Ohio's Research Initiative for Locals (ORIL) Research On-Call 2021-ORIL6 (Task 2): Current Practices and Experience for Using Chip Seal Interlayer by Ohio Local Public Agencies to Mitigate Reflection Cracking

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Prepared for:
Ohio's Research Initiative for Locals
The Ohio Department of Transportation,
Office of Statewide Planning & Research

Project ID Number 112863

November 2021

Final Report

<table>
<tr><td>1. Report No.</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td>FHWA/OH-2022-04</td><td></td><td></td></tr>
<tr><td colspan="2">4. Title and Subtitle</td><td>5. Report Date:</td></tr>
<tr><td colspan="2" rowspan="3">Ohio's Research Initiative for Locals (ORIL) Research On-Call 2021-ORIL6 (Task 2): Current Practices and Experience for Using Chip Seal Interlayer by Ohio Local Public Agencies to Mitigate Reflection Cracking</td><td>November 2021</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td></td></tr>
<tr><td colspan="2">7. Author(s)</td><td>8. Performing Organization Report No.</td></tr>
<tr><td colspan="2">Munir D. Nazzal, Safaa Swaleh, Ahmad Al-Hosainat, and Ala R. Abbas</td><td></td></tr>
<tr><td colspan="2">9. Performing Organization Name and Address</td><td>10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2" rowspan="3">Department of Civil Engineering
Ohio University
Athens, Oh</td><td></td></tr>
<tr><td>11. Contract or Grant No.</td></tr>
<tr><td>34878</td></tr>
<tr><td colspan="2">12. Sponsoring Agency Name and Address</td><td>13. Type of Report and Period Covered</td></tr>
<tr><td colspan="2" rowspan="3">Ohio Department of Transportation
1980 West Broad Street, MS 3280
Columbus, Ohio 43223</td><td>Final Report</td></tr>
<tr><td>14. Sponsoring Agency Code</td></tr>
<tr><td></td></tr>
<tr><td colspan="3">15. Supplementary Notes</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">16. Abstract</td></tr>
<tr><td colspan="3">This report summarizes the results of a research task that was conducted to identify the current state of the practice of local public agencies (LPAs) for using chip seal interlayer (CSI) to control or reduce reflection cracking of overlay and summarize the results of different studies on the use chip seal interlayer. To achieve these objectives a comprehensive literature review of all studies that evaluated the use of CSI was conducted. In addition, surveys of LPAs were conducted and interviews with selected LPAs was performed. Finally, limited number of local roads with CSI were evaluated. The results of this task indicated the CSI has been used by LPA in Ohio to reduce and delay the development of reflection cracking. Several LPAs indicated that CSI was effective and had resulted in improving the service life of overlays. Based on the results of this task it is recommended to collect more data from roads with CSI to accurately determine the cost effectives of CSI.</td></tr>
<tr><td colspan="2">17. Keywords</td><td>18. Distribution Statement</td></tr>
<tr><td colspan="2">Chip seal Interlayer, reflection cracking, thermal cracking</td><td>No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161</td></tr>
</table>

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	**47**	

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November 2021

Prepared in cooperation with the Ohio Department of Transportation
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Acknowledgments

The research team would like to thank the Ohio Department of Transportation (ODOT), the Ohio’s Research Initiative for Locals (ORIL), and the Federal Highway Administration (FHWA) for sponsoring this study. The research team would like also to thank the members of the Technical Advisory Committee (TAC): Mr. Steve Luebbe, Mr. James Young, Mr. Mark Eicher, Mr. Greg Butcher, Ms. Jennifer Elston, and Mr. Steven Bergstresser. Special thanks are extended to Ms. Michelle Lucas for her time and assistance throughout the project.

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1. Project Background

Asphalt overlay is a common technique transportation agency in Ohio use for rehabilitation of structurally or functionally deteriorated roads. One of the main types of distresses that develops in overlays is reflection (also known as reflection) cracking. This type of cracking develops in an asphalt overlay and is caused by continuous movement at the discontinuities (cracks or joints) prompted by thermal expansion/contraction and traffic loading. Different types of treatment methods have been evaluated to control reflection cracking (1,2). Some of these methods control reflection cracking by acting as a reinforcement such as the use of geotextile, geogrid, fiberglass, and geo-composite. In addition, other methods control the reflection cracking by acting as a strain energy absorber, also known as stress relieving layer. An example of such methods, is the use stress-absorbing membrane interlayer (SAMI) between the existing old pavement and the new overlay.

SAMI and reflection cracking control methods have been used for several decades by local public agencies (LPAs). However, the use of these methods results in a considerable increase in a project price. For example, the use of SAMI results in an estimated cost increase of more than $175,000 per year for one city in Ohio where SAMI is extensively used. Therefore, several LPAs in Ohio during the past decade have started using less expensive stress relieving treatments such as chip seal interlayer (CSI) to help deter, control or minimize reflection or thermal cracking. CSI treatment appears to be gaining in popularity mostly due to its economics particularly when compared to more expensive other reflection cracking control methods. However, the CSI effectiveness is still not quantified or validated to date as there is no data on the improvement in the performance and service life of overlays when CSI is used. Therefore, research is needed to evaluate the benefits and cost-effectiveness of using CSI.

This ORIL Research-On-Call task identified the current state of the practice of LPAs in Ohio for using the CSI to control or reduce reflection cracking of overlay. The task answered questions about: the factors that are used to select projects the CSI can be used in such as the existing pavement conditions and types, the properties of CSI, the extent CSI is used by LPA in Ohio, the experience of LPAs with CSI, performance data of overlay with CSI that any LPA has on record.

2. Research Context

The objectives of this task are:

1- Identify current state-of-practices for using chip seal interlayer by LPAs in Ohio and Nationwide to control reflection cracking in asphalt overlays.
2- Summarize the results of different studies on the use chip seal interlayer by LPAs
3- Provide recommendations for the next steps that need to be taken to ensure the effectiveness of using chip seal interlayer to reduce reflection cracking in overlays.

3. Research Approach

3.1 Conduct Literature Review

This task involved conducting a comprehensive literature review of all active and completed studies on the use of CSI to control the reflection cracking and low-temperature cracking in asphalt overlays. In addition, the research team reviewed the existing literature to identify the effectiveness of CSI in controlling and factors found to affect cracking; including the properties of overlay, CSI properties and composition, existing pavement type and conditions. Special focus was on studies that compared the performance of pavement with CSI to those without. The research team also reviewed the literature to identify factors that need to be considered when using CSI. The emphasis was on studies that involved the use of chip seal interlayer for municipal and local roads.

The literature search included all standard databases such as Transportation Research Information Services (TRIS), National Transportation Information Service (NTIS), Compendex/Engineering Village, and Web of Science. In addition, the research team consulted with experts on this subject.

