Introduction of Rumble Strips to National Highways in Hokkaido Prefecture, Japan

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Abstract

Hokkaido Prefecture is characterized by a higher fatality rate among serious accidents relative to other regions of Japan. One reason for this high fatality rate is the fact that most highways in Hokkaido Prefecture are two-lane roads, and such highways are prone to head-on collisions, run-off-the-road accidents, collisions with roadside structures, and other types of fatal accidents that characterize suburban areas.

In the U.S., to reduce the number of such accidents, "rumble strips" have been increasingly installed along roads. Rumble strips are grooved belt-like sections of pavement installed along the centerline or shoulder to warn drivers who are in danger of crossing the centerline or running onto the shoulder, by means of noise and vibration. They are considered an effective countermeasure to driver drowsiness and inattention.

This paper reports the results of a driving test on a test track, and a camera observation test on a national highway. The tests were conducted to examine the applicability of rumble strips as a countermeasure to head-on collisions.

We had road users drive/ride on the test track with rumble strips of three different depths: 9 mm, 12 mm, and 15 mm. During their driving, we conducted physical quantitative measurements for objective evaluation of each depth. After their driving, we gave the users a questionnaire to assess their subjective evaluation of safety for each depth. It revealed that drivers of two-wheeled vehicles did not feel the strips to be dangerous when they were 12 mm deep or shallower. This depth was adopted as a standard because drivers did not rate centerline strips of this depth as dangerous.

Rumble strips were judged to be an effective countermeasure to head-on collisions, in terms of smooth driving and cost-benefit, through experimental installation on a national highway.

KEYWORDS: TRAFFIC SAFETY / SUBURBAN ACCIDENT / HEAD-ON COLLISION / RUN-OFF-THE-ROAD ACCIDENT, RUMBLE STRIP.

1. Study on Groove Patterns and Milling Equipment of Rumble Strips

1-1 Study on groove patterns

Most rumble strips in the U.S. have a standard length of 400 mm or greater. The length adopted for the tests was 350 mm, so that the strip would fall within the width of the

Table 1 Groove patterns

	Pattern 1	Pattern 2	Pattern 3
Transverse width : a	350	350	350
Lengthwise width : b	127	147	163
Spacing : c	175	155	139
Depth : d	9	12	15

Unit: mm

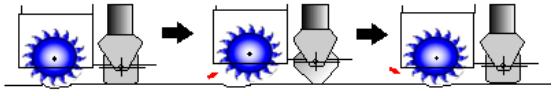

Figure 1 Milling by a vehicle that employs a wheel of non-circular profile

Photo 1 Milling vehicle

double centerline (500 mm). (The double centerline indicates a no-passing zone.) Table 1 shows the groove patterns studied.

1-2 Milling equipment

Continuous milling achieved by using a wheel with a non-circular profile was applied (Figure 1, Photo 1).

2. Test Installation at the Test Track of the Institute

2-1 User driving tests and results

At the test track of the Institute, rumble strips of three different depths were installed, and the user driving test was conducted. During the test, driving was observed by video, and afterwards the drivers answered questionnaires on driving conditions.

The questionnaire survey was conducted in November 2001. Test drivers numbered 52 and included those from accident-prone demographics (women and the elderly). The test vehicles were lightweight or compact cars (1500 cc or below), motorcycles and bicycles. The main purpose of testing small vehicles including bicycles was to evaluate the driver's/rider's subjective assessment of safety on rumble strips. The test drivers were asked to drive/ride on rumble strips whose depths were 9 mm, 12 mm, and 15 mm, and then to answer the questionnaire on sense of safety. Afterward, they were asked to drive another type of vehicle, and then to answer the same questionnaire.

The questionnaire on the first and second tests (Figure 2) reveals that the deeper was the depth, the smaller was the percentage of respondents who answered "Not dangerous." The percentage of respondents who answered "Somewhat dangerous" and "Dangerous" for the depth of 15 mm was greater than that for the other two depths.

The video recording did not reveal any dangerous driving or riding, such as sudden braking, sudden steering, or falling.

