SWZDI

Smart Work Zone Deployment Initiative

Report Title	Report Date: April 2006

Evaluation of Portable Rumble Strips--ATM

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Supplemental Funding Agency Name and Address (if applicable)

Supplemental Notes

Abstract

The ATM product is similar to that evaluated previously by the smart Work Zone Deployment Initiative (1999, 2002) from the same manufacturer. These strips were approximately 300 mil thick and 4 inches wide (they are cut to length). The adhesive is factory applied with a protective backing that is removed immediately prior to application. Previous studies have found the strips at this thickness to generate in-vehicle noise and vibration levels similar to those produced by traditional raised asphalt rumble strips (i.e., in Kansas). The strips have been demonstrated to be durable both in terms of strip wear and adhesive longevity. This study was aimed at examining the reuse of the strips facilitated by the application of a supplemental adhesive layer following each installation and removal. A test was devised to provide a relative measure of the adhesive's ability to resist vertical loading. The baseline for the tests was the strip with only the factory applied layer of adhesive, which has been demonstrated to perform satisfactorily. The second point of observation was the amount of effort required for repeated installation and removal. The application of supplemental layers of adhesive was found to significantly increase the strip's resistance to vertical loading, suggesting that a reapplied strip would perform at least as well as those observed in earlier work. The strips were also significantly more difficult to remove, although after the second layer of supplemental adhesive was applied, the strips could still be removed by hand by a single person, although some workers may not be able to do so. The supplemental adhesive was easily applied, and the reinstallation of the strip was comparable in effort to the initial installation. Based on the results of this and previous studies, these strips can be recommended for reuse using supplemental adhesive as per manufacturer recommendations.

Midwest Smart Work Zone Deployment Initiative

2004 Program Year

Research Proposal

EVALUATION OF PORTABLE RUMBLE STRIPS

(Advanced Traffic Markings)

April 2006

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Introduction

A product from Advanced Traffic Markings (ATM) was evaluated with respect to its applicability to temporary applications (i.e., lasting a day or less). Based on past research, the noise and vibration inside a passing vehicle will be similar to that produced by asphalt strips. This evaluation did not examine noise and vibration. For the ATM product, the primary issues at hand were the ability of the strips to remain adhered to the pavement when two or more layers of adhesive have been applied. The product had already been evaluated with only the factory-applied adhesive. Secondly, the reinstallation of the strip was considered, especially under conditions where the replacement adhesive could not be stored in a climate-controlled environment.

Previous research

Studies provide strong evidence that continuous rumble strips along the shoulder reduce roadway departures. (e.g., FHWA, 1998; Carlson and Miles, 2003) Rumble strips in the traveled lane in advance of work zones, however, are more difficult to conclusively prove effective. Accident studies are not feasible because the nature of work zones is that they are temporary, and durations are rarely long enough to observe statistically significant patterns with respect to crashes. Although there are many studies suggesting that rumble strips in the traveled lane are effective, (e.g., Noel et al, 1989; Harwood, 1993; FHWA, 2000; Zaidel et al, 1986; Owens, 1967) there are also studies that find rumble strips to be ineffective. Studies of rumble strips used in work zones are commonly found in both categories. (e.g., Noel et al, 1989; Harwood, 1993; Richards et al, 1985; Benekohal et al, 1992; Fontaine et al, 2000) Nonetheless, the intuitive perception of the value of this type of device has led to very widespread use.

However, there are many work zones for which rumble strips might enhance safety, but for which the duration is so brief that the installation and removal time required to use conventional rumble strips is prohibitive. Recognizing that rumble strips are only an incremental improvement, the safety benefits gained for very short duration work zones is likely offset by the extra worker exposure incurred during installation. To address the need for a rumble strip that can be installed and removed quickly enough to merit use in very short term work zones, the Federal Highway Administration (FHWA), through the Strategic Highway Research Program (SHRP), funded research to develop a portable device to provide audible and tactile warning to drivers. (Stout et al, 1993)

The SHRP-funded research resulted in the development of a rumble mat, a heavy rubber mat with ridges on the upper side that could be set in the roadway to provide rumble and vibration for passing vehicles. Regretfully, the device was only applicable at low speeds (e.g., 40 mph or less). At higher speeds, the wake of tractor trailers is strong enough to lift the mat from the pavement, creating an unsafe condition. These mats are used for low-speed situations by many transportation agencies, but those who have tried them in situations where highway speeds are prevalent have all found that they will not reliably stay on the pavement. Stout et al affirmed the value of the concept and the need for additional research.

