Effective Removal of Pavement Markings

by

Adam M. Pike, P.E. (Corresponding Author)
Associate Research Engineer
Signs and Marking Program
Texas A&M Transportation Institute
3135 TAMU
College Station, Texas 77843-3135
Phone: 979-862-4591
Fax: 979-845-6006
Email: a-pike@tti.tamu.edu

Paper prepared for the 95th Annual Meeting of the Transportation Research Board

Total Words: 144 (abstract) + 6331 (body) + 1000 (4 Figures*250) = 7475 words
Effective Removal of Pavement Markings

Adam M. Pike

ABSTRACT

This paper documents the results of NCHRP Report 759, Effective Removal of Pavement Markings. Researchers evaluated the state of the practice of pavement marking removal by conducting a literature review and nationwide survey in combination with field tests and field observations of pavement marking removal. The survey yielded 55 responses from a combination of state and local agencies as well as contractors, equipment manufacturers, and industry groups. Five different removal methods were evaluated in the field while removing eight different pavement marking types on multiple pavement surfaces. In an attempt to quantitatively compare the various removal techniques, the field removal testing utilized multiple performance metrics. The resulting measures of performance coupled with the field observations and survey results yielded recommendations to aid in the selection of pavement marking removal techniques. The researchers also developed best practices to improve the results of pavement marking removal.
INTRODUCTION

While the need to remove pavement markings may occur during the end of the service life of a marking, it is also common to remove or obscure markings due to construction work that requires lane shifts or changes in the traffic pattern. Pavement markings that were previously used as guidance need to be removed or obscured so that new markings can be applied to form the new traffic pattern. Markings that are not effectively removed or obscured can be confusing to drivers and create an unsafe driving environment. Ineffective pavement marking removal results in at least two primary outcomes: (1) the marking is not completely removed and results in a marking that may suggest the original travel path is still the intended travel path, or (2) the marking is completely removed, but the removal technique has produced a scar or surface discoloration that provides a significant texture or color contrast with the surrounding pavement surface that may also suggest the original travel path is still the intended travel path.

The Federal Highway Administration (FHWA) Manual on Uniform Traffic Control Devices (MUTCD) addresses pavement marking removal in two sections as seen below (1).

Section 3A.02 Standardization of Application
Standard: Markings that are no longer applicable for roadway conditions or restrictions and that might cause confusion for the road user shall be removed or obliterated to be unidentifiable as a marking as soon as practical.
Option: Until they can be removed or obliterated, markings may be temporarily masked with tape that is approximately the same color as the pavement.

Section 6F.77 Pavement Markings
Standard: For long-term stationary operations, pavement markings in the temporary traveled way that are no longer applicable shall be removed or obliterated as soon as practical. Pavement marking obliteration shall remove the non-applicable pavement marking material, and the obliteration method shall minimize pavement scarring. Painting over existing pavement markings with black paint or spraying with asphalt shall not be accepted as a substitute for removal or obliteration.
Option: Removable, non-reflective, preformed tape that is approximately the same color as the pavement surface may be used where markings need to be covered temporarily.

The MUTCD does not address how to determine if a removed marking is unidentifiable or what measures should be used to evaluate whether a removal technique is able to minimize pavement scarring. Not addressing these two issues results in a variable quality of pavement marking removal. If an agency establishes a requirement for 100 percent marking removal so that the marking is unidentifiable, the resulting removal may produce an excessive amount of pavement scarring. In contrast, if an agency establishes a policy of minimizing pavement scarring, the removal may result in insufficient pavement marking removal. A compromise between complete removal and limiting pavement damage needs to be made in most situations. This is a difficult problem that is faced by every transportation agency. This is further compounded by the lack of sufficient guidance on the following: (a) what removal techniques are available; (b) what the trade-offs are of each technique with respect to effective removal versus the amount of scarring;
and (c) whether any of these techniques could be combined to improve the percent material
removed, reduce the scarring, and/or reduce the process time and/or cost.

