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CHAPTER 9

NOISE PRODUCED BY TRANSVERSE RUMBLE STRIPS ON ROADWAYS: A CASE STUDY AT KG BATU 30 PONTIAN, JOHOR

9.1 INTRODUCTION

Kg Batu 30 of Pengkalan Raja, Pontian is a rural settlement area with a population living in 60 native houses. Most of the houses are built lining the road which connects the city of Pontian to the city of Skudai, Johor. The roadway is the only route that passes through Pontian to Johor Bahru. Transverse roadway strips (TRS) are a common approach used by the local authority for the purpose of road safety and in this case there are several TRS installations in the region which aim to slow down the speed of vehicles passing through an area which has houses, schools and government clinics. TRS alert the road user to a changing roadway environment where there is a need to exercise extraordinary caution, by generating a certain sound and vibration as a warning to vehicles driving over them. However, the excessive noise produced by TRS has prompted local residents to lodge complaints to the district Public Works Department (PWD) and seek help from Innovative Construction (ICON), UTM. No previous studies have been carried out on noise pollution caused by the installation of TRS in rural areas. Consequently, investigation of this phenomenon is required.

Noise is defined as "undesirable sound", while annoyance is a feeling of displeasure that is believed to negatively affect an individual or group of people. Many previous studies have proved that traffic noise has a significant impact on human health, both physically and psychologically. Exposure to traffic noise can cause sleep disorders. Once this problem occurs, it can lead to other problems for humans, such as frustration, lowered tolerance, reduced general coping mechanisms, increased risk of accidents, fatigue and somatic complaints. Boer and Schroten [1] listed the effects of traffic noise on health as including: (i) annoyance; (ii) sleep disturbance; (iii) disturbed cognitive functioning (learning and understanding); (iv) cardiovascular disease; and (v) adverse effects on mental health. However, according to Fyhri and Klaeboe [2], sensitivity is a key factor in human health problems caused by traffic noise, although they argued that health problems are caused absolutely by the direct impact of traffic noise. One example of direct impact of traffic noise exposure is deafness. A study conducted in a Jalgaon, India concludes that traffic noise can damage hearing if humans are exposed for a long time [3]. In their study, Ingle et al. chose as a sample 50 traffic policemen of all ages who worked in a noisy environment for 10-12 hours daily, and they found that 84% of them reported hearing loss and defined at least some hearing difficulty in one or both ears.

9.2 RELATED WORKS

TRS can always be seen on a road approaching a crossroads, road hump, curve, or toll plaza. According to Miska [4], the TRS seeks to call the road user’s attention to standard regulatory and warning devices or to alert the road user to a changing roadway environment where there is a need to exercise extraordinary caution. To attract the attention of drivers to the hazards that may exist in front of them, the TRS generates a certain sound and vibration to vehicles passing over it. When a TRS is run over by the tyre of a car, a significant tyre/road interaction noise is generated. The sudden increase of noise is supposed to sharpen the attention of the driver [5]. However, there are trade-offs between the potential operational and safety impacts of rumble strips on non-freeway facilities, such as the exterior noise created when vehicles travel over the rumble strips and its impact on adjacent residences and businesses [2]. This situation worsens in situations of non-stop day- and night-time use and this is in contrast with other noise pollution such as construction noise which usually happens only during the day.

According to Bendtsen et al. [5], noise from rumble strips is actually pulsating or impulse noise which is generally more annoying than continuous noise. The sounds have a similar pattern to the sound of a knocking hammer, firecrackers or an explosion. Therefore, the equivalent noise level for impulse noise has to be adjusted or increased by as much as 5 dB as a “penalty” to the actual noise level in order to compare it with continuous noise as concerns annoyance. Nevertheless, very few studies have been conducted into the relationship between the noise generated by TRS and annoyance to people, although some complaints from local residents to the authorities regarding this matter have been reported in the news. For example in Reno, Kansas, USA, the local authority finally agreed to remove transverse rumble strips following arguments from local residents [7]. The rumble strip had initially been installed to reduce the speed of vehicles approaching a roundabout.