Since the development of the Rumble Mat, other products have been developed in attempts to address the same problem. A forerunner of one of the products that evaluated in this study was previously tested for use as a removable rumble strip (i.e., applications of a day to several months). (Meyer, 2000, Meyer, 2003) The strips were found to be similarly effective at producing noise and vibration perceptible to the driver. No attempt was made to reuse these strips.

Product Description

The rumble strip proposed by ATM for use as a portable rumble strip was similar to their products previously tested by the SWZDI. There were two distinctions. First, the strip is thicker so that it is not necessary to use a double thickness to achieve acceptable levels noise and vibration conveyed to the driver. Second, additional adhesive was provided in rolls that could be cut to length and applied over the used adhesive on the bottom of the strip, once it is removed from the pavement. The manufacturer recommends that each strip be used for no more than 4 total applications, after which either the strip must be discarded, or the adhesive should be cleaned off of the strip to start anew. The reverse of the strip is shown in Figure 1. The strip is 4 inches wide, 300 mil thick, and is delivered in 50-ft rolls to be cut to length by the user. Adhesive is applied at the factory across the entire breadth of the strip. The replacement adhesive strips also are delivered in rolls to be cut to length. The replacement adhesive is approximately 3 inches wide. The protective backing can also be seen in Figure 1. Note that the backing extends beyond the edge of the adhesive strip.

Figure 1. Reverse of the ATM rumble strip with replacement adhesive strip applied.

Installation, Removal, and Reinstallation

The installation process was the same as in previous tests. The strip was cut to length. The pavement was swept clean of sand and debris. The protective backing was removed from the factory-applied adhesive, and the strip was placed on the pavement. A tamper cart weighing (with load) approximately 200 lbs was rolled over the strip three times in each direction.

Following the initial (and subsequent) uses, the strip was removed by pulling upward perpendicular to the pavement. An adhesive strip was applied to the bottom of the strip overtop of the existing adhesive. No cleaning of the used strip was done. The protective backing was then removed from the adhesive and the strip was placed. The tamper cart was again used to ensure adequate bonding between the adhesive and the pavement.

The replacement adhesive strips applied to the strips easily. The protective backing removed easily and cleanly, without any tearing. The thickness of the installed strip was just approximately 5/16 in. After the application of two additional layers of adhesive, the installed thickness was still measured as 5/16 in. The lack of change in the thickness may be because the changes was less than could be measured given the irregularity of the pavement, which served as the baseline. Another possibility is that the additional adhesive was forced into voids on the pavement surface by the force delivered by the tamper cart. Figure 2 shows the protective backing being removed from the replacement adhesive strips, and the strips after the backing was removed and before they were installed. The difference in width between the rumble strip and the replacement adhesive strip made the application of the adhesive to the rumble strip easier because perfect alignment was not necessary, as would be the case if they were the same width.

Figure 2. Applying replacement adhesive.

Data Collection

The durability of the adhesive used on the ATM product has been well demonstrated in previous evaluations. Strips were deployed at active work zones and remained in place for six months without a failure. The approach in this evaluation was aimed at answering three questions. First, would the replacement adhesive adhere to the old adhesive as well as it adhered to the strip itself, given that after use the old adhesive is covered with dust, dirt, and debris? Second, would the multiple layers of adhesive make the strip more prone to sliding? Third, is the effort required for reinstallation similar to that required for the initial installation? The original data collection plan proved to be infeasible due to unavoidable delays and changes in available resources that occurred during the interim. However, an alternate approach was devised to address the goals of the evaluation.