The objective of this research was to determine best practices for the safe, cost-effective, and
environmentally acceptable removal of work zone and permanent pavement markings with
minimal damage to the underlying pavement or visible character of the surface course. The
research was divided into two phases. Phase I of the research focused on collecting information
on pavement marking removal techniques and past experiences through a nationwide survey and
a literature review. Phase II of the research focused on field evaluations of different removal
techniques. This paper will provide an overview of the full NCHRP 759 Research Report (2)

PREVIOUS RESEARCH

Over the years, pavement marking removal methods have evolved and new methods have been
developed. In general, pavement marking removal is completed using some form of blasting,
grinding, burning, laser, chemical, or masking technique (3, 4, 5). The effectiveness of each of
these removal methods is impacted by the type of material being removed, the material thickness,
the pavement surface, the allowed duration of the work activity, and the skill of the equipment
operator(s) (3).

A study conducted in Utah by Berg and Johnson focused on evaluating five specific removal
technologies (3). There were three blasting methods (i.e., high-pressure water, soda, and dry-ice)
and two grinding methods (i.e., carbide and diamond bit). The high-pressure water blasting and
the two grinding methods were conducted using large mobile truck units that provided greater
productivity and ease of operation than the soda and dry-ice blasting. Test removal sections
consisted of waterborne paint on an asphalt chip seal pavement and waterborne paint over an
existing epoxy line on a Portland cement concrete (PCC) pavement. The researchers evaluated
the amount of time with respect to linear feet of line removed per minute for each method for
each test section. The researchers also assessed other subjective factors, such as pavement
surface damage and overall impact of the removal method. While the grinding removal methods
were faster than the high-pressure water blasting, the high-pressure water blasting resulted in the
least amount of pavement damage. The high-pressure water blasting also had the least amount of
during and post application complications with regard to dust and noise concerns. The soda and
dry-ice blasting were both noted to be very slow compared to the vehicle-mounted removal
methods, but the removal left very little pavement degradation except for some pitting of the chip
seal surface. The soda blasting generated a large amount of dust that could be a potential safety
hazard by lowering visibility. The research recommendations/implémentations indicated that the
two grinding technologies are still the most effective in removing lines quickly and leaving the
surface ready to be restriped. It was also suggested that the soda and dry-ice technologies should
be investigated if space is limited or there are other special circumstances, but the speed and
possible visibility issues need to be considered. Finally, the water blasting technology was the
most effective at marking removal with the least amount of damage to the pavement and should
be investigated for future use.

The Florida Department of Transportation sponsored two separate research efforts to investigate
how to eradicate pavement markings, with one focused on the actual removal of the pavement
markings (4) and one focused on methods to mask or cover the pavement markings with an inexpensive surface treatment or black tape (5). In the first study, Ellis, Ruth, and Carola investigated the removal of paint, thermoplastic, and temporary tape on asphalt concrete using high-pressure water blasting (full truck and hand-operated walk-behind systems), grinding (hand-operated walk-behind system), and a combination of those two methods. The researchers focused on asphalt concrete because it is the most common pavement surface in Florida, and this pavement type had the most pavement marking removal problems.

The removal methods were evaluated based on the measured rate of removal, degree of removal, condition of the pavement surface after removal, and potential for scarring to confuse the motorist. The condition of the surface after removal was based on subjectively evaluated changes in color and texture from the surrounding pavement. The potential for the scarring to confuse a motorist was subjectively based on the visual appearance of any scar present after the removal. The subjective evaluations were conducted during the day as well as during the night in dry and wet conditions. The nighttime evaluations resulted in similar findings to the daytime evaluations. While the researchers did not recommend a specific removal method, they had several useful findings. They indicated that pavement scarring is possible with both grinding and water blasting, but grinding appears to present the largest possibility for pavement scarring. Subsequently, they reported that the high-pressure water blasting method appears to be the most effective at removing pavement markings with the least amount of surface scarring. The researchers also experimented with using reflectance to quantitatively evaluate the removal. The results were promising, so the researchers recommended further study.

In the second Florida study (5), Ellis investigated pavement marking eradication alternatives that masked or covered pavement markings with an inexpensive surface treatment or temporary black tape, thus negating the need for actual marking removal. The measures of effectiveness were focused on the blending of the masking material with the existing pavement, the durability of the surface, the surface friction of the seal coat material, and the associated costs with each method. The surface friction measurements and the estimated costs were objective measures, and the durability and blending were subjective measures. The estimated costs were $0.47 per linear foot and $1.83 per linear foot for the modified sand seal coat and temporary black pavement markings, respectively. While the study period with regard to durability was short at 30 days, each method proved effective. Friction characteristics of the modified sand seal coat were deemed acceptable. The blending of the black tape to the surrounding new black asphalt road surface was deemed satisfactory but would not have been satisfactory on an aged/faded asphalt surface or PCC surface. Both methods were recommended to be adopted as optional methods to either mask temporary markings or temporarily mask pavement markings.

