulder running would not impact specific time periods, the safety benefit of rumble strips could be needed at any time. This study aims to quantify the rumble strip impact to enable the full shoulder strength for hard shoulder running while retaining the safety benefits of rumble strips.

Keywords: Rumble strips; Shoulder; Cracking; Pavement performance; Hard shoulder running

1. Introduction

Shoulder rumble strips (SRS) have been around for over sixty years for safety improvements on roadways. It was not until the eighties that SRS became wide spread through the United States. Since then, the research has focused on the safety impacts of SRS on various classifications of roadways not only in the United States and Europe.

With the growing congestion problem in the United States, the asset utilization has become increasingly important. One method being researched is hard shoulder running (HSR), which uses the shoulder lane as a temporary lane during high congestion periods. One issue with HSR is the possible damage of shoulder pavement integrity the overall usability of the shoulder as a lane. The Delaware Valley Regional Planning Commission currently recommends removing the rumble strips (RS) for any shoulder operational use [1,2]. The safety benefits should not affect the implementation of HSR and should be retained when the effects on pavement performance are found to be minimal. The use of SRS provides a more sustainable roadway by providing a safer roadway that reduces the amount of accident related delay on the roadway on top of saving lives from injury or death. The proposed study aims to

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quantify the effect of SRS on shoulder pavement using study sites along Interstate 476 (I-476) in the state of Pennsylvania. The distresses forming on the shoulder will be monitored for shoulders with and without RS and based on the analysed distress values, the effects of RS on shoulder performance will be determined.

2. Literature review

2.1. Rumble strips

Research for SRS has been occurring since it was first installed in New Jersey in 1955 [3]. In the eighties, the use of SRS was more common and thus research into the overall benefits of SRS became more predominate. Table 1 shows a brief selection of the research done on SRS performance since the eighties along with the findings on the benefit of SRS. SRS could reduce run-off-road (ROR) crashes from anywhere from 13% all of the way up to 70% reduction [4,5]. The range is large as it is dependent on many variables such as the roadway geometry, the environment, the driver's specific situation and the number of crashes in general. Even though the reduction is varied it overall benefits society. The SRS reduction of crashes improves/maintains traffic operations, at a minimum reduces injuries of persons involved in the crashes, and save society money in crash related costs, an overall more sustainable transportation system. John Hickey modelled the roadway's safety performance to determine the expected crashes in the analysis period in addition to the before-after analysis associated with the SRS implementation [6]. Hickey's model takes into account the expected traffic growth that would transpire regardless of the implementation of the SRS providing a more accurate prediction of the crash reduction [6]. In addition, research has found a very high benefit cost ratio (BCR), between 4 and 195 [7,8]. With similar reasons to the crash reduction, the range of observed BCR values was large. As seen in Table 1, research has consistently centred on examining the beneficial crash reduction and the BCR of the SRS. Some of these studies have looked into the effects on cyclists and the use of skip patterns, gaps within the RS to allow bicycles to cross them without hitting them specifically [9]. Since the proposed study focuses on roadways with heavy traffic where cyclists are not allowed, the research pertaining to cyclists' experiences are not included in Table 1.

2.2. SRS impacts on safety and vehicles

The ROR crash reduction can range from 14% to 70% as the value is function of various parameters such as crash type, roadway geometry, and driver's current

Table 1
Summary of previous studies.

Study	Findings
Ligon et al. 1985 [11]	SRS produced a 19.8% crash reduction at test sites and the control sites increased by 9.3%
Harwood 1993 [12]	SRS could have about a 20% total crash reduction system wide but up to 70% on longer more monotonous roadways
Chen 1994 [13]	Virginia study compared rolled and milled RS. Milled produced 12.5 and 3.35 times more vibrations and sound, respectively. It was found that rolled RS are ineffective on trucks compared to milled
Cheng et al. 1994 [14]	Utah study showed roadways without SRS ROR crashes at 33.4% of total crashes versus the 26.9% when SRS were present
Wood 1994 [5]	Pennsylvania (PA) Sonic Nap Alert Pattern project reviewed crash data and found a 70% drop in ROR crashes causing PA to install SRS on the Turnpike.
Khan and Bacchus 1995 [7]	Found SRS a high BCR, 4 or more, due to high benefits and low costs
Hickey 1997 [6]	Re-examined Wood (1994) study to adjust for vehicle-distance travelled and overall crash reduction decreased to 65%
Perrilo 1998 [15]	Study used data from NY State DOT and NY State Thruway Authority to find a reduction of at least 65% for ROR crashes
Griffith 1999 [16]	Studied alcohol/drug related ROR and found a 18.3% reduction on all freeways and 21.1% reduction on rural freeways
Outcalt 2001 [9]	Tested vibration and sound readings for cyclists and 4 vehicles types. SRS rated best by cars and worst by cyclists. Recommended design was 3/8″ depth, 12″ width, 48′ skip pattern with SRS and 12′ gap
Gårder and Davis. 2006 [8]	Sleep related crashes dropped by about 58% on average with at least 41% reduction overall, 43% on dry road ROR crashes and 27% on all ROR crashes. A Maine study found a BCR of 195:1
Patel et al. 2007 [4]	Using a small sample size on two-lane rural roadways the injury inducing crashes reduced by 18% and overall crashes by 13%
Torbic et al. 2010 [17]	On rural freeways, overall ROR crashes reduced by 11% while fatal crashes reduced by 16%. On rural two-lane roads, overall ROR crashes reduced by 15% while fatal crashes reduced by 29%
El-Basyouny and Sayed 2012 [18]	This study compared intervention models both linear and Koyck models. The Koyck model fits the safety performance function better than the linear model. Koyck model showed an initial crash reduction of 24.9% which later levelled off at 19.2% crash reduction
Khan et al. 2013 [19]	This study found a 14% ROR crash reductions overall with a higher percentage for curved roadway sections than straight sections
Coulter and Ksaibati 2013 [20]	Severity of critical and serious ROR crashes reduced severity with SRS installation