3.2 Identify Current State-Of-Practices for Using Chip Seal Interlayer by LPAs In Ohio

The research team assessed the current state-of-the-practice for using the CSI to control reflection cracking by LPAs in Ohio. To achieve that, an on-line survey was conducted to gather information and seek details from different LPAs in Ohio about the use of a chip seal interlayer to control reflection cracking in asphalt overlays. A draft survey questionnaire was sent to the Technical Advisory Committee (TAC) members for review before its distribution for solicitation of responses. Modifications were made and some questions were added/deleted based on comments received from the TAC. The revised survey was implemented in for distribution to LPAs. The survey invitations were sent on May 27, 2021. The survey included 20 questions. The following information were collected in this survey: the extent of use of chip seal interlayer, experience with using chip seal interlayer, effectiveness of chip seal interlayer in reducing reflection cracking, properties of chip seal interlayer, specifications of chip seal layer, performance data on record for overlayers with chip seal interlayer, factors that were found to affect chip seal interlayer, and factors used to select the projects for using chip seal interlayer. More than 58 responses were received from different types of LPAs. The results were analyzed and compiled for each county. A summary of the survey results is provided in Appendix B.

3.3 Identify Current State-Of-Practices for Using Chip Seal Interlayer by LPAs Nationwide

A nationwide survey was conducted to document LPAs in the US current practices and experiences with using Chip Seal Interlayer (CSI) to reduce and control reflection cracking. A draft survey questionnaire was prepared by the research team and sent to the TAC. Modifications were made and some questions were added/deleted based on comments received from the TAC. The survey was sent by Ohio LTAP to all LPAs in the US on June 7, 2021. The survey included 21 questions that were. Over 55 respondents were received from different types of LPAs in different states. The results were analyzed and compiled. Appendix C presents a summary of survey results.

3.4 Conduct Interviews with Selected LPAs In Ohio

Based on the obtained survey results, interviews were conducted with selected LPAs to seek more information about their experience with CSI. To this end, several interviews were conducted with LPAs that have used CSI. The interviews were one-hour in length that were conducted using Microsoft TEAMS. Follow-up emails were made to obtain more information based on the interview. All interviews were recorded and the transcript of these interviews was saved. A set of questions were developed, which were asked during the interview. However, based on the conversation other questions were asked. The interviewed LPAs were

- Licking County Engineering: Jared Knerr, (County Engineer)
- Delaware County: John Huffman (Pavement Engineer)
- Scioto County: Darren LeBrun (County Engineer)
- City of Wooster: John Rice (City Engineer)
- City of Chardon: Paul Hornyak (Director of Public Works) and the City Engineer.

In addition, an online meeting was held with Mr. Jim Marszal from the Flexible Pavements of Ohio about the use of CSI in Ohio. Appendix D summarizes the results of all of the conducted interviews.

3.5 Visit and Evaluate Local Roads with And Without CSI

Based on the interview conducted with LPAs, local road sections that were paved with and without CSI were selected and evaluated in Licking County, Delaware County, and Scioto County. Figure 1 shows the location of the sections that were evaluated. The sections in Licking County were constructed in 2015 and were part of a resurfacing project on Morse Road. The project was 2 miles in length. The first portion of the project had a 0.75-mile section that had a 1.75-inch asphalt overlay: 3/4-inch intermediate course and 1 inch of surface course. In addition, the second portion of the project had a 1.25-mile section that had CSI interlayer but a thinner overlay (1-inch overlay).

The CSI section that was evaluated in Delaware County was part of resurfacing project on Bunty Station Road between South Section Line Road and Ford Road. The section was 1-mile in length and was constructed in 2006. CSI layer was installed prior to placing a 1-inch overlay. Finally, three sections were evaluated in Scioto County. Two sections had CSI installed prior to placing overlay and one did not include using CSI. These sections were on Bonser Run and Turkey Foot Road. The third section evaluated did not have CSI. This section was part of a resurfacing project on Bussey Road. Appendix D provides more details about evaluated sections.

Figure 1. Location of sections with and without CSI evaluated in Licking, Delaware, Scioto counties

4. Research Findings and Conclusions

Appendices A, B, C, and D present a detailed summary of the results and analysis of the literature review, surveys, interviews, and evaluation of CSI section performed as part of this task. The main findings of this task are summarized below.

Main Findings of Literature Review

- Chip seal interlayer (CSI) prevents transferring of the existing cracks to the asphalt overlay by its elongating and dissipating the horizontal strains in the vicinity of cracks.
- A national survey reported in a previous study indicated that 30% of surveyed DOTs regularly use CSI to control reflection cracking.
- In addition, 60% of the surveyed indicated that CSI positively contribute to delay reflection cracking.
- The results of study by National Center for Asphalt Technology (NCAT) indicated that the use double chip seal interlay resulted in significant reduction in reflection cracking after 20 million ESAL of loading.
- A study by Montana DOT concluded that the benefits of using chip seal interlayer with 3.25-inch overlay was difficult to quantify even though no cracking occurred in the section with CSI until the final inspection, since only two cracks were detected in the control section over the evaluation period of 10 years.
- Based on the literature review by the Nevada DOT, asphalt-rubber chip seal overlaid with 1.5-in. asphalt overlay delayed reflection cracking up to 5 years
- Louisiana DOT study found that the use of CSI improved the pavement service life by 4 years on average.
- Previous studies indicated the ability of the CSI to reduce the tensile stresses increases as with increase of it thickness (i.e. single vs. double chip seal), binder content, as well as the flexibility of the binder increases.
- Results of previous studies suggest that chip seal interlayer is best suited for low to medium traffic roads.

Main Findings of LPA Survey and Interviews

- More than 20 of the responding agencies in Ohio has indicated that they have used CSI sometimes or often to reduce reflection cracking.
- About half of the responding LPAs agencies that have used CSI indicated that it improves the service life of overlay. However, the other half indicated that they do not know. The agencies indicated that CSI improved the service life of the overlay by 3 years on average.
- The majority of responding agencies indicated that using CSI is cost effective as it eliminates the need for milling or thicker overlay as well as reduce the maintenance cost.
- The main factors that were identified by responding agencies to affect the improvement due to using CSI included existing pavement condition, road traffic volume and existing road type.
- The majority of agencies that have used CSI indicated that they use similar design method and specifications for chip seal interlayer as that used for a typical chip seal treatment.
- Several of responding agencies recommended allowing traffic to run on the chip seal interlay for a week or two before placing the overlay.

Main Findings of Interviews with LPAs and Evaluations of CSI Sections

- The CSI seems to help delay reflection cracking particularly when used with overlays with thickness less than 1.5 inch.
- The pavement condition seems to affect the benefits to a certain degree.
- LPAs who have used CSI indicated it is cost effective but they do not have data to verify that.
- In general, LPA either used no tack coat or tack coat with very low application rate (<0.03 gsy).
- Chips seal with coarser aggregates might be better but there is no data to validate that.
- Based on evaluation of limited number of sections with and without CSI, the CSI seems to delay the development of reflection cracking and improve the service life of the overlay.