In 2006, Mathis and Ward completed a pavement marking removal synthesis for Washington DOT (WSDOT) (6). This effort did not focus on investigating new methods of pavement marking removal, but rather on the existing policies and methods that various agencies were using to provide WSDOT guidance on how to minimize ghost markings in work zone activities. The resulting recommendations emphasized the use of tape for masking unnecessary pavement markings during construction, specification revisions, preplanning, solid white lane markings in transition areas, and detailed review during project development.
The Nebraska Department of Roads sponsored the University of Nebraska-Lincoln to conduct a research project on the effectiveness of temporary pavement marking removal methods (7). The project sought to identify effective removal methods and procedures on concrete and asphalt pavements. The research team conducted a five-question survey on which removal methods are used, which are most common, which are most satisfactory, what common problems exist, and what marking materials are used most. The survey was completed by 50 respondents including at least one representative from 25 states. Grinding was indicated for use in all responding states, with 80 percent of states stating they use water blasting, and 60 percent using sand blasting. The research team generated a list of common problems identified for each of the removal methods. Based on the comments, each technique has the ability to damage the road surface or leave a scar while removing markings.

In addition to the survey, the research team conducted a controlled field evaluation of several removal techniques: water blasting, dry-ice blasting, grinder, scarifier, polycrystalline diamond cutter grinder, chemical removal, and heat torch (7). All removal methods were hand operated including the water blasting, which was a lower pressure setup that used a wand. Yellow paint lines 12 mil and 20 mil thick were evaluated. Half of the markings of each thickness were water-based paint, whereas the other half were solvent based. Evaluation criteria consisted of rate of removal, completeness of removal, and condition of the surface after removal (degree of scarring). Completeness of removal was subjectively and objectively evaluated through the use of digital image analysis to determine the percent of material removed.

The research results showed that the blasting and grinding techniques could remove most, if not all, of the markings. The exception was that the dry-ice blasting on PCC did not remove the paint very well. The shot blasting and grinding techniques scarred the PCC surface the most, and all removal techniques scarred the asphalt surface. The chemical removal system was an off-the-shelf product that does not contain Methylene Chloride (MeCl). Therefore, it was determined to be environmentally safe, as the Environmental Protection Agency (EPA) only has regulations for chemical paint strippers that contain MeCl. The paint stripper was coated on the marking, allowed to sit for 30 min, and then power-washed off. The markings were completely removed on both surfaces, leaving no scar. The objective image analysis of the removal provided results similar to those of the subjective analysis as far as completeness of removal. Overall, the research found that the paint was most effectively removed with the chemical stripper and that the image analysis could be a useful tool in quantifying marking removal.

PHASE I SURVEY

The Phase I research focused on the identification, description, and evaluation of available and emerging removal processes. This was carried out through a literature review of past research and a nationwide survey of transportation practitioners. The survey was distributed to each state department of transportation (DOT), to over 100 cities nationwide, and to other industry representatives. The survey yielded 55 responses from a combination of state and local agencies as well as contractors, equipment manufacturers, and industry groups.

The final survey included 15 questions, many of which requested details or explanations about the answers. The five subsections of the questions are as follows: general pavement marking
removal practices, removal quality evaluation, costs and removal rates, environmental and worker safety concerns, and past removal experiences. The questions included in the survey included the following:

- Does your organization have any standard practices or specifications for pavement marking removal?
- What types of pavement marking removal methods are used or have been used by your organization?
- Describe your organization’s preferred removal technique and indicate whether this varies by marking or road surface type?
- Is there a method you would prefer to use or like to try but do not due to environmental impact, cost, unavailability or some other factor?
- Are you aware of any emerging technologies in the field of pavement marking removal such as chemical systems or a combination of mechanical processes?
- Discuss how much pavement damage (surface scarring) is acceptable to completely remove a marking. Are there acceptable threshold levels?
- Are traces of marking on the road surface acceptable if the majority of the marking is gone? Are there acceptable threshold levels?
- Does your organization have any measurers of effectiveness to determine the quality of marking removal?
- What are typical removal costs, listed by removal technique/road surface type/mark ing material?
- What are typical production quantities for marking removal?
- Describe any environmental concerns or issues associated with pavement marking removal processes used by your organization.
- Describe any worker/general public safety concerns or issues associated with pavement marking removal processes used by your organization.
- Have you received any public comments about the removal of markings?
- Please describe past pavement marking removal experiences (either good or bad) that may be of benefit to this research.
- Do you know of any other research projects that have evaluated pavement marking removal issues?

