



Planning the Next Generation of Seal Coat Equipment Guidelines and Implementation

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PLANNING THE NEXT GENERATION OF SEAL COAT EQUIPMENT: GUIDELINES AND IMPLEMENTATION

by

Darlene Goehl
Research Specialist V
Texas A&M Transportation Institute

Charles Gurganus
Associate Research Engineer
Texas A&M Transportation Institute

William Crockford
Research Engineer
Texas A&M Transportation Institute

and

Deepika Ravipati
Graduate Student
Texas A&M Transportation Institute

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Darlene C. Goehl, P.E. #80195.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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INTRODUCTION

Using the results from prior tasks, researchers have developed guidelines for documenting pavement condition changes, application rate adjustments, and designing the next generation of spray bar equipment. For this product, researchers:

- Developed guidelines for documenting pavement condition, which included procedures and recommended equipment for documenting pavement condition.
- Developed application rate adjustment guidelines, which included:
 - Procedures for adjusting asphalt application rates based on pavement condition.
 - Procedures for adjusting asphalt application rates based on traffic conditions.
- Developed equipment guidelines, which included:
 - Recommended changes to existing equipment or develop specifications for new equipment development.
 - Recommended changes to construction process requirements.

GUIDELINES AND IMPLEMENTATION OVERVIEW

This project focused on improvements to seal coat construction. A successful seal coat project relies on field adjustments to application rates. These field adjustments are affected by the pavement surface condition and the amount and type of traffic. In this project, TTI researchers evaluated innovative ways to document the pavement surface condition, adjust application rates, and improve equipment to apply variable application rates.

High-definition video (HDV) and Mobile Light Detecting and Ranging (LiDAR) were the two systems evaluated in this study to document pavement conditions. Researchers evaluated several field sites of actual seal coat projects to document pavement surface conditions and evaluate adjustments for binder application rates. The field adjustment table was developed based on the traffic and pavement conditions and experience with rate adjustments. Using traffic data and the pavement condition, researchers recommend adjustment to binder application rates as documented in this report.

In the current state of Texas practice, two methods for transverse variation of shot rate were identified:

1. Changing nozzle orifice characteristics at appropriate locations across the distributor bar.
2. The use of a dual bar distributor system.

During the study, some evidence of attempts to use other methods were identified. Some of these methods are pulse width modulation (PWM) for simulating analog behavior to achieve variable shot rates and replacing the nozzle/ball valve/cylinder actuation combination with direct control of an iris type nozzle.

This document provides the key findings from the field sites, guidelines for adjusting asphalt applications rates, recommendations for equipment improvements, and recommendations for future work to further improve seal coat construction.

PAVEMENT CONDITION

HDV

Summary

HDV provides a method to document the existing pavement condition at highway speeds using a camera mounted to a mobile vehicle. Along with the video logging system, software is available to help the designer document pavement condition changes. This method offers an alternative to visual field inspection. The ability to collect data at highway speeds mitigates safety concerns by providing a safe method to collect pavement condition information.

Conclusions

While video logging mitigates safety concerns, processing the data and gathering useful information from the data requires manually watching the video to identify surface changes and locations for design changes. The labor intensive nature of this method makes it less attractive and can also lead to potential errors as manually watching video can lead to improper identification or grouping. However, the HDV system is ready to implement and safer than the current visual inspection methods. Additionally, there are several uses of the video including visual tracking of pavement changes and availability to view the video at meetings to discuss potential issues with the project.

Recommendations

Researchers recommend using the HDV system. The system is ready to implement and is safer than the current manual procedure. Additionally, there are only a few HDV systems in the districts, so researchers recommend that all districts consider acquiring an HDV system.

The procedure described should be used for the HDV system to document existing conditions of the pavement:

1. Collect High Definition Video of the roadway.
2. Use PaveView Software to visually analyze the video.
 - a. Document conditions in the “Crack” Dialog box.
 - b. Output the “Crack” Dialog file.
 - c. Load “Crack” Dialog file into excel.
 - d. Calculate area and locations of different pavement conditions.
3. Provide the information to construction personnel to assist with rate adjustments.