5. Recommendations

Based on the results of the of this study, the following recommendation are made:

- More data is needed to validate the cost effectiveness of CSI. Therefore, it is recommended to evaluate several local roads with and without CSI in different LPAs in Ohio and obtain maintenance costs to determine the service life and life cycle costs.
- Future research should also determine the optimum pavement condition for a road to use CSI.
- Future research should also determine the optimum properties of the chip seal interlayer to obtain the greatest improvement.

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2. Elseifi, M., & Bandaru, R. (2011). Cost effective prevention of reflective cracking of composite pavement (No. FHWA/LA. 11/478). Louisiana. Dept. of Transportation and Development.

Appendix A Literature Review

A.1 Reflection Cracking

Hot Mix Asphalt overlays are a very common rehabilitation practice when pavement reaches an undesirable level of performance. HMA overlays are typically applied on pavements that are distressed and have functional problems such as rutting and cracking. Therefore, overlays are usually designed to resist the existing pavement distresses. However, an associated issue of reflection cracking can appear in the new asphalt overlay shortly after construction, resulting in premature failure. Reflection cracking in an asphalt overlay can be described as the propagation of the underlying pavement cracks as a result of the continuous movement at discontinuities due to thermal stresses and traffic loading. Figure A.1 below shows a schematic of the mechanisms of reflection cracking as in (Hu, Zhou, & Scullion, 2010).

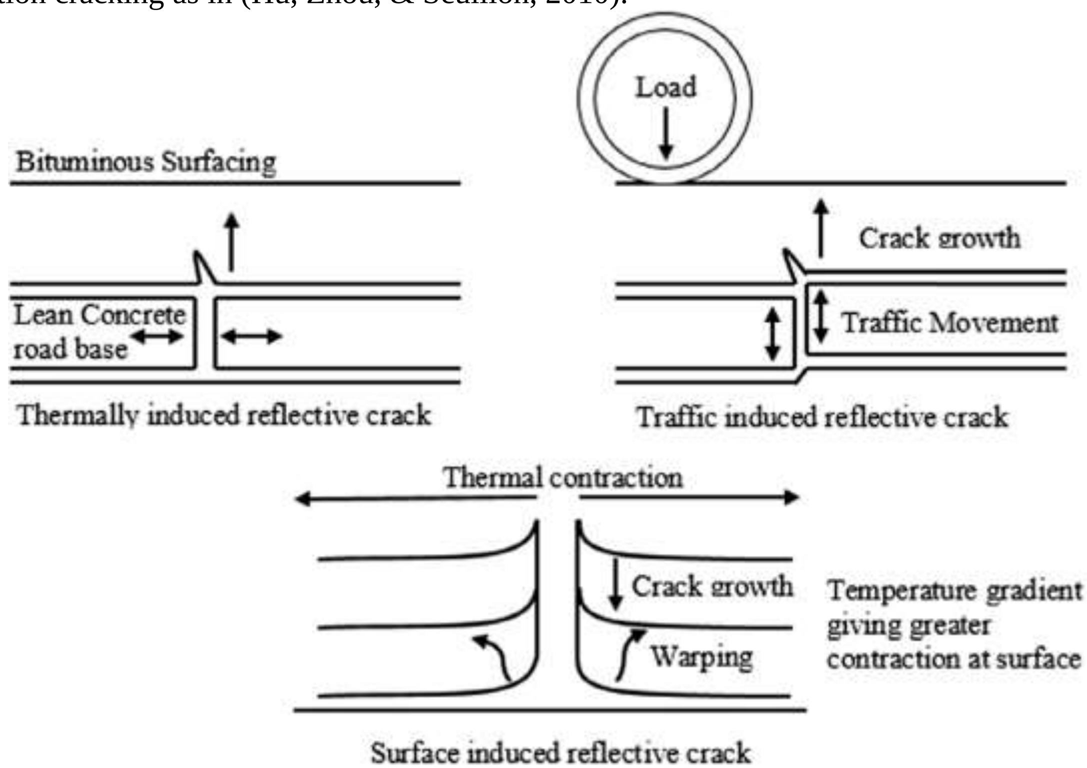

Figure A.1 Reflection cracking mechanisms based on (Hu, Zhou, & Scullion, 2010)

Different mitigation strategies have been reported in the literature to control reflection cracking in pavement overlays. (Dhakal, Elseifi, & Zhang, 2016) provided a summary of different treatment methods found in the literature, their main function, and the estimated cost of each method, as shown in Table A.1. Basically, most of the available methods serve as interlayer systems to control or delay reflection cracking in pavement overlays. These systems work based on two main mechanisms (Button & Lytton, 1987). First is to distribute the induced stresses over a larger area and provide better tensile stress resistance. Second is to absorb and dissipate the resulting strain energy in the underlying pavement layer.

Table A.1: Summary of available reflection cracking treatment methods adopted from (Dhakal, Elseifi, & Zhang, 2016)

Treatment method	Function	Estimated unit cost
Galvanized steel netting	Reinforcement	$3.0-5.0/yd^2
Geogrid	Reinforcement	$1.8-4.0/yd^2
Geonet	Reinforcement	$3.0-4.0/yd^2
Glass-grid	Reinforcement	$ 4.0-7.0/yd^2
Paving fabric	Stress relief	$ 0.6-1.05/yd^2
Geocomposite	Stress relief	$ 8.0-9.2/yd^2
SAMI	Stress relief	$ 3.5-6.5/yd^2
Fractured slab methods	Elimination of movement	$ 6.0-8.5/yd^2
NovaChip	Stress relief	$ 3.0-4.0/yd^2
Strata	Stress relief	N/A
Chip Seal Interlayer	Stress relief	N/A
Saw and seal	Reflection crack control in overlay	$1.0-2.0/ft

A.2 Chip Seal Interlayer (CSI)

CSI is a highly flexible layer which reduces the magnitude of the tensile stresses before they intersect with the new HMA layer (Figure A.2). Chip seal prevents transferring of the existing cracks to the HMA overlay by its elongation and dissipating the horizontal strains in the vicinity of cracks. CSI Does not prevent or reduce the horizontal movements at cracks and joints but dissipate those movements. It also seals the cracks from moisture. Chip seal consists of asphalt binder (hot or emulsion) layer(s) and embedded aggregate layer(s). The binder is applied to the pavement surface using an asphalt distributor, then a uniform, predetermined rate of aggregate is immediately applied onto the binder using a chip spreader. Chip seal should be applied in one stone thick, and aggregates should be retained by enough binder amount that is not excessive to cause surface bleeding. Selecting the proper type of rollers for orienting the aggregates and properly embedding them into the binder depends on the binder type, aggregate type and size, and actual type of chip seal being constructed. Pneumatic rollers are the types of rollers that are typically used for all chip seal applications. The rollers are followed by the brooms that remove excess aggregate from the finished surface.

