

Research Report
KTC -13-07/SPR441-12-1F

Evaluation Of Alternative Snowplowable Markers And Snowplowing Procedures

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Research Report KTC-13-7/SPR441-12-1F

**EVALUATION OF ALTERNATIVE SNOWPLOWABLE MARKERS and
SNOWPLOWING PROCEDURES**

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and

Federal Highway Administration
U.S. Department of Transportation

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<p>16. Abstract</p> <p>The objectives of this study were to investigate viable alternatives to the currently approved snowplowable raised pavement marker and alternative methods and equipment used to snowplow roadways. The study included evaluating any potential durable and effective pavement marker that is not disruptive to snowplowing operations and alternative snowplowing procedures and equipment that do not damage pavement delineation and pavements. Implementation possibilities resulting from the research project include a recessed snowplowable marker and improved/alternative snowplowing procedures and equipment.</p> <p>The alternative snowplowable markers included in the evaluation were the current steel casting marker and a recessed marker. The evaluations confirmed past research that the steel casting marker can be used on new pavement if the casting and lenses are properly installed and maintained. Also, the pavement surrounding the casting must be maintained. The limited experience with the recessed marker has shown it to be an effective alternative to the current steel casting marker. The durability and effectiveness of the recessed marker should continue to be monitored.</p> <p>There are alternatives to the current snowplowing procedure of using steel blades with full weight on the pavement. Several types of blades were evaluated with varying levels of success. Evaluation of alternative snowplowing procedures should continue using information found from these initial trial tests. Contractors should be allowed the flexibility to use alternatives to steel blades with their performance monitored.</p>			
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TABLE OF CONTENTS

	Page
Executive Summary.....	ii
Implementation	iii
Acknowledgments.....	iv
1.0 Background.....	1
2.0 Objectives.....	2
3.0 Work Plan	2
4.0 Alternative Snowplowable Pavement Markers	3
5.0 Alternative Snowplow Procedures.....	5
6.0 Test of Alternative Snowplowable Markers.....	13
7.0 Evaluation of Snowplow Equipment	14
8.0 Conclusions.....	17
9.0 References.....	18

EXECUTIVE SUMMARY

The objectives of this study were to investigate viable alternatives to the currently approved Type V snowplowable raised pavement marker and alternative methods and equipment used to snowplow roadways. Completing the objectives of the study involved determining the state of practice related to the use of pavement markers in areas subject to snowplows and the state of the practice related to snowplowing procedures and equipment. The study included evaluating any potential durable and effective pavement marker that is not disruptive to snowplowing operations and alternative snowplowing procedures and equipment that do not damage pavement delineation and pavements. Implementation possibilities resulting from the research project include a recessed snowplowable marker and improved/alternative snowplowing procedures and equipment.

The alternative snowplowable markers included in the evaluation were the current steel casting (Type V) markers and a recessed marker (Marker One). The evaluations confirmed past research that showed the Type V marker can be used on new pavement if the casting and lenses are properly installed and maintained. Also, the pavement surrounding the casting must be maintained. The limited experience with the recessed marker has shown it to be an effective alternative to the Type V marker. The durability and effectiveness of the recessed marker should continue to be monitored.

There are alternatives to the current snowplowing procedure of using steel blades with full weight on the pavement. Several types of blades were evaluated with varying levels of success. Evaluation of alternative snowplowing procedures should continue using information found from these initial trial tests. Contractors should be allowed the flexibility to use alternatives to steel blades with their performance monitored.

IMPLEMENTATION

The initial evaluation of the recessed marker (Marker One) has found it to have potential as an effective alternative snowplowable marker. Installation of the recessed marker has been included in additional projects. Evaluation of these markers on a larger scale will allow a basis for a decision of their future use. Alternative designs for the placement of the two lenses in the groove will be evaluated.

Installation of the steel casting (Type V) marker will continue on multi-lane highways. The installation process will insure that the markers are not installed on the pavement joint. Lenses must be replaced on an appropriate interval to maintain effectiveness with the condition of the surrounding pavement evaluated.

Contractors will be allowed to use alternative snowplow blades. The effectiveness of alternative blades will continue to be evaluated as they are used on a larger scale.