Note that the PaveView software documents the picture number in the comment file of the last picture in the sequence for a designated area when comments are added to the “crack” dialog box. Additionally, pictures of various conditions can be captured using “Snipping” Tool (or other screen capture tool) and saved for reference.

LIDAR

Summary

Mobile LiDAR provides an attractive technology to collect data at highway speeds, improving the safety of data collectors and the traveling public. Typically, LiDAR provides distance or elevation data along with the reflectivity of the target surface. Within this study, only the reflectivity measurements were of interest. Initially, reflectivity data are processed into a 0 to 255 red, green, and blue (RGB) scale. In order to deal with the vast amount of reflectivity data generated with mobile LiDAR, researchers divided the roadway into three areas of interest:

- Left wheel path.
- Between the wheel paths.
- Right wheel path.

Each area of interest was 3-ft wide, and the roadway was further divided into 100-ft stations. The reflectivity data were placed in 1-ft long \times 4-in. wide grids, producing 900 element matrices for each area of interest within each station. By applying the k-means clustering algorithm and a secondary grouping function, reflectivity values were transformed for a 0 to 255 scale into at most a 1 to 7 scale. Using pavement sections in an as-expected condition, researchers were able to determine how an area of interest should look as it relates to the rescaled reflectivity data. The reflectivity data were then reassigned by assigning the largest quantity of rescaled values the new scale value of 1. The reassignment continued until all clustered scale values were reassigned from the largest quantity to the smallest quantity.

With the reduced and reassigned scale, researchers assumed the area of interest functioned like a graph with a central node that fundamentally described the surface characteristics. Using techniques from graph theory, a generalized Laplacian graph was created that could be used to mathematically extract the characteristics of the surface. The characteristics of the surface could be compared with the mathematically extracted characteristics of the control section to determine the relative similarity or difference of an area of interest.

Using a mathematical description of the surface, binder rates could be set based on how mathematically similar or different a section was measured. Computer code was written to perform these calculations in an automated fashion.

Conclusions

Mobile LiDAR was effective in capturing the pavement surface reflectivity. Reflectivity data accurately detected surface changes that when compared to a desired condition could be used to determine flushing, patching, and other surface type changes. Using mobile LiDAR reflectivity data, the location and length of surface changes could be accurately found and noted for design or construction needs. Researchers developed automated techniques to identify and extract these surface changes.

Mathematical techniques successfully identified the relative difference between a pavement surface area of interest and the as-expected or as-desired surface. Algorithms applied binder rate reductions based on the differences identified through reflectivity data and mathematical analysis of the pavement surface characteristics. These algorithms assigned surface descriptors and binder rate changes to each area of interest summarized based on 100-ft stations. This was done in an automated fashion that has the potential to improve and speed up rate decision making. The use of mobile LiDAR reflectivity limits exposure to traffic because the data can be collected at highway speeds. The automation of binder rate changes can reduce labor hours and prevent tedious video logging or dangerous manual inspection. Mobile LiDAR also helps in identifying exact points where changes need to be made without introducing subjectivity or potential error created by changing light conditions. For example, when a roadway runs east and west, depending on the time of day, light conditions will change the appearance of surface characteristics. Because reflectivity data are based on the actual reflectivity of the surface and is not affected by light conditions, this potential error is eliminated.

Recommendations

Evaluation and development time was short for this project, and researchers would like TxDOT to consider further development of the automated system to document pavement changes based on the LiDAR data. There are several advantages to this system including removing subjectivity from the evaluation of the pavement condition. This is essential to reducing risk especially as the department moves toward using more third-party inspectors. Reduction of risk will lead to economical projects. Future work would allow for additional validation of the process and improving the efficiency of data analysis. Since the reflectivity portion of the data was used, future work would include investigation of simpler, more cost-effective equipment to collect the data.