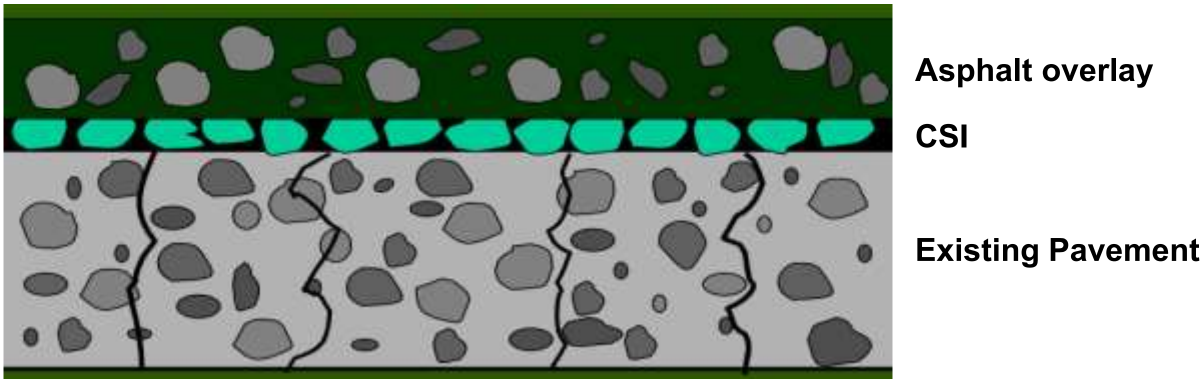

Figure A.2 Chips seal Interlayer (CSI)

Dhakal et al. (2016) reported a synthesis for different strategies used by different highway agencies to control reflection cracking. The study included survey of different of highway agencies in the US and Canada on the current state of practices to address reflection cracking. Figure A.3 shows the treatment methods that respondents indicated they regularly used to delay reflection cracking. It is noted that CSI is one the commonly used among state agencies to delay reflection cracking.
Based on a national survey, Dhakal et al. (2016) reported that 60% of the survey respondents indicated that CSI can contribute positively to reflection cracking delay (Figure A.4). In addition, the survey respondents indicated that chip seal interlayer was recommended to be selected in both cases of existing asphalt pavements and existing rigid pavements because of its low cost, its ability to control the reflection cracking, and its ability to be used with weak subgrades. Dhakal et al. (2016) indicated that an acceptable performance for CSI was reported by most of the studies, with a positive effect on reflection cracking mitigation when it is used with paving fabric. However, this method is suitable for low to medium traffic roads.

NovaChip was also mentioned as a treatment method for overlay procedures *(Dhakal et al., 2016)*, it is a two-steps method where the polymer-modified asphalt emulsion is applied on concrete pavement surface, then a gap graded AC layer is applied. Based on the results obtained from North Carolina DOT, NovaChip is commonly used on jointed concrete pavements and the reported service life resulted from applying this method was 10 years or more, even in the case of high traffic and high truck percentage.

Dhakal et al., 2016 concluded, based on the results of life cycle cost analysis conducted in San Diego county, that the reflection cracking and crack sealing were eliminated, and the annual cost reduced half by using the process of placing a paving fabric on the existing pavement then applying a single or double chip seal. However, it was recommended not to use this method in the cases of vertical grades with a slope greater than 10%, at the last 100 ft of approaching intersections, when the ADT is more than 10000, and at roads having freezing-thawing cycles. The application rate of binder application within the fabric was recommended to be varied according to the climatic conditions. A range between 0.30 and 0.35 gsy was recommended in cold climates, while a range between 0.25 and 0.30 gsy was recommended for hot climates.

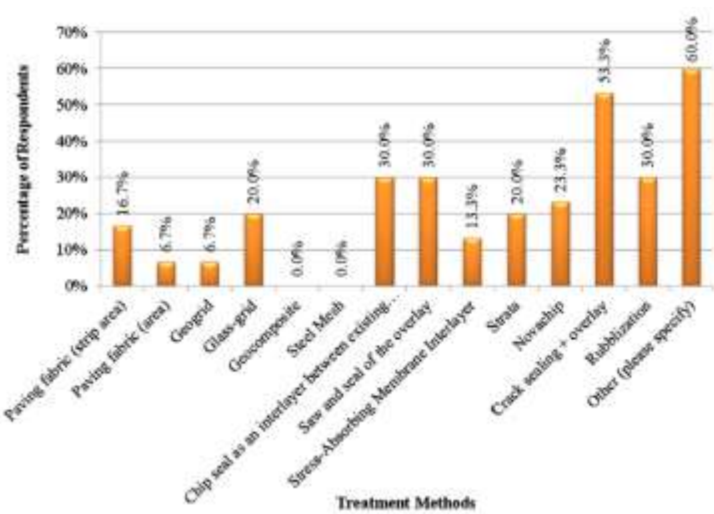

Figure A.3 Treatment methods regularly used to delay reflection cracking

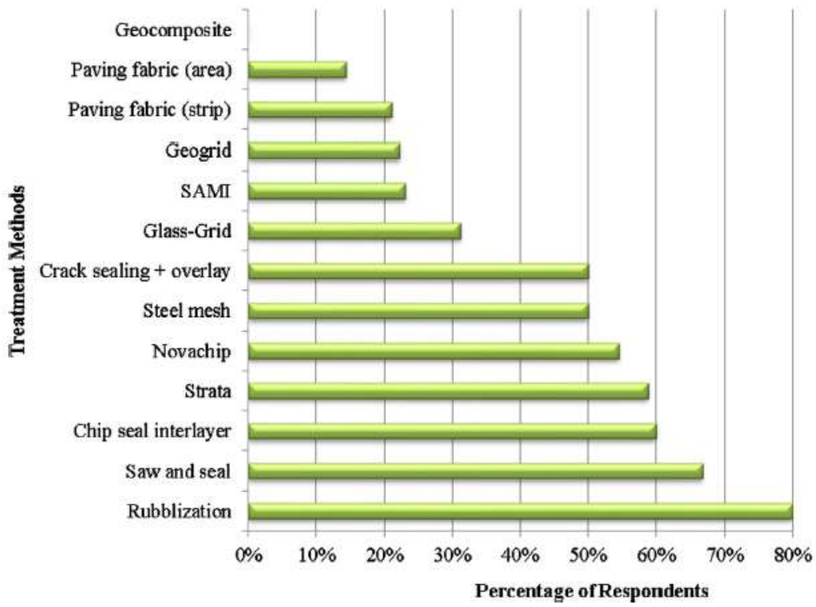

Figure A.4 Treatment methods that positively contribute to delay reflection cracking