Given that similar strips with a single layer of adhesive have been previously demonstrated to perform well, the alternative approach was to measure the adhesion of the strips with the replacement adhesive applied and compare it with a single layer of adhesive. If debris embedded in the initial application of adhesive prevented the replacement adhesive from properly bonding to the strip, or if the increased thickness of adhesive material would stretch, allowing the strip to move without severing the bond between the adhesive and the pavement, then less force would be required to detach the strip from the pavement. The following procedure was used to measure the adhesion of the reused strip relative to the original application.

1. Six strips were installed as per the manufacturer’s recommendations.

2. A nail was inserted between the strip and the pavement. A hammer was used to drive the nail.

3. The loops on either end of a pull cord were placed over the ends of the nail, straddling the strip.

4. A tensile scale was attached to the center of the pull cord. Figure 3 shows the hammer, nail, fisherman’s scale, and pull cord.

5. Using the scale, the nail was lifted with a force of 20 lbs.

6. The strip’s movement was monitored, measuring the height of the top of the strip compared to the pavement. Figure 4 shows the strip being lifted. The white tape on the end of the board was marked in half-centimeter units for measuring the movement of the strip. Once the nail was inserted between the strip and the pavement, the hammer was used to weight the board so that it would not blow over.

7. The strip was considered to have stopped moving when no noticeable movement occurred for three seconds.

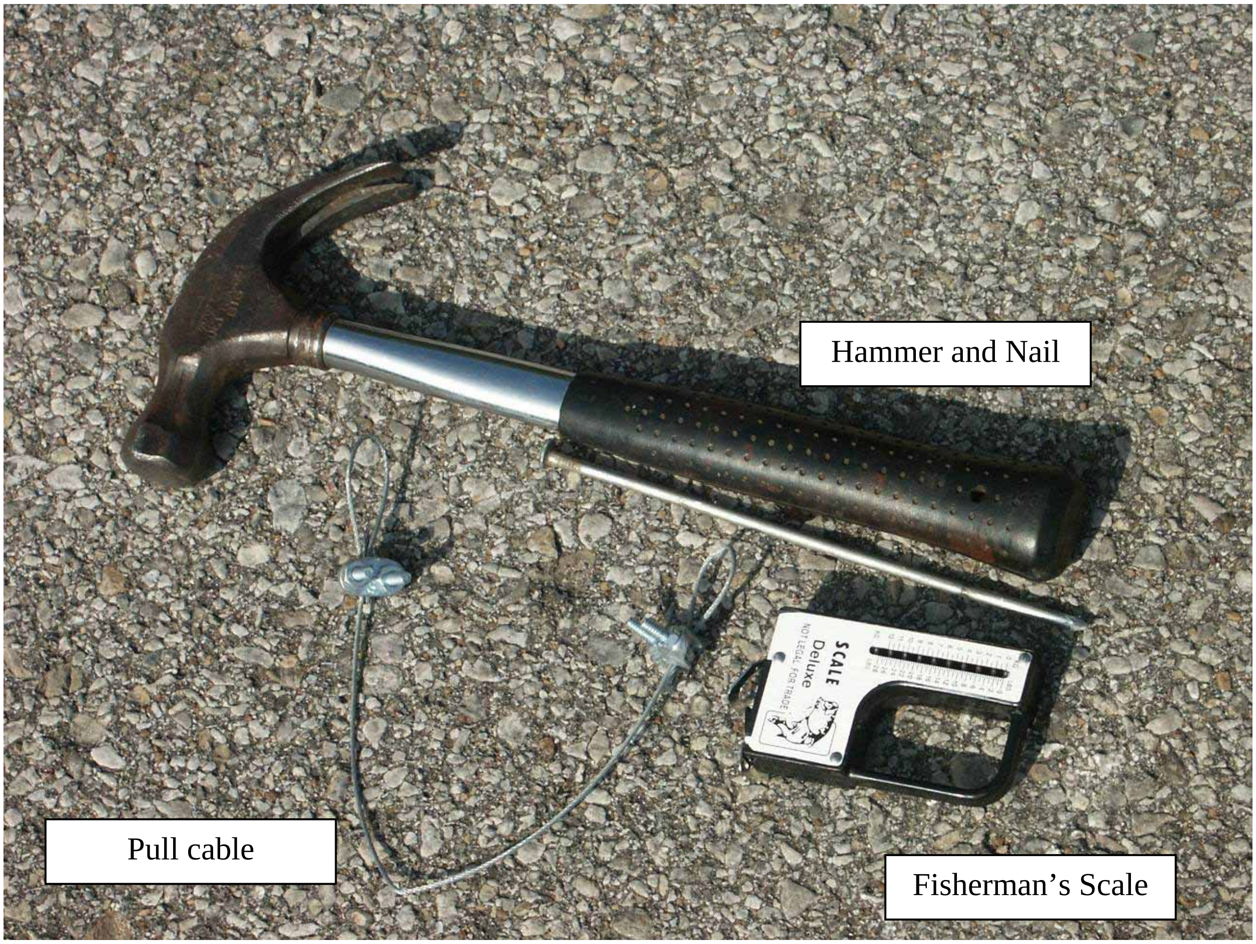

Figure 3. Tools used to measure the strips resistance to tensile force.