The procedure described should be used for the LiDAR system to document existing conditions of the pavement:

1. Collect LiDAR data for the roadway.
2. Use software to analyze the reflectivity portion of the LiDAR data.
 - a. Designate a usual pavement condition as reference control section.
 - b. Analyze the data by comparing reflectivity data to the control sections reflectivity data.
 - c. Use the comparison to establish adjustment thresholds.
 - d. Define locations for adjustments and adjustments.
3. Provide the information to construction personnel.

Researchers recommend an implementation project that includes the following tasks:

1. Review of test locations from this study. Mobile LiDAR reflectivity measurements should be used on test sections to identify surface changes and make rate adjustments.

Initially, this can be done retroactively. The roadways used in this study were part of the FY 2018 seal coat program. Researchers have already run the automated reflectivity process to generate binder rate changes. Researchers can identify sections with high binder rate change suggestions and follow-up with the district to determine actual shot rates. The performance of the section can be visually determined, and a conclusion can be drawn as to the accuracy of the automated method.

2. Additional test sections and validation. If the aforementioned validation appears promising, researchers should work with a district to identify roadways for the next seal coat cycle. Researchers should work with maintenance supervisors to know when final surface preparations are completed to the selected roadways. Once this has taken place, researchers will collect reflectivity data and apply the automated algorithm to determine initial rate adjustment suggestions. Researchers will then work with the area office to track the seal coat contract so that reflectivity data can be measured again, approximately two weeks prior to seal coat construction. The method will be run again to produce binder rates that should be used in the field. In addition to providing the actual binder rates for construction, a time analysis can be performed on the data taken after preparations and just before construction to determine the time sensitive nature of the reflectivity data. Ideally, reflectivity data can be collected a few months prior to construction so that rates can be provided at the pre-construction conference.
3. Evaluate equipment. Other reflectivity measuring devices should be evaluated for potential use. Mobile LiDAR has the luxury of collecting reflectivity measurements across the entire area of interest, but deploying this at the statewide level will be challenging. The challenge is exacerbated if the reflectivity data prove to be time sensitive. Other reflectivity measuring devices are available that might be less difficult to deploy. If these devices exist, the algorithms will need to be modified as necessary to process the data and provide surface descriptions and recommendations. This should be vetted during an implementation project.

Ultimately, the algorithms developed during this work could directly feed a smart distributor to make binder adjustments on the fly. One can envision a distributor or lead truck outfitted with a reflectivity device, measuring surface characteristics in real-time. Based on the real-time measurements, the distributor could adjust rates both longitudinally and transversely on the fly. If the distributor was also equipped with a surface and ambient temperature sensor, additional adjustments could be made to the rates on the fly. Developing and perfecting the reflectivity algorithms produced in this study set the stage to move seal coat construction in that direction over the next decade.

BINDER APPLICATION RATE ADJUSTMENTS

Summary

Texas has various roadway surface conditions. These conditions change as maintenance activities are performed. Constructing a successful seal coat relies on achieving the proper

aggregate embedment. Low embedment leads to aggregate loss while high embedment leads to flushing and bleeding. Adjustment of the binder application rate is a function of the existing conditions due to the hunger factor of the existing pavement. For example, a cracked, dry, oxidized pavement will have a need for additional binder. This asphalt will go into the old pavement, leaving less on the surface to embed the aggregate, so additional binder will be needed. Conversely, a bleeding pavement will have excess binder and less new binder will be needed. Traffic affects this by providing extra force to embed the aggregate, so very high traffic levels will require less new binder while very low traffic will require more binder.

Conclusions

The binder rate adjustments that were provided by researchers at the kickoff meeting were found to be realistic and represented the different pavement conditions found in Texas. The traffic adjustments ranged from 0.5 gal/sy added for very low traffic to -0.04 gal/sy for very high traffic.