As part of a study funded by Louisiana DOT, several treatment methods for controlling the reflection cracking were also evaluated by Elseifi and Bandaru (*2011)* based on the performance, cost-effectiveness, and constructability of pavements constructed with the use of these treatment methods across Louisiana. Results indicated that the use of chip seal interlayer improved the performance against the reflection cracking in projects evaluated. In addition, the performance rating values were higher in the sections that has chip seal interlayer than that untreated sections. The majority of the sites showed an improvement in service life due to the use of chip seal interlayer. Twenty-five percent of the sections showed an improvement from 1 to 3 years and 33 percent of the evaluated sections showed an improvement from 4 to 10 years. The average level of improvement to the pavement service life due to the use of chip seal was 2 years. Elseifi and Bandaru (2011) also indicated from the results of cost effectiveness conducted on the evaluated sections that most of the evaluated sections that the use of chip seal interlayer was more cost -effective compared to the those were HMA overlays was used only. The study recommended applying an asphaltic surface treatment (chip seal) as a crack relief interlayer prior to the HMA overlay particularly since the average cost of using chip seal interlayer was $2 per square yard.

In another study for Louisiana DOT Bandaru (2010) evaluated 12 projects where chip seal was used as an interlayer. Some projects where on states routes while others where on interstates in Louisiana. The results of this study showed that 33% of the evaluated sections showed an improvement of 4 to 10 years. 25% of the sections showed an improvement from 1 to 3 years. However, the remaining 42% of the sites showed no improvement or negative contribution. On average, the use of chip seal improved the pavement service life by 4 years. Bandaru (2010) reported that the use of chip seal increased the cost of initial placement of HMA overlay by 25% on average. Based on the total annual cost (TAC) concept the majority of the sections (75%) indicated that chip seal interlayer was cost-effective, compared to regular HMA overlays.

In a study by West et al. (2019) in Georgia DOT to evaluate two methods for reducing reflection cracking in the 2012 NCAT Test Track cycle; the first method involved using a double chip seal interlayer (section N12), the second method involved using an open-graded interlayer (OGI) (section N13). To simulate cracking, deep saw cuts were made in both test sections and filled with sand to avoid self-healing. Section N12 was covered with a cracking relief interlayer consisting of a double chip seal with thickness of about 0.7 inches thick and surfaced with a 1.5-inch-thick layer of 12.5 mm dense-graded mix. Section N12 reflection cracking treatment was constructed by placing No. 7 stone followed by No. 89 stone. A sand seal surface was then placed over the No. 89 stone before adding the asphalt surface layer. Section N13 was covered with a 1.1-inch thick OGI mixture and a 1.1-inch-thick overlay using the same 3/8-inch mix as section N12. Results at the end of the 2012 and after approximately 10 million ESALs indicated that cracking was beginning to develop in both sections. After 2 more years and around 20 million ESALs of loading, the amount of cracking in section N13 increased with 50% of the saw cut area having reflected through to the surface. For section N12, reflection cracking was found for only 6% of the saw cut area. Section N12 had higher rut depths at the end of the 2015 research cycle as compared to section N13.

In a study conducted by Abernathy (2018) for Montana DOT, a conventional chip seal interlayer was used under the overlay of thickness 76 mm (3 inch) was evaluated in terms of mitigating the reflection cracking. Two trial sections were constructed in June 2008 and evaluated after 10 years of construction in 2018 to evaluate the ability of chip seal to seal existing cracks and mitigate the reflection cracking. The trial section with 305 m (1000 ft) of length and chip seal as an interlayer was compared to the control section with same length, similar distresses condition, and no chip seal application. The AADT was estimated at 700 for the project period. Visual evaluation and crack mapping were performed to document the performance of both sections. Results of the evaluation indicated that moderate severity crack in (>1/2” - <3/4”) in the control section, whereas no noticeable cracks were reported in the section with chip seal interlayer. Final inspection 10 years after construction indicated no additional cracking or further noticeable distresses to those reported in the control section 7 years after construction. It was concluded that the efficiency of using chip seal interlayer was difficult to quantify even though no cracking occurred in the section with chip seal application until the final inspection, since only two cracks were detected in the control section over the evaluation period of 10 years.

Based on the literature review by the Nevada DOT, asphalt-rubber chip seal overlaid with 1.5-in. conventional dense-graded HMA or gap-graded HMA delayed reflection cracking up to 5 years
Based on the literature review by the Nevada DOT, asphalt-rubber chip seal overlaid with 1.5-in. conventional dense-graded HMA or gap-graded HMA delayed reflection cracking up to 5 years (Bandaru, 2010).

Many factors can affect the performance of chip seal such as: construction procedure, existing pavement condition, the properties of used asphalt binder and aggregate, equipment condition, and the knowledge and skills of the personnel applying the chip seal and inspection personnel (Shuler et al. 2011, Testa and Hossain 2014). The ability of the CSI to reduce the tensile stresses increases by increasing its thickness through using double chip seal layers instead of the single layer). In addition, CSI benefits improve with increasing the binder content or increasing the flexibility of the binder. However, using a thick, rich and highly flexible interlayer may cause potential rutting and shoving problems under heavy traffic. Therefore, an optimum design must be established in order to effectively mitigate reflection cracking without negatively impacting the overlay performance. The benefits seem to depend on the overlay thickness such that the benefits are more pronounced when the overlay thickness is 1.5 inch or less. CSI also seems to be better suited for low to medium volume roads.

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Appendix B Ohio LPAs Survey Results

A survey of LPAs in Ohio was conducted to document their current practices and experiences with using Chip Seal Interlayer (CSI) to reduce and control reflection cracking. A detailed survey was prepared by the research team and sent to ODOT Technical Advisory Committee (TAC) of this project for review it. Modifications were made and some questions were added/deleted based on comments received from the TAC. The survey was sent by Ohio LTAP to all LPAs in Ohio on May 27th, 2021.

The survey included 23 questions which investigated the following information:

- The extent of use of CSI.
- Experience with using CSI.
- Effectiveness of CSI in reducing reflection cracking.
- Properties of CSI layer.
- Performance data on record for overlays with CSI.
- Factors that were found to affect CSI effectiveness.
- Factors used to select the projects for using CSI.

A total of 58 responses were received from different types of LPAs. Figure B.1 shows the different types of LPAs that were covered in the survey. The results were analyzed and compiled for each.