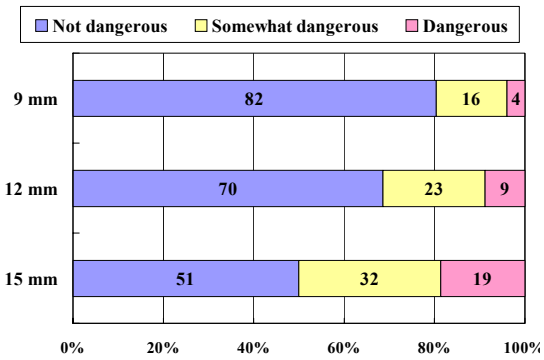

Figure 2 Subjective evaluation of damages by questionnaire on the user driving test

2-2 Physical quantitative evaluation of rumble strip effectiveness

(1) Vibration

To measure the vibration experienced by the driver, the pickup of a vibration meter was fixed to the steering wheel (Photo 2).

Photo 2 The pickup of a vibration meter fixed to the steering wheel

When a vehicle encounters a rumble strip, the driver feels strong vibrations. A considerable awakening effect can be expected from the strips. In all but one of the

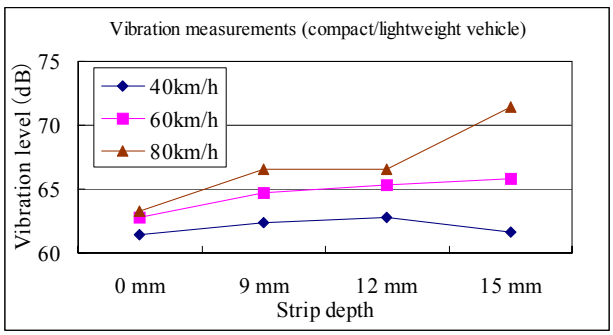

Figure 3 One vibration measurement (compact/lightweight vehicle)

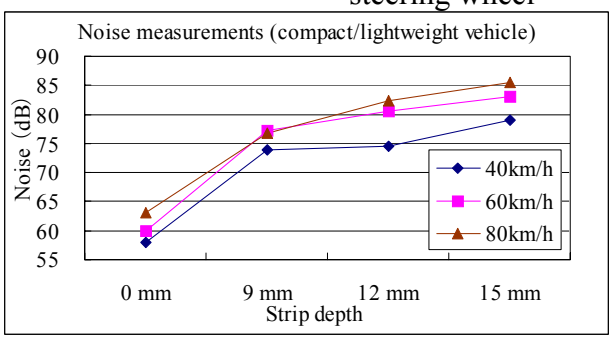

Figure 4 One noise measurement inside the vehicle (compact/lightweight vehicle)

measurements, the vibration when a vehicle runs on the rumble strip is 1 to 4 dB greater than when it is not running on the strip. The vibration is proportional to the driving speed, but not to the strip depth. Figure 3 shows the results of one vibration measurement.

(2) Noise

Noise clearly increases as the depth increases. This is true for measurements not only inside but also outside the vehicle. The awakening effect of noise is expected to be high. The results of one noise measurement are shown in Figure 4.

The rumble strip is not installed on wheel tracks of the traffic lane. Therefore, the noise it causes is not expected to be an environmental problem.

3. Experimental Installation on National Highway 5 in Yakumo Town, Hokkaido Prefecture

3-1 Standards of rumble strips installed

(1) Outline

The video recording of the test drivers at the test track of the Institute did not show any dangerous reactions to rumble strips of any depths. However, the questionnaire results show that many test drivers were concerned about the strips of 15 mm depth. The depth of rumble strips to be experimentally installed along National Highway 5 in Yakumo Town, Hokkaido Prefecture, was proposed to be 12 mm for safety reasons, and this proposal was accepted.

The transverse length of rumble strip was set at 350 mm for the reasons stated in Section 3-2 above (Figure 5). The road was closed in one direction during installation, which was performed by the installation vehicles shown in Figure 6.