The pavement condition adjustments ranged from 0.08 gal/sy to -0.04 gal/sy with a grade 3 aggregate, from 0.06 gal/sy to -0.04 gal/sy with grade 4 aggregate and from 0.05 gal/sy to -0.03 gal/sy with grade 5 aggregate. The conditions found in Texas could consist of a need to make large changes transversely and as you travel down the roadway. This can make the seal coat very challenging to construct.

The rate adjustments are based off of starting with the original design rate and changing from what is an expected rate to the adjusted rate. It is very important to remember when adjusting rates that there may need to be a large adjustment if the condition changes by extremes. Technical memorandum 3 contained a matrix that laid out the total adjustment needed when moving from one condition to the next.

Recommendations

Application adjustment rates are based on traffic and pavement condition at the time of construction, but the initial application rate is determined through experience or design methods. TxDOT is funding a new research project 0-6989, "Update Seal Coat Application Rate Design Method" starting in September 2018, and researchers recommend incorporating the adjustment criteria into the updated rate design method.

Researchers recommend the adjustments shown in Table 1 and Table 2. The traffic adjustments are based on the annual daily traffic (ADT) and vehicles per lane per day for multilane highways. The adjustment recommendations are for changes both longitudinally and transversely along the roadway. These adjustments factors may be slightly modified for each district depending on local materials and conditions.

Table 1. Traffic Adjustments.

ADT	gal/sy
SHLD	0.05
50–100	0.05
100–250	0.04
250–400	0.03
400–500	0.02
500–650	0.01
650–900	0
900–1100	-0.01
1100–1500	-0.02
1500–2000	-0.03
>2000	-0.04

Table 2. Surface Condition Adjustments.

Aggregate Size		GR 3	Gr 4	Gr 5
Surface Type	Surface Condition	gal/sy	gal/sy	gal/sy
Asphalt Concrete	Very dry with many cracks	0.08	0.06	0.05
	Dry with some cracks	0.05	0.04	0.03
	Good condition with few cracks	0.02	0.02	0.01
Seal Coat	Very dry with many cracks	0.06	0.06	0.04
	Dry with some cracks	0.03	0.03	0.02
	Good condition with few cracks	0	0	0
	Flushed	-0.02	-0.02	-0.01
	Bleeding	-0.04	-0.04	-0.02
Patch	Dry or fresh patch	0.03	0.03	0.02
	Fogged patch	0	0	0
	Flushed patch	-0.03	-0.03	-0.03
Prime	Dry surface, lightly primed	0.02	0.02	0.02
	Inverted prime w/ GR 5	0.03	0.02	0.02
	Good prime rate, well penetrated	0	0	0
	Waxy and wet, not well penetrated	-0.03	-0.03	-0.02

The procedure described can be used to adjust binder application rates:

1. Look up current ADT on statewide planning map, plans, or other resource.
2. Use the binder application rate determined from aggregate size and district design method as a starting point.
3. Adjust starting rate based on current traffic and adjustments shown in Table 1.
4. Review the pavement condition.
 - a. Drive the roadway to document visually the changes in pavement condition and/or
 - b. Use HDV and PaveView software to document the changes in pavement condition and/or
 - c. Use LiDAR data through an automated process to determine pavement condition changes.
5. Use the application rate that has been adjusted for traffic as the starting rate to adjust based on condition.
6. Adjust the rate based on conditions and adjustments shown in Table 2.

Example: Starting rate is 0.33 gal/sy for a Grade 4 aggregate. The roadway from FM 1 to SH 1 has an ADT of 425 and from SH 1 to US 1 has an ADT of 2250. The adjusted rates would be 0.35 gal/sy (0.33+.02) and 0.29 gal/sy (0.33-0.04), respectively. FM 1 to SH 1 is a seal coat surface that is dry with some cracks, and SH 1 to US 1 is asphaltic concrete surface that is in good condition with few cracks. The adjusted rates would be 0.38 gal/sy (0.35+0.03) and 0.31 gal/sy (0.29+.02).