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1.0 BACKGROUND

Typical traffic paint and tape do not provide effective delineation during wet, nighttime conditions. Snowplowable markers (Kentucky Transportation Cabinet (KYTC) Type V Marker) have been used since the 1980's to provide delineation under these conditions. In recent years there have been increased maintenance issues related to the Type V snowplowable marker which has been used in Kentucky and many other states with significant snowfall. A recent evaluation of the use of snowplowable raised pavement markers (1) concluded that the currently approved Type V marker could be used if it was properly installed on new pavements with a commitment to maintain the pavement and marker. A recommendation from that research was that alternate and innovative snowplowable marker designs should be evaluated.

There is a need to develop a method of marking the pavement and delineating travel lanes with a durable marker which will provide wet-nighttime delineation and will be compatible with snowplow operations. Also, the method of snowplowing should minimize damage to the pavement markers, other pavement delineation, and the pavement.

A potential method of alleviating damage to pavement markings and to the pavement is to modify the current "bare pavement" using the full-weight of a steel snowplow blade on the surface. The goals of the KYTC snow and ice control program are to:

- provide bare pavement or adequate traction on road surfaces
- keep traffic moving in a safe and uninterrupted manner
- provide statewide uniformity of pavement conditions within each snow and ice control priority system
- consider economic and environmental factors while achieving safe driving conditions

Alternative procedures are used in other states to reduce the damage to pavement markings during snowplow operations. These include using alternative types of snowplow blades, procedures to reduce the weight of the plow on the pavement, and plowing without the blade riding on the surface.

This project investigated: a) alternatives to the current Type V snowplowable marker and b) alternative snowplowing procedures to provide adequate traction on road surfaces.

2.0 OBJECTIVES

The objectives of this study were to investigate:

- viable alternatives to the currently approved Type V snowplowable raised pavement marker and
- alternative methods and equipment which could be used to snowplow roadways.

Completing the objectives of the study involved following phases of work:

- determine the state of practice related to the use of pavement markers in areas subject to snowplows,
- determine the state of the practice related to snowplowing procedures and equipment,
- evaluate any potential durable and effective pavement marker that is not disruptive to snowplowing operations, and
- evaluate alternative snowplowing procedures and equipment that do not damage pavement delineation and pavements.

Implementation possibilities resulting from the research project include:

- identifying an alternative snowplowable marker and
- improved/alternative snowplowing procedures and equipment.

3.0 WORK PLAN

Following is a summary of the phases of the work plan used to achieve the objectives of the study.

Task 1: Alternative Snowplowable Pavement Markers

The literature was reviewed to determine available pavement markers which could be used effectively in conjunction with snowplows. This task included a review of relevant research, a review of state specifications for snowplowable markers, and contact with state representatives to determine their experience with a marker which can be used with snowplows.

Task 2: Snowplowing Procedures

The literature was reviewed and information from various states were obtained to determine alternative procedures and equipment which can be used to provide effective snowplowing operations. Also, a survey of each of the twelve Kentucky Transportation Cabinet (KYTC) highway districts was conducted to determine the status of snowplowing procedures in Kentucky and possible alternatives in the future. Visits were made with representatives of some cities in Kentucky who were using procedures or equipment different from the KYTC. Several companies marketing alternative snowplow equipment were contacted to obtain information about their products. KYTC snowplow contractors were contacted with visits made to some that used different types of snowplow blades.

Task 3: Test of Alternative Snowplowable Markers

After the review determined any available alternative snowplowable markers, the objective was to evaluate the performance of any identified markers. This included test installations of any potential alternative.

Task 4: Evaluate Snowplowing Procedures

Alternative snowplowing procedures and equipment were identified. Potential snowplow procedures and products were tested at selected test locations.

4.0 ALTERNATIVE SNOWPLOWABLE PAVEMENT MARKERS

The first evaluation of snowplowable raised pavement markers (RPM) in Kentucky was conducted in 1982 (2). The evaluation of several potential types of snowplowable markers resulted in the recommendation that the Stimsonite 96 (steel casting) marker and a recessed marker design should be used. The first large scale installations of these two types of snowplowable RPM were awarded in 1984 and 1985. An evaluation of these installations found they were effective with the recommendation that the steel casting type of marker should continue to be used (3).