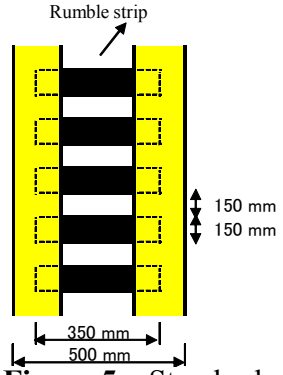

Figure 5 Standard of installed rumble strip

Figure 6 Installation vehicles

Photo 3 Rumble strips in service

(2) Installation results

On a section of National Highway 5 in Yakumo Town, rumble strips were installed in July 2002. The installation was completed in a single day. Rumble strips were successfully installed at a milling rate of approximately 3 m/min. Also, they were visually recognized by running drivers. They were judged to have a visual effect in addition to their awakening effect.

3-2 Traffic conditions on a section installed with rumble strips

The effects of rumble strip installation on traffic conditions were assessed. For this assessment, running speed and distance between the shoulder-side wheel and the white shoulder line were measured on the sections with and without rumble strips.

The distance between the shoulder-side wheel and the white shoulder line was measured by video camera. Marks were made every 20 cm from the white shoulder line for measurement. For one hour, the cameras measured traffic in both directions on the sections with and without rumble strips. Figures 7 and 8 show average distances between shoulder-side wheels of large vehicles (buses and freight vehicles) and small vehicles, and the white shoulder line on the two aforementioned sections. The average

distance between the wheel of vehicles and the white shoulder line on the section with rumble strips was compared with that distance on the section without the strips. The difference was 24.8 cm for small vehicles and 21.6 cm for large vehicles. The distance from the white shoulder line appears to be reduced by the presence of rumble strips. The drivers drove so because they recognized rumble strips. Rumble strips are potentially effective in reducing head-on collisions.

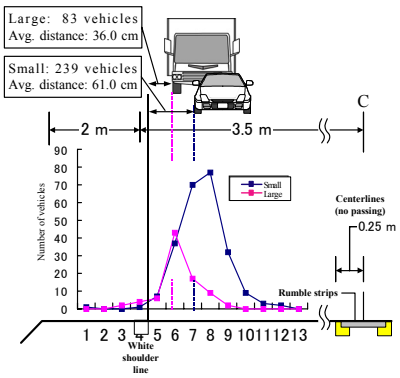

Figure 7 Distance between shoulder-side wheel and white shoulder line on a section w/ rumble strips

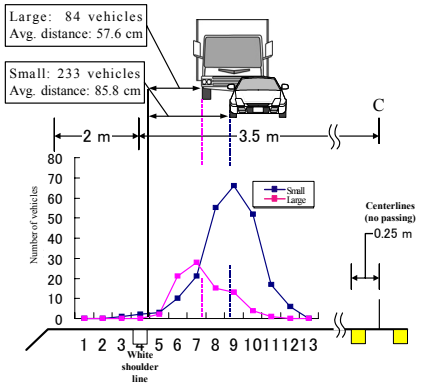

Figure 8 Distance between shoulder-side wheel and white shoulder line on a section w/o rumble strips

4. Examination of Cost-benefit

We calculated the cost-benefit of rumble strips installed along National Highway 5 in Yakumo Town.

Table 2 presents human causes for the party most responsible for head-on collisions on suburban sections of national highways in Hokkaido Prefecture, from 1995 to 1999. Delay in detection of oncoming vehicles, which is caused by drowsiness and inattention, accounts for 39% of all accidents. We assumed that the awakening effect of rumble strips could prevent accidents caused by drowsiness and inattention on these suburban sections. Under this assumption, we calculate the benefit below.

Table 2 Causes of head-on collisions on national highways in Hokkaido (suburban sections, 1995 - 1999)

Delayed detection (drowsiness and inattention)	Misjudgment (reckless passing, et al.)	Mis-driving (mis-steering, mis-braking, et al.)	Negligence (e.g., drunk driving), lack of driving skill	Unknown
※ 956 39%	488 20%	940 38%	85 3%	5 0%

Note: Upper figure is number of accidents; lower is % of accidents preventable by rumble strips.