GUIDELINES FOR EQUIPMENT INNOVATIONS

Summary

Since a successful seal coat project relies on field adjustments to application rates, having equipment that can quickly and easily be adjusted will improve the construction process. The spray bar technology innovations investigated in this study show potential for improvements to asphalt distributors.

Conclusions

The most effective control of the transverse application would be to require closed-loop functionality. In the first stage of equipment innovation, the least resistance to change would likely come about by modifying current technology as opposed to starting from scratch, even if the latter approach might be more effective in the long run.

During the study, some evidence of attempts to use other methods were identified. One of these was PWM for simulating analog behavior to achieve variable shot rates. While PWM is a mature technology in terms of its usage in various process control applications, researchers do not consider it the best approach for asphalt distributor equipment. Other ideas have come up, such as replacing the nozzle/ball valve/cylinder actuation combination with direct control of an iris

type nozzle, but this approach is not considered to be feasible in this harsh environment at this point.

Recommendations

Improvements to the asphalt distributor spray bar system are needed to improve the overall construction process. Researchers recommend further development of the technologies to improve the spray pattern changes during application:

- The adjustment factors do not make any reference as to whether they are in the wheel path or outside of it. Innovation should be geared toward addressing surface condition, no matter where it is located on the pavement, and wheel path versus non-wheel path then becomes a secondary factor in research and development (R&D) efforts.
- Since the adjustment factors are dependent on two factors, surface condition and aggregate, future R&D efforts should consider if and how the complete system process can be better addressed. This potentially includes transversely variable aggregate delivery rates/sizes in addition to binder application rates.
- Nozzle orifice design is not a trivial matter. For that matter, any orifice in what is basically a pressurized hydraulic system like an asphalt distributor generally has undergone a detailed design process. Typically, nozzle housings have a valve that is often like a ball valve associated with them on the bar. That valve is typically operated in a binary state open/shut mode. Future R&D is that anything done to alter existing functionality of the distributor, such as this local control assembly (i.e., ball valve/nozzle), must be analyzed for unintended consequences.
- Tex-922-K suggests using water in the calibration process. This is a safety hazard if not properly handled as is noted in the procedure. Future R&D should look for technologies and procedures that enhance safety simultaneously with improving performance.
- While talented, experienced operators may be worth their weight in gold, reducing subjective interpretation, position uncertainty, and reaction time is a goal of the future state. Future R&D efforts should be focused in this area by capitalizing on the evolution of hardware and software technology.

ADDITIONAL RECOMMENDATIONS

Researchers recommend investigating maintenance work that would limit the need for transverse variable rates. Some of these methods are removal of flushed or bleeding material, combinations of maintenance repairs that have a similar adjustment factor, and changing the width of repairs.

GUIDELINES AND IMPLEMENTATION SUMMARY

This study found promising innovations in technology to improve the seal coat construction process. Researchers concluded:

- The HDV system is an excellent tool for documenting the surface condition and is ready for implementation.
- The LiDAR system shows much promise to remove a significant amount of subjectivity when determining variations in surface conditions. Additional work is needed so that this technology can be automated to identify surface conditions and suggest rate changes, thus reducing labor hours and improving efficiency. With automation, the methods developed using mobile LiDAR can be deployed shortly before actual construction, making decisions more real-time. More real-time decisions will ultimately lead to better performance.
- Binder application rate adjustments should be made during construction. The binder adjustments shown in Table 1 and Table 2 should be used, but these adjustments can be fine-tuned for local conditions and aggregate sizes. This information should be incorporated into TxDOT's upcoming research project, 0-6989, "Update Seal Coat Application Rate Design Method" starting in September 2018.
- The spray bar technology innovations investigated in this study show a potential for improvements to asphalt distributors and should be investigated further.

Researchers believe that implementing these methods will improve the seal coat construction process and reduce risk to TxDOT.