Use of the snowplowable RPM continued in Kentucky for many years on a system of about 5,400 miles until issues with durability started to occur. A national study questioned the effectiveness of RPM in reducing crashes (4) and one state conducted a survey to evaluate the durability of these markers (5). These concerns resulted in a study to evaluate the effectiveness and durability of snowplowable RPM installed in Kentucky (1). The study

concluded that continued use of the currently approved snowplowable marker can be justified if the castings are properly installed on new pavements with a commitment that the pavement and castings will be maintained. The study recommended an evaluation of: a) alternative snowplowable marker designs, b) paint and tape marketed as having the capability of providing delineation during wet conditions, and c) use of centerline and edge line rumble stripes.

The literature was reviewed to determine the status of alternative snowplowable marker designs. Specifications providing marker designs for other states were reviewed. Also, various manufacturers were contacted to determine the status of alternative designs.

Specifications were located for a few states which had various designs for recessed markers. The states and the date of the specification include: California (May 2011); Arizona (June 2008); Oregon (December 2008); and Alaska (April 2006). The California, Arizona, and Oregon specifications have drawings for both one-way and two-way traffic while Alaska is for two-way. The specifications are very similar as far as the dimensions of the cut.

Observations were made of a large-scale installation of recessed markers in Maryland. The recessed marker has a length of four feet with the lenses from a steel casting marker placed at the end of the groove. Nighttime observations showed these markers provided effective delineation.

Some manufacturers indicated they were experimenting with snowplowable marker designs using a lighter material than that used for the steel casting of the currently used marker. However, no manufacturer indicated they had progressed to having a marker which could be used in a test installation.

One manufacturer has developed a new design for the typical steel casting marker. None of these markers have been installed.

A new design of a recessed marker was reviewed. The design (referred to as the Marker One pavement reflector) uses the lenses placed in the traditional steel casting placed in a long, shallow recessed groove. Either one or two lenses are placed in a groove which has a length of eight feet. The depth of the groove goes down to 0.37-inch except for the area where the lenses are placed which has a depth of one inch. If one lens is used it would be placed in the middle of the groove. If two lenses are used, two possible placements could be used. The possibilities are placing one of the lenses near the middle and one near the end or to place each lens about three feet from either end of the groove.

The largest installation of the Marker One marker has been in Missouri. In May 2012 both day and night observations were made on large installations of this marker placed on I-44 and I-70 around St. Louis. Each groove had two lenses. The markers on I-44 were almost one year old with the I-70 installation about a year older. These interstates are in an urban area with very high traffic volumes. The markers were installed on both asphalt and concrete pavements. The cost to cut the groove and install the markers was about \$35 per groove. Daytime observations showed that most cases where there was a lack of observed nighttime reflectivity were due to lenses damage (rather than the total marker missing). A state representative noted that too much sealant on the concrete resulted in some lenses coming up with a thin layer of concrete attached. Nighttime observations on I-44 of about 2,400 grooves (or about 4,800 lenses) found 13 percent of the lenses not reflective. There were about 17 percent of the grooves with one lenses reflective and 4.4 percent with neither lenses reflective. On I-70 for about 1,150 grooves (or about 2,300 lenses), 31 percent of the lenses were not reflective. There were about 32 percent of the grooves with one lenses reflective and 15 percent with neither lenses reflective.

5.0 ALTERNATIVE SNOWPLOW PROCEDURES

5.1 KYTC District Interviews

Interviews (either in-person or by telephone) were conducted with a representative from each of the twelve district offices of the KYTC. A person knowledgeable of the snowplowing procedure used in each district was identified. Following is a list of the questions included in the interview. The questions attempted to identify past experience in the district and their opinion about possible changes which could be used to improve the current procedure.

1. Have they had experience with any type of snowplow blades except the steel blade? If yes, describe.
2. Have they ever used the shoe on their plow while plowing? If yes, describe their experience.
3. Are they aware of alternative types of snowplow blades?
4. Do they believe it would be beneficial to evaluate alternative types of blades?
5. Have they had problems with damage to their blades? Describe.
6. What is the estimated life of a blade using the current procedures?
7. Have they had situations where the blade damaged the pavement?
8. What is their experience with plowing the “steel casting” marker?