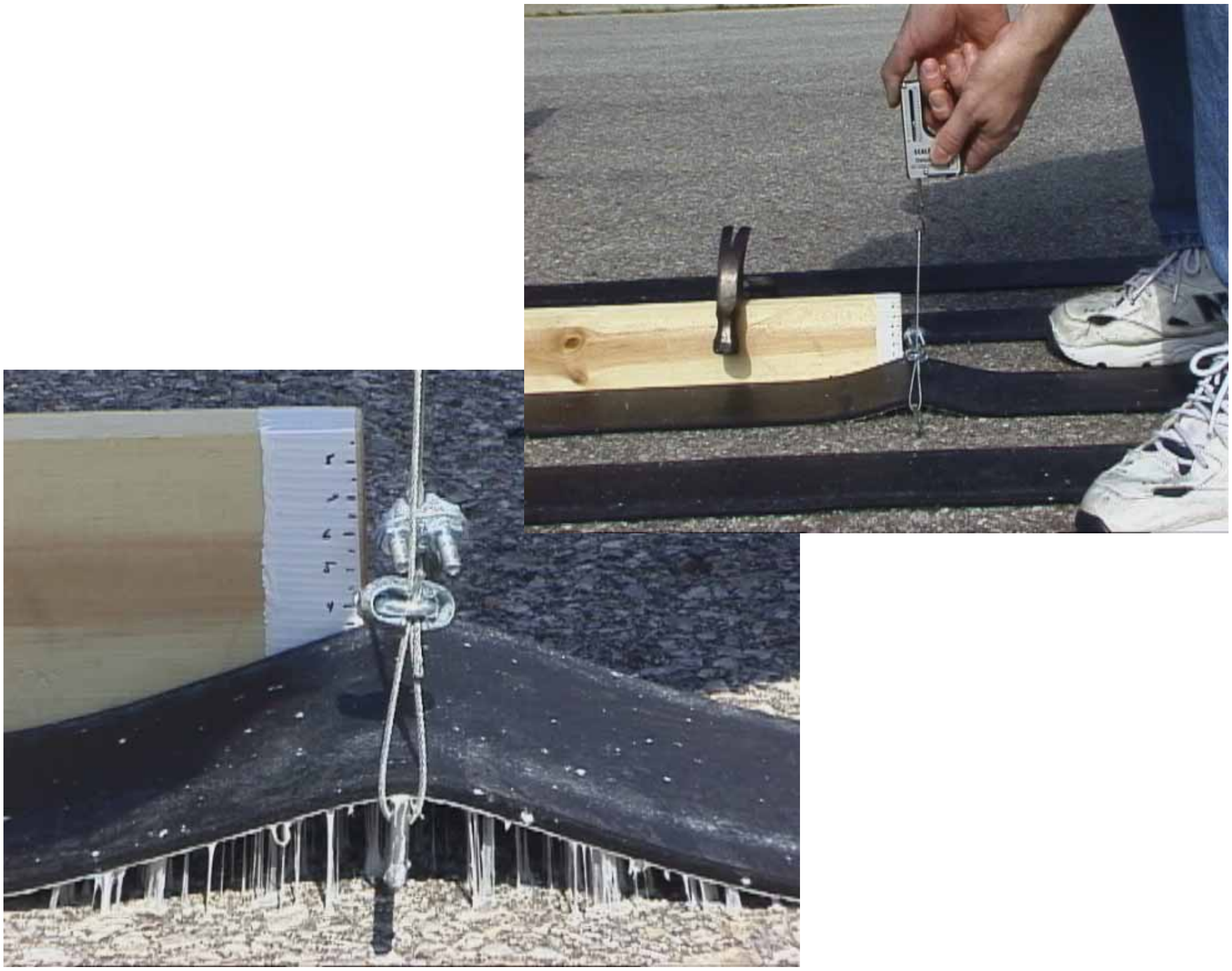

Figure 4. Measuring strips resistance to vertical force.

Results

The installation and reinstallation of the strips was easily done by one person, although application of strips longer than 4 ft would benefit from a second worker. The time required for reinstallation was similar to that required for the initial installation. The replacement adhesive had to be applied for reinstallation, but the strip did not have to be measured and cut. The thickness of the strip did not increase appreciably with the addition of two layers of replacement adhesive.

Following the procedures described, six strips were tested for their resistance to removal. Following the initial installation, the lifting assembly was set up and applied separately to each of the six strips. In all cases, the strip reached the top of the board (approximately 8 cm) without stopping. Following the first reinstallation, each of the six strips was tested again. They each reached between 3.5 cm and 4.5 cm before motion stopped. Following the second reinstallation, two strips were tested, each reaching between 2.5 cm and 3.5 cm before they stopped moving. No further strips were tested because the additional adhesive was clearly increasing the strips' resistance to movement.

The removal was similar for the strips at each stage of use (i.e., initial installation and reinstallation). The replacement adhesive bonded very well with the used adhesive layer, and the bonding with the pavement increased with each additional layer of adhesive. After the third installation, the strips were very difficult to remove. They could still be removed by one worker, but all workers may not be able to remove the strips under these conditions.

Recommendations