To comprehensively look at the state of the practice, the researchers looked up the pavement marking removal standards for all 50 states if they were not provided in the survey response. The full research report documents the pavement marking removal standards for each state (2).

**PHASE II FIELD EVALUATIONS**

The Phase II research used results from Phase I to develop a field study to evaluate various combinations of pavement marking removal. The removal combinations to be evaluated were based on combinations of the type of removal process, type of marking material, and type of road surface. The field study consisted of two different study types. The first study type was controlled pavement marking removal evaluations where the researchers controlled the marking types, road surfaces, and removal methods used. The second study type was the evaluation of
pavement marking removal operations as part of planned highway maintenance or construction as
they occurred or after they were recently completed. In addition to the field studies, the research
team explored several other areas of pavement marking removal. These areas were the
environmental and worker safety issues associated with marking removal, the removal of
temporary tape pavement marking materials, and the usage of masking and blending techniques
to either cover markings or help conceal removed areas.

Controlled Pavement Marking Removal Evaluations

It was not feasible to evaluate every type of pavement marking removal, on every road surface,
for every type of pavement marking during this research project. The survey and literature
supplemented the results of the field study for removal types, road surface types, and material
types that were not evaluated. The controlled pavement marking removal evaluations took place
at 3 pavement marking test areas. These test areas had combinations of paint, thermoplastic,
plural component, and permanent tape pavement markings on asphalt and PCC road surfaces.

Several pavement marking removal techniques were evaluated by the researchers. The types of
removal evaluated are listed below and are shown in Figure 1.

- Grinding:
  - Carbide tipped drum, flailing, full-size truck-mounted system.
  - Carbide tipped drum, flailing, hand-operated system.
  - Carbide tipped rotary/orbital flailing system, mounted to skid steer.
- High-pressure water blasting, current state-of-the-art full-size truck system.
- Combination testing.

The combination testing was a light pass from the full-size flailing truck followed by the high-
pressure water blasting. This combination system was intended to take advantage of the pros of
the two systems while minimizing the cons. The flailing truck was setup so that it would remove
most of the marking, while not damaging the road surface. The high-pressure water blasting
would then remove the remaining marking at a high rate of speed.
The effectiveness of pavement marking removal can be established in several ways. Based on various factors for each given situation, the impact of each of the measures that affect the effectiveness of a removal technique may vary. The measures for which the effectiveness of pavement marking removal can be established are indicated below:

- Quality of the actual marking removal itself:
  - Scarring depth.
  - Changes to the roadway surface characteristics.
  - Percent marking material removed.
  - Retroreflectivity characteristics.
- Speed at which the marking is removed.
- Cost of the marking removal.
- Environmental impact.
- Availability of the removal equipment.
- Required skill of the operator and room for operator error.

Figure 2 provides images of one test site after the marking removal. The researchers used several devices to collect quantitative data after the marking removal. An electronic depth gauge, a portable retroreflectometer, a colorimeter, a laser texture scanner, and a charge-coupled device (CCD) photometer were used to collect data. The researchers collected data on the removed area and the adjacent road surface area. The goal of the measurements was to determine if it is possible to quantify the changes to the roadway surface characteristics and the retroreflectivity characteristics of the removed marking area. The retroreflectometers were used to evaluate retroreflectivity. The colorimeter was used to measure surface brightness (Y) using illuminant D65. The laser texture scanner was used to estimate the texture depth of the surface. The CCD photometer captured luminance images during both the day and night (see Figure 3). The camera was positioned at driver eye height in a vehicle 32 m away from the markings. The 32 m
data collection distance was selected to achieve a similar geometry to that of standard retroreflectivity measurement while allowing all of the markings across the lane width to be captured in a single image. At night, the markings were only illuminated with the vehicles’ headlights. During the day, combinations of CCD luminance measurements were taken with the sun in various positions to see its impact on the visibility of the removed areas. In addition to the quantitative data, the researchers also subjectively rated the quality of the removal.