9. Have they noted damage to pavement markings (striping) as a result of snowplow operations? If yes, describe.
10. If a shoe could be developed which would be durable, do they believe it would be beneficial to evaluate use of this device during plowing operations?
11. Does the procedure of allowing the blade to ride “full weight” on the pavement cause any problems with the operation of their vehicle? If yes, describe.
12. Is there a potential use of a “plow weight control system” device which would allow decreasing the weight of the plow applied to the surface?
13. Note the major types of complaints made by the public relative to snowplow operations.
14. Should a procedure where the plow rides on a shoe and does not directly contact the pavement (where chemicals and traffic combine with the plowing to remove “all” the snow) be evaluated?
15. What is the benefit of applying the full weight of the plow directly to the pavement (rather than using a combination of alternative procedures to remove the snow)?

Following is a summary of information obtained from the interviews with the representatives from each highway district. In nine districts the interview was conducted at the district office with the other three interviews conducted by telephone.

- All state trucks equipped with snow plows use steel blades. The only current experience with an alternative blade on a state-maintained highway has been the use of a rubber blade by two contractors in District 6 (on interstate highways). A rubber blade was used many years ago on state trucks but was discontinued due to excessive wear.
- Some cities (Owensboro, Bowling Green, and Richmond) are using rubber blades.
- Statewide there are substantially more state trucks used to snowplow than contract trucks. The exceptions are the more urban districts (Districts 5, 6, and 7) which have more interstate highways where there are more contract trucks.
- The plow shoe is not currently used in the plowing process. The shoe may remain on new plows but is commonly off older plows. There was limited use of the shoe in the past in an attempt to reduce wear on the blade but the results were not successful.
- A version of the shoe has been used in conjunction with rubber blades to reduce wear to the blade. Positive results were reported by the contractors in District 6.
- The districts have no experience with the use of alternative blades. Some were aware of the use of other types of blades in other states.

- Most felt it would be beneficial to evaluate other types of blades. However, the other blades must be shown to be effective and capable of achieving the current “bare pavement” policy.
- Most questioned the ability of alternative blades to remove packed snow or ice conditions.
- There was a range in opinion concerning the extent of damage to steel blades using the current procedure. A major source of damage was contact with bridge ends and manhole covers. Some reported that blades would break before wearing out. A couple of districts noted that they have recently received a new type of steel blade which appears to be more durable.
- The life of a steel blade depends on the type of plowing. For example, on a one-inch snow where the blade scrapes the pavement the life will be reduced. The experience of the driver is also a factor. The expected life of a steel blade ranged from a low of 12 to 20 hours noted in a few districts to others using the same blade all winter.
- There has not been a documented problem with the blade damaging the pavement. The plow has a mechanism to trip the plow which minimizes this type of damage. The plow may damage bridge ends and manhole covers. Pavement patches can create a problem.
- There has been no problem with plowing milled rumble strips (either centerline or edge line).
- The plow has removed steel casting markers from the pavement (typically along with a section of asphalt adhered to the marker) in situations where the marker is loose. This typically occurs when there is pavement deterioration around the marker. This is more of a problem when the marker is installed too close or on the pavement joint. The plow will also damage the marker and lenses. Some drivers will attempt to avoid the marker which results in a strip of snow along the centerline or lane line.
- Damage to typical paint striping is not obvious but the plow results in obvious damage to pavement tape and thermoplastic markings. There was agreement that the current policy results in extensive damage to the pavement marking system.
- There is skepticism that a more durable shoe could be effectively used during the plowing process.
- The general opinion was that experienced drivers do not have a problem with the handling of the snowplow truck using the current procedure. It was noted that the plow will affect steering.
- There was general agreement that it would be beneficial to evaluate the use of a “plow weight control system.” Questions of the use of such a system included how it would be used with the current plow and if it would be effective in removing packed snow.
- The major complaint from the public is not plowing their road soon enough.