Based on prior evaluations, the thickness of these strips is sufficient to provide passenger car drivers with noise and vibration comparable to that of asphalt strips, and the strips are amply durable in their factory-delivered condition. The testing done in this evaluation clearly showed that the use of replacement adhesive strips to facilitate reuse increased the adhesion of the strips to the pavement for at least two reapplications after the initial application. Given that the thickness of the strips did not increase significantly, additional applications may be possible, although if removal continued to become more difficult with each application, the ability of crews to remove the strips could become the limiting factor.

In general, this product is recommended as a viable alternative to other rumble strips for portable rumble strip applications. The following recommendations are made for the use of this device.

1. The protective backing should not be removed until immediately before the strip is installed. This applies equally to the initial installation and any subsequent reinstallations. The adhesive is extremely sticky, and minimal opportunity should be given for the strip to stick to other strips or equipment during transport, or for debris or dust to collect on the adhesive surface.

2. If the strips are to be reused, the replacement adhesive should be applied immediately upon removal from the pavement. While the adhesive may have collected some debris, it will still likely be very sticky upon removal of the strip, making it very difficult to store or transport the strips. Applying the replacement adhesive will allow the strips to be stacked, facilitating easier handling and transport.

3. To speed installation, some experimenting might be done to see if a lesser tamper cart might be used or if fewer passes would still be sufficient for the strips to perform adequately.