9.3 TRANSVERSE RUMBLE STRIPS LAYOUT

The designs of the TRS in Malaysia follow the guidelines outlined in "REAM-GL8/2004 (Guidelines on Traffic Control Devices and Management), Part 4, pavement marking and delineation". Typical designs of TRS in Malaysia are illustrated in Figure 9.1 and Figure 9.2. Unfortunately, there is no specific pattern or profile and the TRS profiles currently installed are chosen by the Public Work Department (PWD) District Engineer or local council road engineers. In the REAM guideline the dimensions are 2250 mm centre to centre, with a width of 300mm and thickness of 3-7 mm. Figure 9.3 shows the profile of TRS in this study area. This surface profile has a possibility of affecting the magnitude of noise generated by the TRS when hit by passing vehicles, depending on three main factors: distance centre to centre (between the individual stripes - L), the width of the individual stripes (W) and the thickness of the individual stripes (H). According to Bendtsen et al. [5], TRS noise level can be lowered if the L, W and H are decreased.

TRS have been installed as a major traffic safety approach near to sensitive areas such as where schools, homes and business areas are located less than 50m away (Figure 9.4). There is no specific guidance in REAM on the installation of TRS near to these sensitive areas. However, TRS must not be located within 200 m of a residential area in order to avoid the noise problem to residents. Miska [4] has also come up with an even stricter suggestion, insisting the distance from the rumble strips to nearby residences must be 500 m in rural environments and 200 m in urban environments.

Figure 9.1: Typical view of Transverse Rumble Strips

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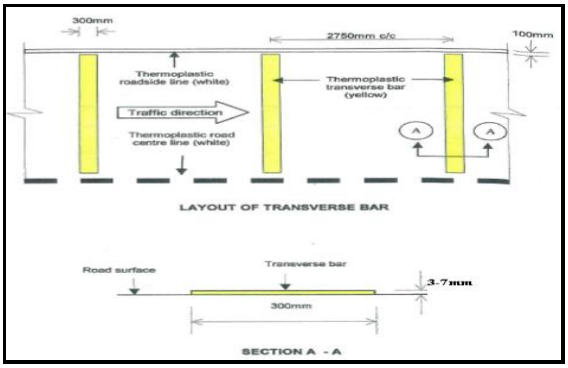

Figure 9.2: Design of typical TRS in Malaysia

Figure 9.3: TRS profile

Figure 9.4: Surrounding location of case study

9.4 OBJECTIVES AND METHODOLOGY

The primary objectives of this investigation are (1) to evaluate the external noise produced by rumble strips installed in Kg Batu 30, and (2) to evaluate the annoyance response in the rural area due to installation of TRS. Noise is measured by a sound level meter, which is an instrument which responds to sound in approximately the same way as the human ear and which gives reproducible measurements of sound level [8]. The equivalent continuous equal energy level (L_{Aeq}) is applied to impulse or fluctuating noise level. The L_{eq} is defined as the constant noise level that expends the same amount of energy as a fluctuating level over the same time period [7]. The time period over which L_{eq} is defined has to be relatively long (1, 8, 12 or 24 h). The statistical levels L_{10}, L_{50}, and L_{90} which are the noise levels that are exceeded for 10%, 50%, and 90% of the time respectively [9] are calculated from the 1 hr noise level, L_{Aeq}. L_{10} provides an indication of the upper end of the level range; while L_{90} constitutes the background level in the absence of nearby noise sources. The general practice in Malaysia is to use the same L_{10} (18 h) descriptor as used in the United Kingdom. This noise index can result in a reasonable outcome if it correlates well with dissatisfaction, and if it contains an accurate set of design rules for predicting the index [8].

A Pulsar sound level meter and a sound level calibrator were used to measure noise level throughout this investigation, and the noise was given as dB(A). The external noise produced by TRS was measured at 2 locations with and without rumble strips (Figure 9.5). The noise meter was mounted on a tripod about 1.5 m above the ground. The sound index that was measured is the $L_{Aeq(1minute)}$ for 1 hr taken from 09:00 to 10:00 and 10:00 to 11:00 during week days. The measurements were taken at two points: with TRS and without TRS. All measurements were carried out at 5 m from the road shoulder and carried out at the same period of time. L_{10}, L_{50}, L_{90} were obtained using the cumulative frequency of data reading for 1 hr. The traffic noise index (TNI) is a method used to estimate annoyance responses due to traffic noise, and is computed using the following formula [10]:

$$TNI = 4 \times (L_{10} - L_{90}) + (L_{90} - 30) \tag{9.1}$$

It should be noted that a TNI of 74 dB(A) has been reported to be associated with less than 3% annoyance in social surveys and is therefore the level suggested for planning purposes with regard to determining an optimum distance for dwellings from roadways.