- The public is accustomed to the “bare pavement” policy and any change must be accompanied with public information.
- The consensus was that the blade must contact the pavement. Use of a procedure where the plow does not contact the pavement and relying on chemicals and traffic to remove all the snow would result in the use of more salt than currently used.
- The benefit of applying the full weight of the plow to the pavement is to achieve the “bare pavement” objective for hard packed snow. This procedure reduces the amount of time required to complete the plowing operation.
- There is an objective to reduce the amount of salt used in the snow removal process. The use of salt has been lowered from a range 400 to 500 pounds per two-lane mile down to 200 to 250 pounds.
- Contractors commonly use an excessive amount of salt. Their use of salt must be monitored.
- While a “bare pavement” policy may be appropriate on interstates and parkways and other high volume roads it is not needed on other roadway classifications.
- There should be increased pavement pre-treating and use of chemicals and less use of salt.
- Care should be taken so that the road is not plowed before the pre-treatment starts to effectively work.
- Various types of chemicals have been used in an attempt to increase adhesion to the pavement, reduce corrosion to equipment, and reduce the use of salt.
- The cost per ton of salt is more than that for asphalt. This illustrates the need to reduce the use of salt.
- The current procedure requires all routes to be clear before operators can stop. This results in drivers using the quickest method to remove the snow (which might not be the most appropriate).
- The cost to the entire roadway system must be considered when evaluating the cost of the snow plowing operation.
- Placing a different blade on the section of the plow which contacts the pavement marking system (striping and markers) could be an alternative.
- The shoulder should be plowed to prevent drainage back onto the travel lanes.
- The “bare pavement” policy can have a negative effect on safety if it creates a false sense of security for drivers who then encounter isolated ice spots.
- A potential alternative is to use a combination blade with a metal blade (which does not contact the pavement) followed by a rubber blade (which removes the remaining snow). However, the cost of this type of blade may be prohibitive.

- The proper speed of the snowplow must be maintained. Problems occur when the speed becomes too high.
- There was a past proposal for the plow to use a shoe with the blade not contacting the pavement but this method was not implemented.
- They have had to stop operators from having their blades down when it was not necessary. This increases the damage to the roadway and equipment.
- Various mixtures of chemicals have been used to lower the temperature where they can be effectively used.
- It may be easier and safer to use a blade lighter than the steel blade.
- Opinions were inconsistent concerning whether chains could be used to lessen the weight of the plow on the pavement.

5.2 KYTC Contractor Interviews

As a result of the district interviews a couple of contractors who had used alternatives to the typical steel snowplow blade were identified. Both of the contractors plow interstates in northern Kentucky. Following is information obtained from visits and interviews with these contractors.

Kentucky Materials Transport (KMT)

1. They use rubber blades which, in their opinion, are superior to steel blades in normal snow.
2. Steel blades are no better on packed ice than rubber blades.
3. The weight of the plow to the pavement is limited to pressure from its hanging weight. The only method to remove ice is to increase pressure with use of a blade under the truck.
4. Using their procedure, the rubber blade lasts four to six times longer than steel blade. Rubber blades will last 40 to 46 hours compared to eight to 10 hours for a steel blade.
5. Metal wheels on the plow are used to prevent contact with the plow moldboard and the pavement.
6. The rubber blade is installed between a single metal plate and the moldboard. When the rubber blade is worn it is moved upward in a slot. The bolt attaching the blade to the plow is initially positioned at the bottom of the slot. When the blade is worn it is moved upward in the slot. After more wear the blade is flipped which allow several positions of wear for the blade.
7. They plow at 35 to 40 mph. Higher speeds cause more wear.
8. They removed rollers/coasters from the plow and gauge wear from the moldboard.

9. Cost of a 12-foot blade is about \$150 less for rubber than a one-inch thick steel blade. The cost is about \$165 for a rubber blade. The blades are 10-inches in height with a depth of 1.5 inches.
10. They plow on interstates (I-75 and I-275) using the rubber blade.
11. The state operates on non-interstates in their district where speeds are less and blades last longer.
12. Steel blades cause damage to manhole covers, etc.
13. Rubber blades do not damage snowplowable raised pavement markers.
14. They are not familiar with a system that would reduce pressure on blades on the pavement but believe this could be effective (depending on driver).

A demonstration of the equipment used by KMT was attended by KYTC representatives. The performance of the rubber blades was described with information provided to describe how they can be used most effectively.

Bray Trucking

1. They use a hard rubber blade until freezing temperature and then will use steel.
2. The rubber blade is better when used over snowplowable markers than steel.
3. The cost of rubber is about one-half that for steel.
4. Rubber blades last about the same as steel (rubber will last 20 hours on one side and then flip and use another 20 hours; steel will last about 36 hours).
5. Rubber blades are not as rough on equipment or pavement compared to steel blades.
6. They use rubber wheels on their plows but the blade will touch the pavement. The wheels are replaced but will last all winter. The wheels will take some pressure (shock) off blade.
7. They plow interstates (on I-471, I-275) as well as the AA Highway and US 27.