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SWZDI

Smart Work Zone Deployment Initiative

Report Title	Report Date: April 2006

Evaluation of Portable Rumble Strips--RTI

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Supplemental Notes

Abstract

The product from RTI conformed to acceptable dimensions as recommended in previous work done by the Smart Work Zone Deployment Initiative. The application and reapplication of the strips as portable rumble strips was considered with respect to the adhesion using the vendor supplied methods and the removal and reinstallation effort required. Of several adhesives provided by the manufacturer, none were deemed appropriate for the application of temporary rumble strips. The strip alone is not heavy enough to remain in place without adhesives under traffic traveling at highway speeds. Consequently, the strips as tested cannot be recommended for use as temporary rumble strips. It should be emphasized that the reason the strips cannot be recommended for this application is that the adhesives were not appropriate. The strips themselves would likely perform satisfactorily in a longer term context with the vendor supplied adhesives or in a temporary context if another more appropriate adhesive could be identified.

Midwest Smart Work Zone Deployment Initiative

2004 Program Year

Research Proposal

EVALUATION OF PORTABLE RUMBLE STRIPS

(Recycled Technologies, Incorporated)

April 2006

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Introduction

A product from Recycled Technologies Incorporated (RTI) was evaluated for its applicability to temporary rumble strip applications (i.e., applications lasting less than a day). Based on past research, the noise and vibration inside a passing vehicle will be similar to that produced by asphalt strips, so this evaluation did not examine noise and vibration. The RTI product was also evaluated with respect to installation and adhesion. Several adhesives were provided by the manufacturer, all of which are discussed.

Previous research

Studies provide strong evidence that continuous rumble strips along the shoulder reduce roadway departures. (e.g., FHWA, 1998; Carlson and Miles, 2003) Rumble strips in the traveled lane in advance of work zones, however, are more difficult to conclusively prove effective. Accident studies are not feasible because the nature of work zones is that they are temporary, and durations are rarely long enough to observe statistically significant patterns with respect to crashes. Although there are many studies suggesting that rumble strips in the traveled lane are effective, (e.g., Noel et al, 1989; Harwood, 1993; FHWA, 2000; Zaidel et al, 1986; Owens, 1967) there are also studies that find rumble strips to be ineffective. Studies of rumble strips used in work zones are commonly found in both categories. (e.g., Noel et al, 1989; Harwood, 1993; Richards et al, 1985; Benekohal et al, 1992; Fontaine et al, 2000) Nonetheless, the intuitive perception of the value of this type of device has led to very widespread use.

However, there are many work zones for which rumble strips might enhance safety, but for which the duration is so brief that the installation and removal time required to use conventional rumble strips is prohibitive. Recognizing that rumble strips are only an incremental improvement, the safety benefits gained for very short duration work zones is likely offset by the extra worker exposure incurred during installation. To address the need for a rumble strip that can be installed and removed quickly enough to merit use in very short term work zones, the Federal Highway Administration (FHWA), through the Strategic Highway Research Program (SHRP), funded research to develop a portable device to provide audible and tactile warning to drivers. (Stout et al, 1993)

The SHRP-funded research resulted in the development of a rumble mat, a heavy rubber mat with ridges on the upper side that could be set in the roadway to provide rumble and vibration for passing vehicles. Regretfully, the device was only applicable at low speeds (e.g., 40 mph or less). At higher speeds, the wake of tractor trailers is strong enough to lift the mat from the pavement, creating an unsafe condition. These mats are used for low-speed situations by many transportation agencies, but those who have tried them in situations where highway speeds are prevalent have all found that they will not reliably stay on the pavement. Stout et al affirmed the value of the concept and the need for additional research.

Since the development of the Rumble Mat, other products have been developed in attempts to address the same problem. A forerunner of one of the products that evaluated in this study was previously tested for use as a removable rumble strip (i.e., applications of a day to several months). (Meyer, 2000, Meyer, 2003) The strips were found to be similarly effective at producing noise and vibration perceptible to the driver. No attempt was made to reuse these strips.