Figure 2. Removal Results on Asphalt Example.
Planned Maintenance and Construction Pavement Marking Removal Evaluations

The researchers worked with local contractors to evaluate several pavement marking removal projects at the time of removal or shortly thereafter. The researchers were only observers of the work, specific removal techniques or operations were not requested. The researchers wanted to evaluate the methodology and results that are typically found in the field. Specifically the researchers were subjectively evaluating the quality of the removal from a percent of material removed, resulting scaring, and changes to texture of the road surface.

In total six different areas were evaluated by the researchers. 1) Full size flailing truck removing thermoplastic markings from PCC and asphalt road surfaces. 2) High-pressure water blasting thermoplastic markings off of asphalt. 3) High-pressure water blasting and failing removing thermoplastic on asphalt. 4) High-pressure water blasting removing waterborne paint on a surface treatment. 5) Removal on asphalt surface, and 6) removal on PCC surface. Figure 4 provides some examples of the field observation sites.

Additional Areas of Study

The additional areas of study were included in the Phase II work to evaluate other factors that should be considered when conducting pavement marking removal. The additional areas of study evaluated numerous environmental and worker safety issues related to the removal methods themselves, the materials being removed, and how they can impact the environment and the workers. Temporary tape pavement markings were evaluated because they are often used on final road surfaces so that removal methods that may damage the road surface are not needed. Data from AASHTO’s National Transportation Product Evaluation Program (NTPEP) was used to evaluate the internal tape strength, adhesive bond to the pavement, tackiness of adhesive remaining on pavement after removal, and the discernibility of the marking after removal. The masking of markings and blending of removed areas was also evaluated as means to improve the appearance of removed areas (blending), and for providing a color/texture matched mask that can cover existing markings.
FINDINGS

The literature review, survey, controlled test deck removal, field observations, and additional research areas all yielded information used in the findings and recommendations of the research. The researchers developed a standalone table of pros and cons of the most common forms of pavement marking removal; see full report for the table (2). The table highlights the advantages and disadvantages of each removal technique, which should aid in the selection of the most appropriate removal technique.

The survey responses indicated that grinding was the most common form of pavement marking removal and that it was preferred by many, even though most noted the drawbacks of pavement scars that are often left behind. Water blasting was also commonly used and is becoming more common as more equipment makes its way to the field. Water blasting was the most common method that the survey respondents would like to try. Both sand and shot blasting were commonly used, but they also both received several responses that indicated they were no longer being used. Outside of those four removal techniques, the temporary masking of markings was the only other method regularly used in the field. Other removal methods, such as chemical, heat, and laser, and other forms of blasting, such as soda, dry ice, or glass, are not commonly being used.
Grinding removal is the most available removal technique and is also the least expensive type of marking removal. Water blasting systems are becoming more common, but availability is limited in some areas. Water blasting is more expensive than grinding. The survey responses and literature review indicated water blasting can average being from 10 to 40 percent more expensive than grinding. The cost of removal is highly dependent on the availability of equipment and size of the removal contract. Typically, only grinding and water blasting are used for long stretches of removal because they can remove marking at a greater rate than other techniques. Other removal techniques such as shot and sand blasting as well as grinding and water blasting are used for shorter removal sections.

There are methods of applying durable coatings over the markings to blend into the appearance of the pavement. The problem is that these coatings and the surrounding pavement may change colors at different rates over time, and the covered area will no longer blend as well as it did originally. The surface texture of the painted areas and the surrounding pavement will also be different and may be noticeable under certain driving conditions, such as the sun being low on the horizon or in wet conditions. Simply covering the markings with a durable material also leaves the possibility that the marking may later be exposed and need to be either removed or recovered with another durable material. Because of this the MUTCD only allows the markings to be covered for temporary conditions. Color-matching paint systems may be better suited in a light application over removed areas in the short term to help blend in color differences after removal until the removed area has time to age and blend into the surrounding pavement. Any materials placed over a marking to mask it need to be maintained so that the marking does not become exposed over time.