5.3 Review of Literature

The review of literature identified alternatives to the current snowplow procedure using used in Kentucky which involves a steel blade with full weight on the pavement. Following is a list of some of the alternative blades/procedures.

- carbide blades
- rubber blades
- tungsten carbide inserted segments in rubber blade
- multi-blades

- polyurethane blades
- polarflex blades
- plow weight control systems
- snow plow shoes

The manufacturer's literature listed the advantages of each of the alternative blade materials. For example, advantages of the polyurethane material described by the manufacturer included better abrasion resistance, less damage to the road surface, and reduction of vibration.

One study predicted the performance of carbide-insert plow blades (6). The goal of the project was to develop standardized testing procedures for carbide inserts that would improve agencies' ability to predict their performance. The study was conducted since many agencies have started to use plow blades with carbide inserts which are made of tungsten carbide. A test procedure was developed to differentiate between carbide-insert blades that perform well and those that will not.

A synthesis of research on use of various plow blades and their performance and wear was conducted by the Minnesota Department of Transportation (7). Improved plow performance, improved blade wear, reduction of impact to surface and pavement markings, and an overall improvement was found with the following blades:

- rubber-encased steel blades
- alternative carbide edge blades
- adjustable blade system

Evaluations of the JOMA rubber-encased steel blades were reported from Ohio, Iowa, Wisconsin, and the Clear Roads project. The evaluations reported favorable results including longer blade life, less maintenance, lighter for installation, less road surface impact, less driver fatigue, smoother and quieter ride, cleaner roads, and better interaction with raised pavement markers. This blade is more expensive than conventional steel blades. Solid rubber blades and carbide edge blades did not receive favorable results compared to conventional blades. Possible adverse effects of current blades on new types of pavements were noted as a reason to evaluate new types of blades.

Three alternative plow blades were compared to the standard carbide blade system in a North Dakota study (8). The three blades systems were:

- Joma (tungsten carbide inserts in rubber casing)
- Polar Flex (carbide inserts)
- Stacked blade traditional carbide steel

The stacked carbide steel blades showed no advantage over traditional carbide blades. The Joma and Polar Flex blade systems conformed better to the road and had reduced noise and vibration. The Joma and Polar Flex blades lasted three to four times longer than traditional carbide steel blades and provided better cleaning performance.

The Kuper Tuca SX36 (rubber and ceramic) plow blade was tested in Maine and compared to the standard carbide blade (9). The Kuper blades were quieter and outlasted the standard blade by an approximate 2.25:1 ratio. Using the increased cost of the Kuper blade, it would have to last about five times as long as the standard blade to be cost effective. After four years of evaluation, the conclusion was the Kuper plow blade did not provide a cost effective alternative to the standard carbide blade.

A report describing snow and ice control discussed alternative blades (10). It was noted that most plow blades are made of steel but it is not unusual to have to change or reverse steel cutting blades every several hours. Steel blades with tungsten carbide or ceramic inserts wear much slower and may have to be changed only once per season in a high use environment. Also, mounting a regular steel cover blade in front of the tungsten carbide blade can extend the life of these blades.

An evaluation of multiple-blades was conducted through a Clear Road project (11). Blades were evaluated from five vendors in five states and included combinations of a flexible cutting edge, squeegee blade, and scarifier blade. The multiple-plow blade was conceived as a way for operators to apply the most appropriate blade based on roadway conditions (snowy, slushy, ice-covered, or hardpack) to clear the roadway with a single pass, without swapping out blades or plows. States discovered that factors such as climatic conditions and the capabilities of existing winter maintenance fleets will affect how a multiple-blade plow is used.

The factors which affect the selection of the cutting edge for a snowplow were discussed in another report (12). The factors include wear and shock resistance of the cutting edge, the nature of pavement markings on the roads, the nature of the pavement surfaces, issues with noise and vibration, and the life-cycle costs. The blades considered included:

- traditional steel blade
- steel and carbide blade
- advanced composite carbide blade
- traditional rubber blade
- advanced composite rubber blade

A substantial amount of research in this area has been a result of the Clear Roads project which is a pooled fund research project for winter highway maintenance. The research has included testing of winter maintenance equipment. For example, one project's goal was to develop and test a new snowplow design that uses new materials and structural components better suited to a more pro-active approach to snow removal.