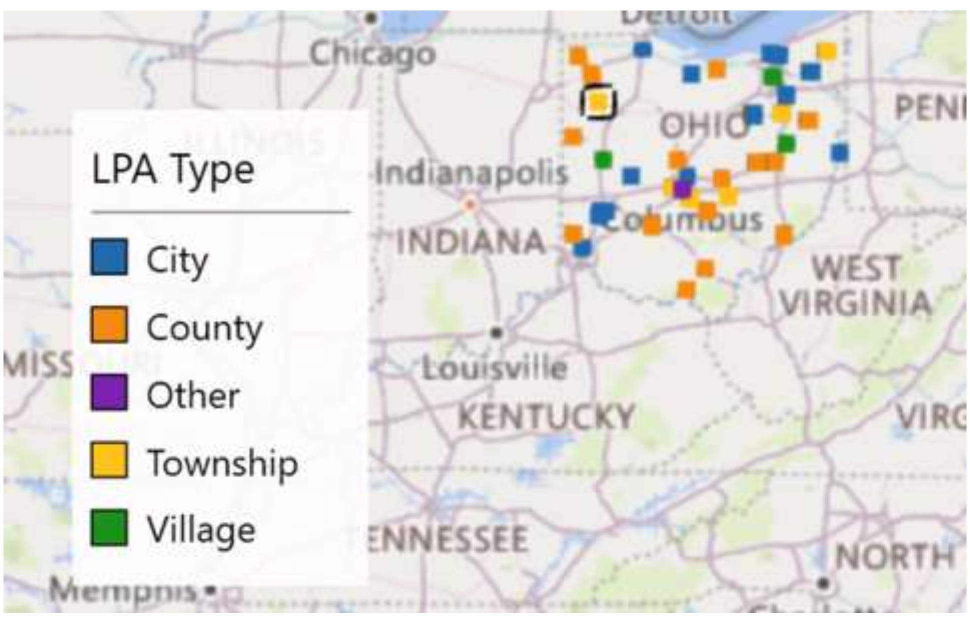

Figure B.1: Locations of Ohio LPAs that responded to the survey

Figure B.2 summarizes the answers to the survey questions regarding the type of LPAs for each agency that responded to the survey (city, county, township, or village). Figure B.2 shows that approximately 33% of the respondents (20 responses) answered “city”, which represent the higher percentage. About 31% of the respondents (18 respondents) answered “county” and 24%

of the respondents (14 responses) are in townships. Just around 5% of the respondents answered "village" (3 responses). In addition, about 7% of the responses (4 responses) mentioned other types of LPAs.

Figure B.3 presents responses regarding whether each agency has used CSI to control reflection cracking or not. Most of the respondents who answered this question indicated that they have used CSI to control reflection cracking before and they are going to use it in the future, which represent more than 60% of the responses (35 respondents). Only about 7% of the agencies (4 responses) indicated that they are not using CSI now, but they have used it in the past. The remining 18 responses (about 33%) haven't used it before.

Figure B.4 summarizes the responses for the question on how often your agency uses chip seal interlayer to control reflection cracking. More than 35% of the responding agencies (11 answerers) answered "often" and about 20% (6 respondents) answered "sometimes". Around 26% (8 responses) selected "rarely" and just 3% of the respondents (1 respondent) has never used it before. About 3% of the responses (just 1 respondent) always uses it. In addition, 13% of the respondents (4 responses) chose to specify other answers such as they used it more in the past but not very much in the current time. On the other hand, some respondents indicated that they are staring to use it more often compared to the past. Others indicated that using CSI depends on the project.

Figure B.5 presents the answers regarding if the agency observes any improvement in the overlay service life when using a chip seal interlayer. Figure B.5 shows that most of the answers are yes (12 respondents who represent 43% of the responses), or I don't know (13 respondents, about 46%). The agencies that answered yes were asked to specify the increase in the overlay service life in years. The answers are on average of 3.2 years. The range is from 1 to 4 years. The remaining 3 answerers (around 11% of the respondents) did not observed any improvement in the overlay service life when using a CSI.

Figure B.6 shows the typical overlay design thickness used when using a CSI. Approximately 43% of the respondents (12 responses) indicated that 1-1.5 inch overlay thickness were used when they used CSI. Furthermore, about 36% of the agencies (10 responses) used 1.5-2 inch. The remaining are split between around 11% of the respondents (3 responses) used 1 inch and another 11% (3 responses) used more than 2 inches.

Figure B.7 summarizes the answers to the survey questions regarding whether a chip seal interlayer allows for a reduction in the design overlay thickness. 60% of the respondents (15 responses) answered no. The rest 40% (10 respondents) answered yes and the answers are ranged from 1 to 2, on average of 1.6 inch. In figure B.8, the respondents were asked whether they think that using CSI is cost effective or not. Most of the respondents answered yes, the percentage is about 64% (18 responses). Some respondents indicated that using CSI eliminates the need for milling. Others indicated that using CSI extends the life of the pavement by creating a waterproof seal between the overlay and the existing pavement and decrease the maintenance cost. Moreover, others indicated it reduces the working hours and eliminates the need for thicker overlays to retard the cracking in the new surface. On the other hand, 25% of the answerers (7 responses) answered I don't know. Just about 11% (3 respondents) answered no, they don't think it is cost effective.