The survey responses indicated that after the removal of pavement markings, fog or slurry seals have been used to help blend the removed areas with the surrounding pavement surface. The use of a fog seal or slurry seal to help blend color changes, scars, or surface texture changes to the surrounding pavement would only be useful on asphalt road surfaces. The researchers propose that on concrete surfaces where a discoloration occurred after marking removal, a larger area could be washed or cleaned with a high-pressure water blasting system to help blend in the removed area to the surrounding pavement. The field studies indicated that when the sun is behind the viewer, it makes the removal area more visible by lighting up the unremoved marking and reflecting off the textured surface. When looking toward the sun, there is glare off smooth surfaces, and textured surfaces look dull. Using a technique such as a fog seal or water blasting a larger area will reduce visibility issues associated with the sun because the area will be more uniform in appearance.

The MUTCD indicates the need to remove or obliterate markings until they are unidentifiable as markings. There are not standards for acceptable levels or criteria for how to determine a marking is no longer identifiable. The level of removal needed to make a marking no longer identifiable will differ for each situation. White markings on lighter-color road surfaces will not require the same level of removal as white markings on a dark surface. Removing a marking to the point of making the marking itself no longer identifiable may result in damage to the road surface that could be confusing to drivers. The MUTCD indicates that the removal of the marking should minimize pavement scarring. Again, there are not standards for acceptable
levels or criteria for how to determine scarring. The wording in the MUTCD regarding how to minimize scarring acknowledges that when removing pavement markings, some scarring may occur. It is the agencies’ job to ensure that appropriate pavement marking removal practices are used to minimize the scarring while removing enough of the marking material to no longer be considered as guidance or be confusing to drivers.

In general, the state DOT specifications call for the complete removal of the markings while limiting damage to the road surface. Several states did call for specific levels of required removal ranging from 75 to 100 percent, with the majority indicating 90 or 95 percent removal. Several states indicted maximum allowable depth of pavement scarring ranging from 1/16 to 1/4 inch, with the majority indicating 1/8 of an inch or less. The survey responses did acknowledge the need for a balance between the percent removal and damage to the road surface. The thought is that to attain 100 percent removal, excessive damage to the road will occur, whereas 90 or 95 percent removal may do minimal damage to the road surface. Leaving marking material on the road surface or damaging the road surface will both be visible to drivers, so an adequate balance needs to be sought for each individual situation. The required level of pavement marking removal should vary depending on the reason for the removal and the roadway conditions where the removal takes place.

The controlled field test deck removal and field observations found many good and some bad pavement marking removal results. High-pressure water blasting provided good removal on the Portland cement concrete (PCC) surfaces with little damage to the road surface and good removal of the marking materials. On asphalt surfaces, the results were mixed. The system typically removed all of the marking, but in some test areas the high-pressure water blasting system removed some of the surface asphalt and fines. The flailing truck had mixed results on both the PCC and asphalt surfaces. To achieve a high level of removal, the flailing truck typically left a scar on the road surface. Minimal scarring may be okay in some areas, but in critical areas such as lane-shift areas, scarring needs to be minimized as much as possible. The speed of removal depended on the marking type and the quality of the removal. The water blasting was as fast as or faster than the grinding for many of the tests. The orbital flailing system was not as aggressive as the full-size truck drum flailing system, and so it left minimal scarring on the road surface. The drawback to this was the system seemed to have difficulty removing paint and preformed thermoplastic markings that found their way into voids below the pavement surface. The orbital flailing system was not a full-size system, which resulted in much slower removal than the other full-size removal methods tested.

**Recommendations**

The recommendations include things to consider that relate to pavement marking removal and a set of best practices to assist in improving pavement marking removal quality. The standalone table of pros and cons of the most common forms of pavement marking removal should be used to help determine which type of pavement marking removal may be best suited for a given situation; see full report for the table (2).

The selection of a removal system needs to take into account many factors, each of which may be more or less influential on some projects. The proper consideration of each of these factors is
the best way to achieve acceptable pavement marking removal results. These factors include the following:

- What marking material is being removed?
- What road surface is the material on?
- How much of the material needs to be removed (what is the purpose of the removal)?
- Is speed of removal important?
- What removal techniques are available and at what cost?
- Are there special environmental conditions that need to be considered?
- How long will the removed area be viewed by drivers (whether a new surface will be installed or markings will be restriped in the future)?
- Is the removed area in a location where confusion could lead to an accident?
- Are there other measures that can be taken to minimize confusion to the driver?