Another Clear Roads project developed and tested multiple blade plow prototypes (13). Four vendors developed multiple blade plows. The prototype blades included a flexible cutting edge, scarifier, and squeegee. Differing experiences and degrees of success were obtained. The squeegee blade met with the greatest success. Some states noted concern about wear with the flexible blades and scarifier.

Clear Roads provided a summary of alternative snow plow designs in a 2006 report (14). Several types of cutting edges were evaluated by various agencies.

Alternative blade material have been evaluated for many years as illustrated by a 1995 evaluation of urethane blades as an alternative to rubber blades (15). The study found that urethane blades cleaned the roadway surface better than rubber blades but were subject to the same problem with low durability.

6.0 TESTS OF ALTERNATIVE SNOWPLOWABLE MARKERS

The Marker One recessed marker design was determined to be the currently available alternative design to the traditional steel casting snowplowable marker. An initial test of 30 grooves (60 lenses) was installed on I-64 at the Fayette County/Scott County line in October 2011. The groove is eight feet in length with one marker placed in the middle and one within one foot of the end of the groove. The durability of the lenses was monitored. Both day and night inspections were conducted during both dry and wet conditions. None of the lenses were missing after two winters. Water was found to drain from the groove quickly. Debris did not accumulate in the groove.

The first large scale test of the Marker One recessed marker was part of resurfacing projects. The projects were on US 127 in Mercer County and US 27 in Jessamine County. Both roads are four-lane, rural roads. The two US 127 projects in Mercer County were 1.5 and 2.7 miles in length with a total of about 550 grooves (1,100 lenses). The US 27 project on Jessamine County had a length of about 0.8 mile with about 110 grooves (220 lenses). These projects were installed in November 2012. The unit cost for these small contracts ranged from

\$31.50 to \$38.00. Each groove was eight feet in length with two lenses in each groove (four feet and seven feet from the start of the groove).

The test sections were monitored during day and night conditions and during both dry and wet conditions. Attempts were made to inspect the grooves during rain to determine if water accumulated in the groove which would decrease the effectiveness of the lenses. There was no water accumulation where there was a grade. Water accumulation in the groove was observed around a hillcrest and on flat sections but infrequently was both lenses covered. For example, one inspection in December 2012 during a substantial rain found no accumulation on the US 27 test (where there is a substantial grade) with only about two percent of the grooves on the US 127 grooves having water over both lenses and about 20 percent having water over one lenses. The marker system remained effective during the rain. The benefit of having two lenses in each groove was demonstrated.

Another inspection in December 2012 during a heavy rain found about 12 percent of the grooves had one lenses covered with water with about three percent having both lenses covered. The water drained very quickly from the groove if there is any grade. On flat surfaces, it took longer for the water to drain from the area adjacent to the lenses where the groove is cut deeper to allow for placement of the epoxy for the marker. Additional inspections have been made during and after varying levels of rain. Similar observations were noted. Water would quickly drain from the groove with one lenses covered with water on flat surfaces for a longer time period.

After one winter (with limited snowplow use) only about three of approximately 1,850 lenses were missing. No damage to the pavement has been noted as a result of the groove.

The initial positive results of the recessed marker installations have resulted in additional tests. The Marker One recessed marker was included in four additional resurfacing projects to be completed in 2013. These projects are on four-lane roadways and cover about 21 miles. Three of the projects are on interstates (with about 11 miles).

Observations were made after installation of the standard Type V marker on I-64 in October 2011. Another installation on the Bluegrass Parkway in October 2011 has been monitored. Type V markers were installed in Garrard County on US 27 along with the recessed markers in Jessamine County. Inspections have found a very limited amount of lenses damage with no damage to the castings.

7.0 EVALUATION OF SNOWPLOW EQUIPMENT

The review of the snowplow practice found alternative materials to the steel blade. Arrangements were made to evaluate some alternative blades.

The following snowplow blades were installed (prior to the 2011-12 winter season) on trucks performing snowplow work in Madison County. The blades were 12 feet in length. The rubber and ultra-high molecular polyethylene (UHMD) were 1.5 inches thick and eight inches high.

- JOMA 6000
- Kuper
- rubber blade
- rubber blade with UHMD backing

The snowplow contractor (Red River Ranch) placed blades on three of their trucks for use on I-75 in Madison County (which has three lanes in each direction). These blades were the JOMA 6000, rubber blade, and rubber blade with UHMD backing. The Kuper blade was installed on a KYTC truck which plowed on US 25 and KY 21.