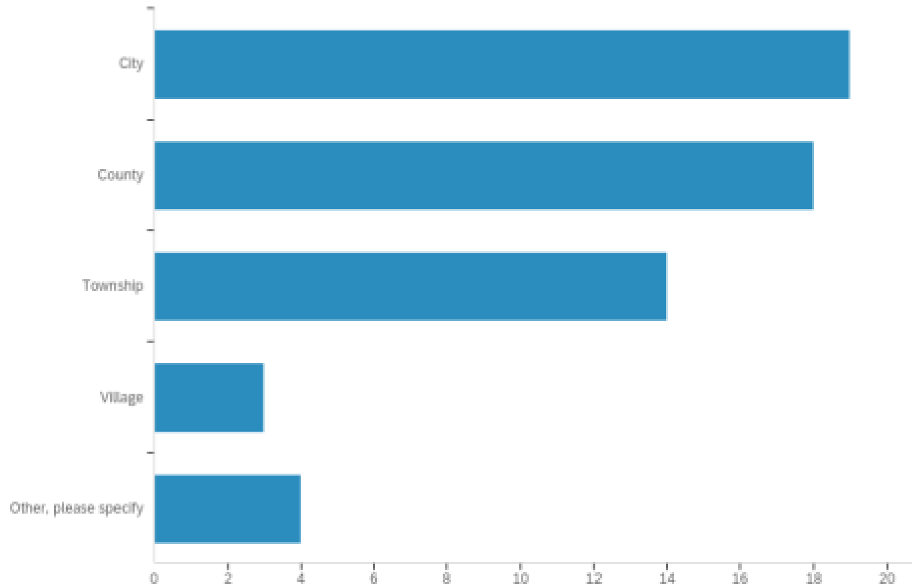

Figure B.2: Agency type

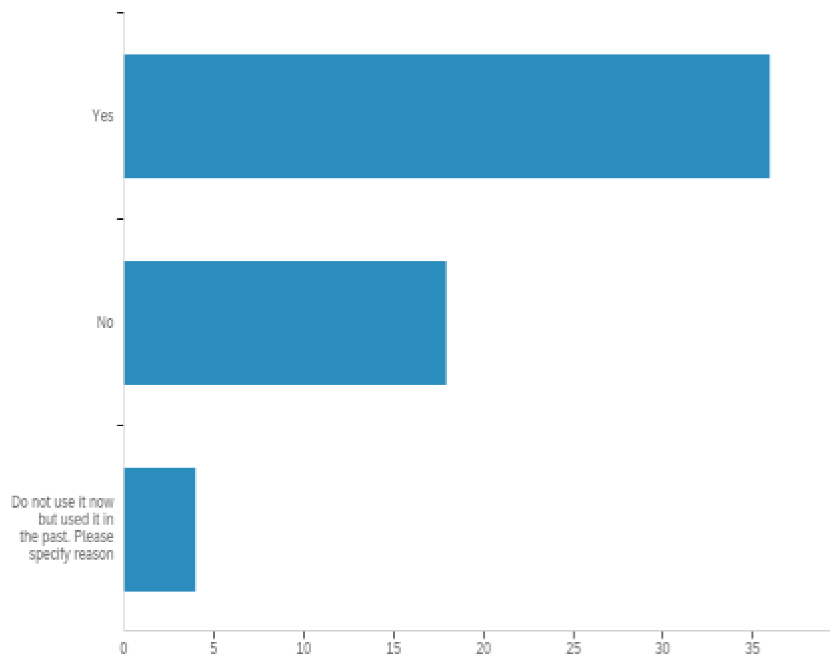

Figure B.3: Have your agency used CSI to control reflection cracking?

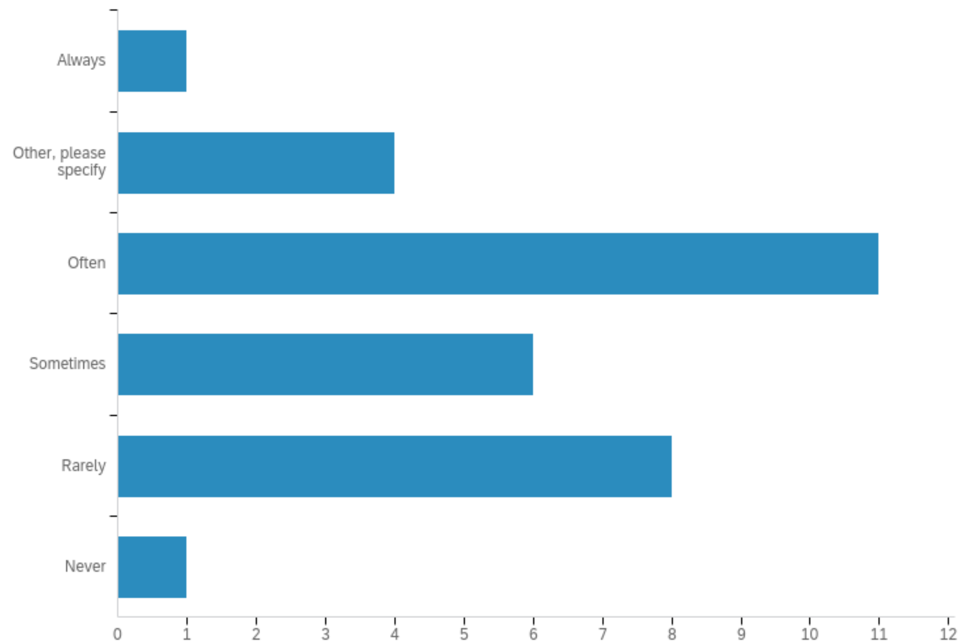

Figure B.4: How often do you use CSI to control reflection cracking?

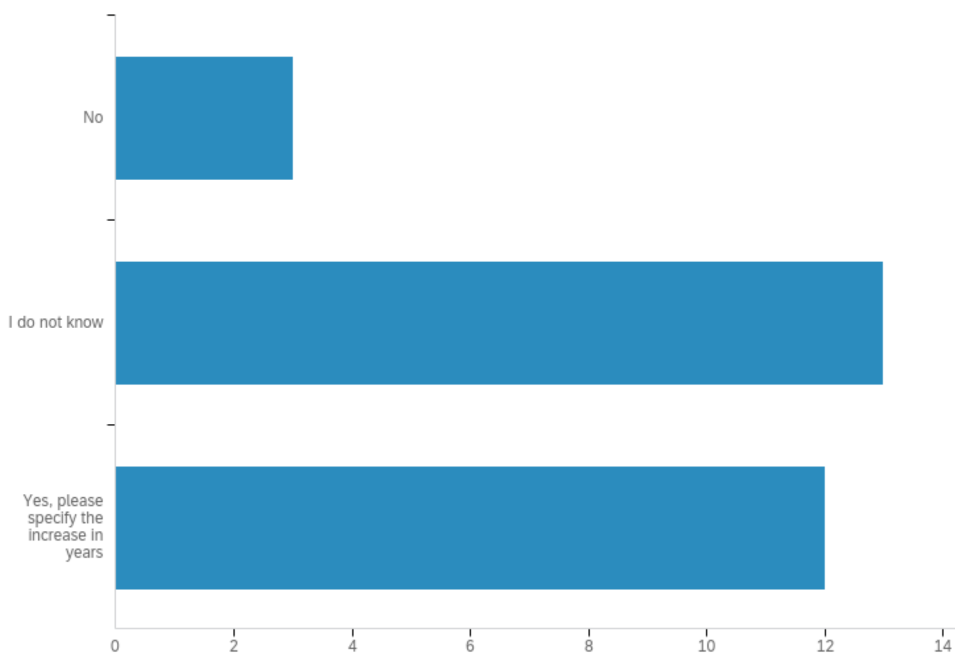

Figure B.5: Did your agency observe any improvement in the overlay service life when using a CSI?