Product Description

The cross-sectional profile of the RTI product is sufficiently similar to that of the Davidson-Plastics rumble strip evaluated in 2002 (under KDOT funding) that the effect on vehicles will be similar. Both are ¾ in high and differences in cross-sectional profile alone were shown to have little, if any, effect on the sound and vibration produced for strips of this height and approximate width. Thus the primary measure of effectiveness of these strips will be their potential to remain in place under traffic.

These strips come in 5 ft lengths, are 6 in wide and have a 45 degree bevel on all sides. They are made of recycled tire rubber, so they should be very durable. Several installation options are available, including various adhesives.

Installation, Removal, and Reinstallation

For all installations using adhesives, the general process is the same: Mark the pavement to identify the strip locations, sweep the pavement clear of dust and debris, and then place the strip. The application of each type of adhesive is different. Three adhesives were provided by the manufacturer. thermo-plastic, two-part epoxy, and a urethane adhesive. The respective installation procedures for each of the adhesives are as follows.

Thermoplastic

The thermoplastic is placed on the pavement and melted with a heat gun, forming a bond with the pavement. A second layer of thermoplastic is melted atop the first and the strip is set onto the thermoplastic before it sets. Once the thermoplastic cools, the installation is ready for traffic.

Epoxy

The two parts of the epoxy are mixed together, spread onto the reverse of the strip, and then the strip is placed onto the pavement. Pressure should be applied to the top of the strip to force the epoxy into the voids on the surface of the strip and of the pavement, but care should be taken not to apply so much pressure that the epoxy is forced out from under the strip. The epoxy must be allowed to set for a short time to achieve ample bonding strength before the strip is subjected to loading.

Urethane

The urethane is provided in tubes that can be applied with the use of a standard caulking gun. The urethane is applied to the reverse of the strip, and the strip is placed on the pavement. Light pressure should be applied to the strip to help distribute the urethane and force it into the voids of the surface of the strip and that of the pavement. Figure 1 shows the urethane being applied to a rumble strip on the left. The right photo shows pressure being applied to the strip. The urethane must be allowed to set for 2 hours before loading.

Figure 1. Applying urethane adhesive (left) and applying pressure to the strip (right).

Data Collection

The following procedure was devised to measure the adhesion of the reused strips relative to the original application.

1. Install strips as per the manufacturer's recommendations.
2. Insert nail between the strip and the pavement.
3. Place the loops on either end of a pull cord over the ends of the nail, straddling the strip.
4. Attach a tensile scale to the center of the pull cord.
5. Using the scale for reference, lift the nail with a constant force of 20 lbs.
6. Monitor the strip's movement, measuring the height of the top of the strip compared to the pavement.
7. Identify the height of the strip when it stops moving, defined as no noticeable movement occurring for three seconds.

Results

Both the thermoplastic and the two-part epoxy application methods were not tested. These methods form permanent bonds which are not desirable for application as portable rumble strips. Previous research has shown two-part epoxies to severely damage asphalt pavement upon removal of the strip.

The urethane adhesive was applied as per the manufacturer's instructions. The strip was allowed to set for two hours, but the adhesive did not set up. The reason is unknown. Perhaps some aspect of the test conditions retarded the setup process. Regardless of the reasons for the adhesive failure, the failure precluded any further testing.

Recommendations

The strip dimensions and fabrication are suitable for application as portable rumble strips. However, the strips cannot be recommended using the adhesives provided by the vendor. The strip is not heavy enough to remain in place under traffic at highway speeds without any adhesive. The adhesives provided would would not be suitable for very short term applications, either because of the damage likely to be done to the pavement upon removal or because the set time for the adhesive is too long to be practical for portable rumble strip applications (or both). Two of the adhesives (thermoplastic and epoxy) would likely be suitable for longer term or possibly even permanent installations. The urethane adhesive would need to be monitored closely in longer term applications.

As provided, this product cannot be recommended for application as a temporary rumble strip. It could be deemed suitable if a more appropriate method of adhesive could be identified.

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