The following costs were noted.

- JOMA 6000 \$3,300
- Kuper \$1,500
- rubber \$24 per foot
- steel \$10 per foot

A form was developed to be completed by the snowplow operators after their use for each snowplow event. The following information was included on the form.

- the height of the blade before and after use
- miles plowed
- hours plowed
- type of event (snow or slush)
- comments (noise; vibration; effectiveness; pavement marker/bridge end issue)

There was a very limited use of the alternative blades on I-75 during the 2011-12 winter season with some use during the 2012-13 winter. The rubber blade sustained substantial wear in a few miles and was removed. The rubber blade with the UHMD backing and the JOMA

blade performed as well as the steel blade with less vibration and bounce when the blade contacted the snowplowable markers.

The Kuper blade was removed after use in the 2012-13 winter season. There was wear on the blade and the operator felt it had started to vibrate. An examination of the blade after removal indicated that the plow had not been rolled forward which resulted in the edge of the blade contacting the pavement rather than the blade being flat with the pavement. This resulted in excessive wear. A discussion with another state found they had successfully used the Kuper blade but made adjustments to the blade pitch to improve wear.

An additional rubber blade was obtained to use in Madison County prior to the 2012-13 winter. The rubber blade was part of a new plow obtained from the manufacturer. A rubber blade was used for about 50 miles during one snow event for about 5.5 hours. There was no excessive wear (with some wear on the back edge of the blade). The blade was quieter than the metal blade and was as effective. There was vibration with the rubber blade with no difference in bouncing of the blade when it hit an object in the road.

Alternative snowplow blades were also obtained in Simpson County. Two rubber blades were used with one blade made of polyurethane material. One of the rubber blades was identical to the rubber blade used in Madison County. The second rubber blade was marketed as being made with a very abrasive resistant rubber material. Both of the rubber blades are 10 feet long with a thickness of 1.5 inches. The heights of the two blades are eight and ten inches. The polyurethane blade had a 10-foot length with a height of 10 inches and a depth of 2 5/8 inches (with a cost of about \$1,000). These blades were not used during the 2011-12 winter. One of the rubber blades was used during the 2012-2013 winter. The rubber blade was used for slightly over 20 miles and sustained substantial wear. An issue with the test section was that it included sections of high friction surface which may have increased wear.

Another highway district has purchased rubber blades for use in the next winter season. One metal strip will be used to attach the blade to the plow. This district has also installed a device on a couple of trucks with the objective of reducing the weight of the plow force on the pavement.

Discussions were held with the contractor in northern Kentucky who has reported successful use of rubber blades. The contractor noted the importance of attaching the rubber blade to the plow with one metal strip (rather than two). The rubber blades had been attached to the plow by two metal strips for the original KYTC tests. Future tests of the rubber blade

should include attachment with one metal strip. Also, the contractor has used a wheel to indicate when the wear on the rubber blade has reached the plow.

Cities have used alternatives to the steel blade. Specifically, discussions were held with representatives from Owensboro and Richmond about their use of rubber blades. Both cities reported positive results with use of rubber blades at low speeds on city streets. Owensboro noted use of caster wheels to reduce the weight of the blade on the surface with no durability problem with the caster wheels. Owensboro has also purchased a multi-blade plow (a steel blade followed by a rubber blade) to test. Richmond has used rubber blades for over 10 years. They estimated the rubber blades last a couple of years with flipping them after wear on one side.

8.0 CONCLUSIONS

8.1 Snowplowable Markers

The alternative snowplowable markers included in the evaluation were the current steel casting (Type V) markers and the recessed marker (Marker One). The evaluations confirmed past research that showed the Type V marker can be used on new pavement if the casting and lenses are properly installed and maintained. Also, the pavement surrounding the casting must be maintained.

The limited experience with the recessed marker has shown it to be an effective alternative to the Type V marker. The durability and effectiveness of the recessed marker should continue to be monitored.

8.2 Snowplow Equipment

There are alternatives to the current snowplowing procedure of using steel blades with full weight on the pavement. Several types of blades were evaluated with varying levels of success. Evaluation of alternative snowplowing procedures should continue using information found from these initial trial tests. Contractors should be allowed the flexibility to use alternatives to steel blades with their performance monitored.

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