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Also, due to the impulsive nature of TRS noise, the procedure in Annex C is utilised to estimate the perceived annoyance. In their article, Marquis-Favre et al. [11] proposed this by introducing penalties in order to better represent the annoyance felt by the residents.

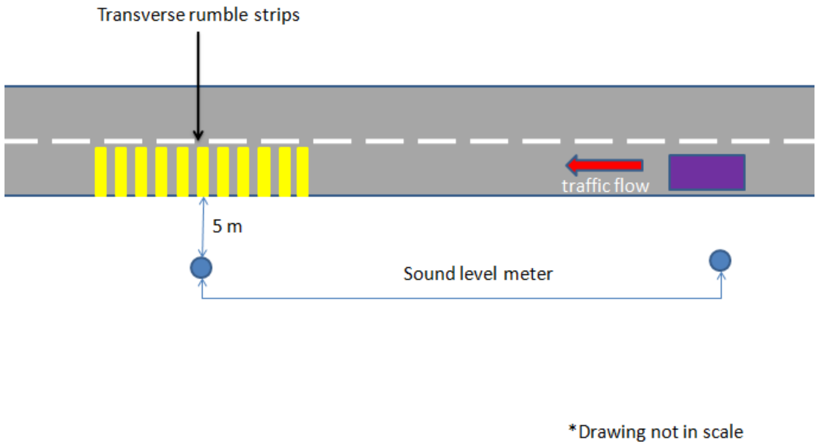

Figure 9.5: Measurement layout

9.5 RESULTS OF EXTERNAL NOISE PRODUCED BY TRS

The acquired L_{Aeq}1minute traffic noise level data from 9:00 to 11:00 are shown in Figure 9.6. The level induced by TRS increased compared with those without TRS. With a significance level of 95%, the independent t-test showed that there was a significant difference between the noise level with and without TRS. It is also noted that noise from rumble strips is actually pulsating and has a similar pattern to the sound of a knocking hammer. The frequency distribution for L_{Aeq1hr} with and without TRS was constructed (Figure 9.7) and the L_{10}, L_{50}, and L_{90} percentile levels, with values exceeding 10%, 50% and 90% of the elapsed time respectively, and L_{max} and L_{min} standing for the maximum and minimum sound levels, were obtained.

The results of the background noise level (L_{90}), the statistical noise level L_{10} (1h), and traffic noise index (TNI) with and without rumble strips for the 2 locations selected for the study in Kampung Batu 30 are given in Table 9.1. It should be noted that the background noise level corresponds to the noise level in the absence of nearby noise sources, while the statistical noise level L_{10} corresponds to the upper end of the noise level range [9].