**Best Practices**

Pavement marking removal should be specified as a percentage of material removed based on the purpose of the removal. The percent material removed equates to the percentage of the road surface made visible where the marking was removed. The purpose of the removal should also play a role in the removal method selected and other measures selected to provide a roadway with delineation that is not confusing to drivers.

Changing pavement marking patterns is the most critical pavement marking removal because the old markings are no longer conveying the travel path to the drivers. Any errors in removal can lead to drivers being confused by the old markings or the removed areas. A high percentage of the material needs to be removed, but damage to the road surface also needs to be considered. Removal should be 90-95 percent, with 100 percent removal in some cases. Based on current practice, damage to the road surface should be 1/8 of an inch or less while changing the road surface texture as little as possible.

Open-graded or tined surfaces may require the material below the pavement surface to be removed with a blasting technique to minimize scarring. Depending on the road surface type and the road conditions, additional measures may need to be taken to reduce driver confusion with the removed markings. These additional measures can include fog or slurry seals over the removed area or the entire lane width on asphalt surfaces. The friction of the road surface needs to be considered, but these techniques will help blend the removed areas with the surrounding pavement. On PCC surfaces, additional light removal around the removed area or across the entire lane width can be conducted with a blasting technique such as water blasting to help blend in the removed area.

Remove and replace is the process of removing the current pavement marking material and restriping in the same location where removal occurred. This type of removal is conducted to remove a poorly bonded material so the new material can form a good bond, to reduce the overall thickness of restriped markings, or to remove an aged marking that is incompatible with the new marking that is being applied. For remove and replace with compatible markings, the whole marking does not always need to be removed, so removal can be limited to at or above the
road surface. This can help limit scarring to the road surface. Removal by grinding may be the best option, but if full removal or removal of material below the surface is needed, then water blasting or another blasting technique may be a better option to minimize scarring.

Practitioners need to consider the work phasing and the final road surface. If markings are to be removed for a short duration prior to a new surface, then damage to the road surface is not as critical compared to a removed area that will be visible for a longer duration. Any removal on the final road surface needs to be accomplished with minimal damage to the road surface. It may be best to use temporary pavement markings on the final road surface until the final marking configuration so that removal will do as little damage to the road surface as possible.

The selection of the most appropriate pavement marking removal system needs to consider the amount of removal that is required and the length of time available to complete the removal. If the removal quantity is large, full-size removal trucks should be used. If the removal quantity is small, hand units and the slower removal methods can be considered.

Symbols and text should be removed in a square or rectangular pattern so that the previous shape is not left as a scar or discoloration. This requires removal of the marking and the necessary removal/cleaning around the marking to help blend in the area with the surrounding pavement by creating a larger removal area that is no longer recognized as a symbol or text.

Older road surfaces that are experiencing cracking or surfaces with joints may need special consideration when removal occurs around these areas. The use of high-pressure water blasting on these surfaces can lead to road damage if the water is allowed to penetrate into the cracks or joints. Grinding may also pose a threat to cracks and joints. Removal around these areas should be conducted carefully such that the joints are not disturbed and that the cracks are not made worse by the removal.

Initially, any pavement marking removal project should begin with testing the removal equipment in a non-critical area to evaluate the removal. This initial testing will show how well the operators can use the equipment to remove the marking material and how much damage is done to the road surface. The test area can be used to adjust the equipment to find the ideal setup for the work required. If the operator and equipment cannot provide satisfactory results, another removal system should be considered.

The quality of removal needs to be evaluated during the day, at night, and during wet conditions. Surface color changes and scarring will have a greater impact during the day than at night, whereas retroreflectivity from remaining marking material or retroreflectivity differences because of surface texture changes will be more noticeable at night. The direction of travel and the position of the sun also need to be considered. Wet conditions may fill pavement scarring, resulting in an area that looks like a wet marking and thus creating confusing delineation. Any areas with color, texture, or retroreflectivity issues should be corrected to reduce or eliminate driver confusion.

Pavement marking specifications for areas where removal has occurred should consider post removal conditions. Wider markings and continuous markings in transition areas will provide
better guidance to drivers and may reduce confusion of the removed marking areas by enhancing the new markings. Markings with high retroreflectivity levels should also be maintained in areas where previous removal could lead to confusion by drivers at night. The high retroreflectivity of the new markings will be more noticeable to drivers than removed areas of markings.

REFERENCES