On a 20-km section of National Highway 5 in Yakumo Town that includes the section with rumble strips, there were 74 head-on collisions and 16 fatalities in the 10 years from 1990. There were also 25 people who suffered severe injury, and 94 who suffered minor injury during those 10 years. Human costs of head-on collisions were estimated according to the *2002 Report of Traffic Accidents and Automobile Insurance Data*[3]. The costs per death are 33.04 million yen and per injury are 1.66 million yen. The property costs are 0.364 million per accident. A per-km cost was calculated from the number of head-on collisions in the 20-km section, which was multiplied by 0.39 (39%) from Figure 9. This calculation produced an estimate of monetary benefit of rumble strips. Human and property costs were estimated as follows:

Benefit by reducing human costs: [((16 people × 33.04 million yen) ＋ (25 + 94) people × 1.66 million yen) / 20 km] × 0.39 (39%) = 14.16 million yen
Benefit by reducing property costs: [(74 cases × 0.364 million yen) / 20 km] × 0.39 = 0.53 million yen

The total benefit achieved by reducing human costs and property costs is 14.69 million yen, or roughly 15 million yen. This means that rumble strips yield a monetary benefit of about 15 million yen in a 10-year period.

The installation cost of the strips that were installed on a test basis was 1.5 million

yen/km. The cost-benefit is calculated as follows:

Cost-benefit (B/C) = 15 million yen / 1.5 million yen = 10.0

The durability of rumble strips is not yet known, but they are expected to have a service lifespan of at least 10 years because they are installed where wheels do not usually pass.

5. Future Challenges

The future challenges are these.

1) To reduce the installation cost by increasing the installation efficiency
2) To clarify the advantages and disadvantages of rumble strips under the snowy and icy conditions of winter
3) To assure the safety of bicycles and other types of vehicles if rumble strips are installed at the shoulder as they are in the U.S.; i.e., to develop a standard that assures safety for all road users

Examination on #3 above has begun. It is outlined below.

Road shoulders in the U.S. are wide. Rumble strips installed at the shoulder have reportedly shown great effectiveness in preventing run-off-the-road accidents[1), 2)].

However, their potential danger to cyclists is of concern. As mentioned above, a bicycle riding test was conducted at the test track of the Institute. Questionnaire respondents evaluated 12-mm and 15-mm grooves as inconvenient but not dangerous.

Toward developing rumble strips that do not inconvenience bicyclists, we will examine the use of rumble strips 80 mm in transverse width by 9 mm in depth.

Narrow-groove rumble strips cannot be milled by the milling drum mounted on conventional milling machines. A traction-based device for narrow-groove milling (Photo 4) was introduced to mill grooves of a certain type. Those grooves were rated by bicyclists as slightly more convenient to ride on than the grooves of the three aforementioned depths.

We are working on determining the minimum shoulder width required for installation of rumble strips at the shoulder, the optimum groove pattern, and other items.

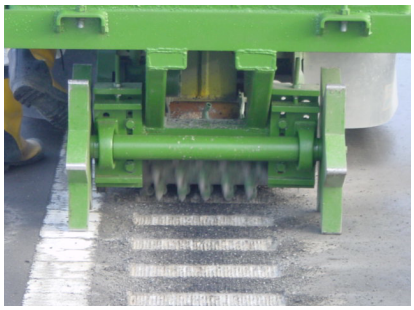

Photo 4 Milling of narrow grooves

6. Postscript

Traffic fatalities in 2002 numbered half as many as in 1970, the peak year. Rumble strips have the potential to be an effective countermeasure to traffic accidents, for their low installation cost, high cost-benefit, and high user acceptability. Rumble strips must not obstruct snow removal, which is very important in the cold, snowy regions that account for approximately 60% of Japan's area. So, they may be more effective than center poles and chatter bars. Furthermore, rumble strips indicate the position of roadway line markings, i.e., the lane, by generating vibrations. This indication is possible even when roadway line markings are not visible due to snow accumulation on the road, snowstorm-induced poor visibility, and other factors.

The Hokkaido Development Bureau has recognized the effectiveness of rumble strips. In the next five years, the total installation length will be increased to approximately 310 km.

References

1) Federal Highway Administration: http://safety.fhwa.dot.gov/programs/
2) Michael S. Griffith: Safety Evaluation of Rolled-in Continuous Shoulder Rumble Strips Installed on Freeways, 2000.
3) The Marine and Fire Insurance Association of Japan, Inc.: 2002 Report of Traffic Accidents and Automobile Insurance Data, March 2003.