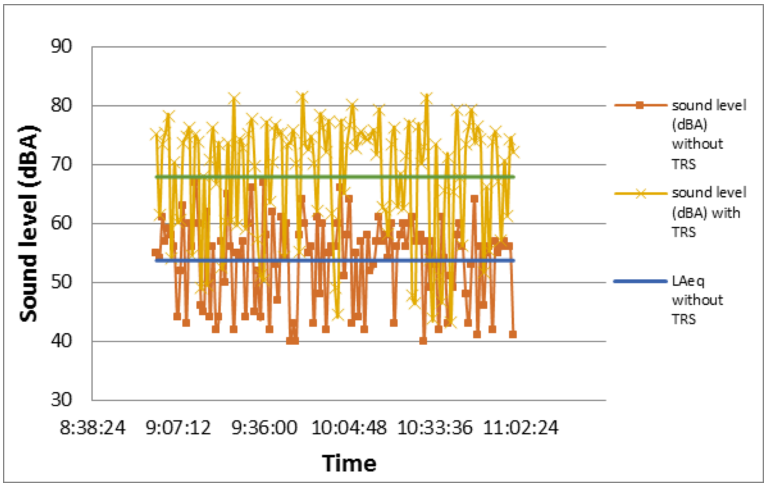

Figure 9.6: Increment of noise level due to TRS

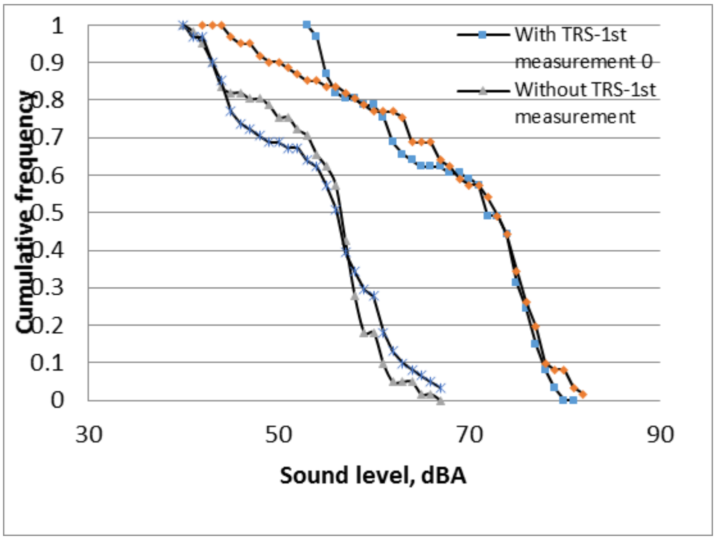

Figure 9.7: Comparison of cumulative distribution for external noise due to normal traffic noise and due to the installation of TRS

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Table 9.1: Comparison of statistical index

L_{index}	With TRS (dB(A))		Without TRS (dB(A))		Differences (dB(A))
	1st circle	2nd circle	1st circle	2nd circle	
L_{max}	81	82	67	67	15
L_{10}	78	78	61	63	16
L_{50}	72	73	56	57	16
L_{90}	50	54	43	43	9
L_{Aeq}	68	67	54	54	14

Investigation of Table 9.1 shows that with TRS the statistical noise level L_{10} has an average of 78 dB(A) and without TRS the average was 62 dB(A) . The levels are somewhat higher in the presence of TRS, and have an average increase of 16 dB(A) or 25% compared with the road without TRS. The increase of external noise is higher than reported by Finley and Miles (2007), who found that TRS generate additional exterior noise 13% greater than the highest noise level measured on smooth roads. Without TRS, L_{Aeq} were below the DOE 2004 maximum permissible limit. Based on the National Guidelines for Environmental Noise Control (2004), a generally acceptable road traffic noise level L_{day} for residential areas should be less than 55 dB(A). This is similar to the recommendation by the World Health Organization (WHO) (1999) of 55 dB(A) for outdoor areas. An area with an environmental noise level less than 55 dB(A) is usually considered as a comfortable environment with little or no annoyance so that there will be no negative physical and mental effects on essential activities such as work, leisure and sleeping. Although Kg Batu 30 is a rural area, the noise levels obtained are similar to those reported for cities around the world in Jordan, Italy, Brazil, Greece and India [8], [9], [13]. Thus it should be noted that the noise levels with TRS are mostly considered unacceptable, resulting in the fact that voices must be raised to be understood, and phone use becomes impossible.

9.6 RESULT OF ANTICIPATED RESIDENT ANNOYANCE

The traffic noise index (TNI) shown in Table 9.2 indicates that TRS increase annoyance responses due to traffic noise, resulting in a TNI of 130 with TRS and 90 without TRS. It should be noted that a TNI greater than 74 dB(A) has been reported to be associated with

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less than 3% annoyance in social surveys. Due to the impulsive nature of TRS, annoyance levels are higher than those indicated by L_{10} and the TNI. Table 2 shows the annoyance response due to TRS. The anticipated resident annoyance response increased from medium to very strong, which also prompted vigorous action from the residents. This is the reason why residents had complained to the district PWD seeking removal of the current TRS installation. Annoyance levels are higher than those indicated by the L_{10} and TNI values due to the nature of the impulsive sound produced by TRS.

Table 9.2: Annoyance response due to TRS

	With TRS		Without TRS	
TNI	132	120	85	93
Anticipated resident response annoyance	Very strong impact, vigorous action		Medium impact, widespread complaint	

9.7 CONCLUSION

TRS are used as traffic safety measures and are widely installed in residential areas. The TRS profile is chosen by local authority engineers. This investigation shows that TRS noise has a very strong impact on the community and this was the reason behind the complaints made by people living in Kg Batu 30 Pontian.

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