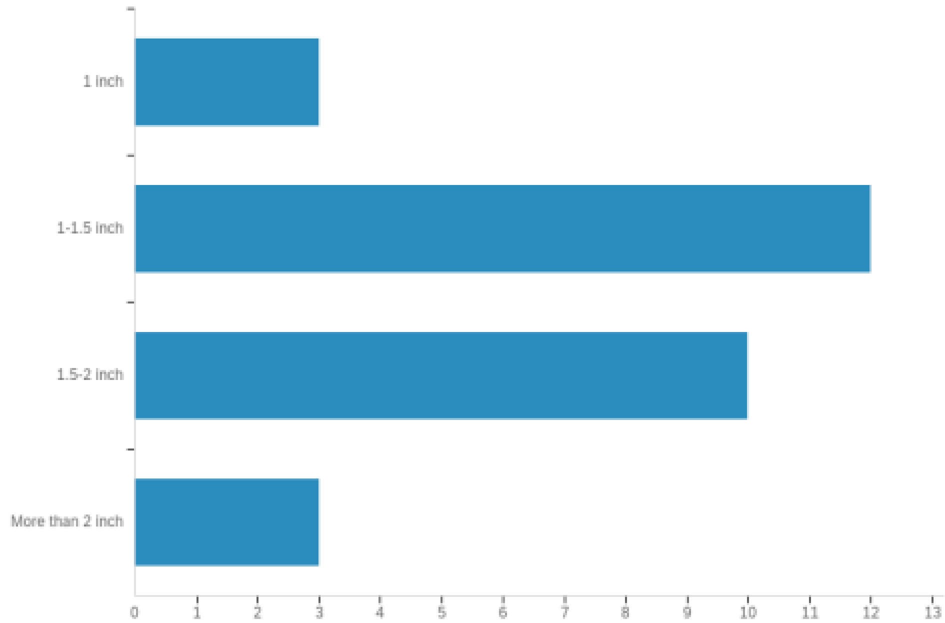

Figure B.6: Overlay design thickness used when using a CSI

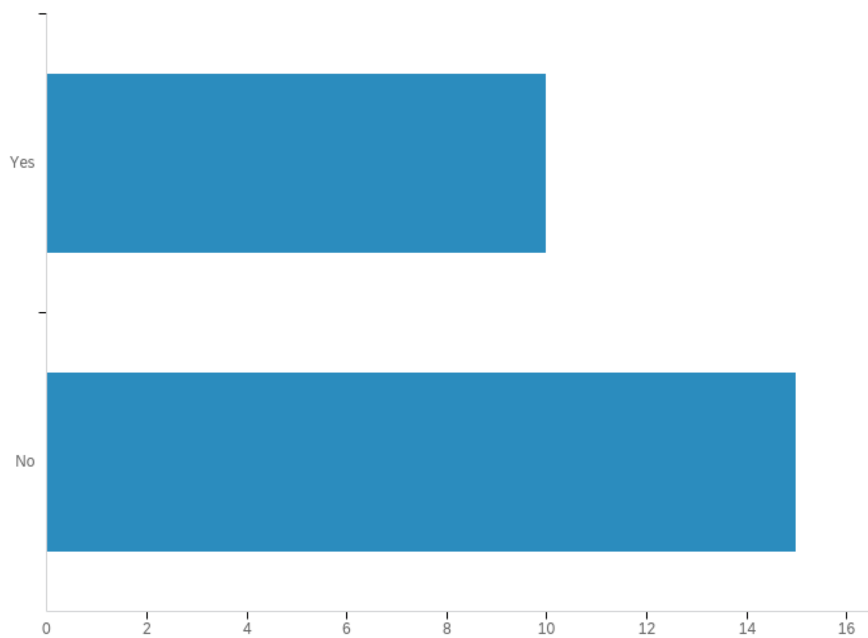

Figure B.7: Does a CSI allow for a reduction in the design overlay thickness?

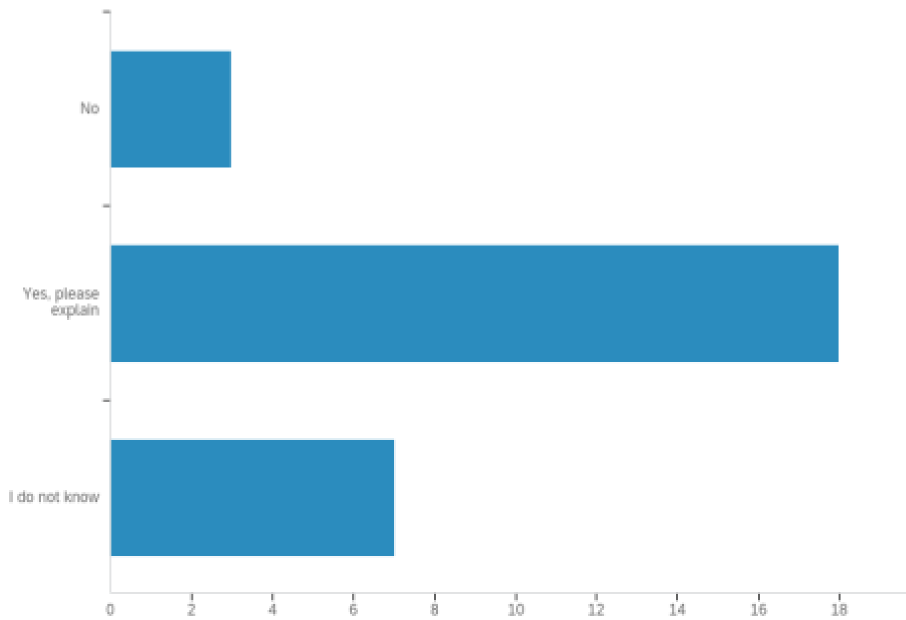

Figure B.8: Whether using CSI is cost effective

Figure B.9 shows the answers when the respondents were asked, what is the cost increase due to using chip seal interlayer. Approximately about 57% of the respondents (16 responses) mentioned the cost per square yard. The answers ranged on average of $2.7/SY. 12 respondents (43% of the respondents) don't know the answer for this question. Figure B.10 shows that most of the agencies do the CSI by a contractor (23 respondents who represent about 79% of the respondents) compared to those who do it in house (6 agencies which represent about 21% of the responses).

Figure B.11 shows that around 46% of the respondents (13 responses) selected the answer "good" to rate their experience with the performance of chip seal interlayer in controlling reflection cracking. About 11% of the agencies (3 responses) indicated that it was an excellent experience. Some of the respondents answered "fair" or "poor" with a percentage of around 14% (4 responses) and 7% (2 responses) respectively. Almost 21.5% of the respondents (6 responses) answered "I don't know".

Figure B.12 shows that most of the respondents answered no when they were asked whether their agencies have any issues with using CSI. Around 36% of the respondents (10 responses) answered yes and some of them are not sure about the reason. Others specified that sometimes the public opinion is an issue. Also, the contractor scheduling or coordination might be an issue. In addition, some respondents mentioned that they occasionally have issues with subcontractor availability. Others indicated that the paver tracks usually start picking up thin layers of asphalt underneath the chip seal because of tracking the chip seal.

Figure B.13 summarizes the response when the respondents were asked what factors your agency consider when using the chip seal interlayer. The existing pavement condition was the most repetitive answer which represent 38% of the total answerers (22 responses). About 26% of the total respondents (15 responses) selected the existing road type. Then, the road traffic volume and the thickness of overlay were selected with percentages of around 17% (10 responses) and 14% (8 responses) respectively. Only about 5% of the total respondents (3 respondents) mentioned other factors such as the contract requirements.

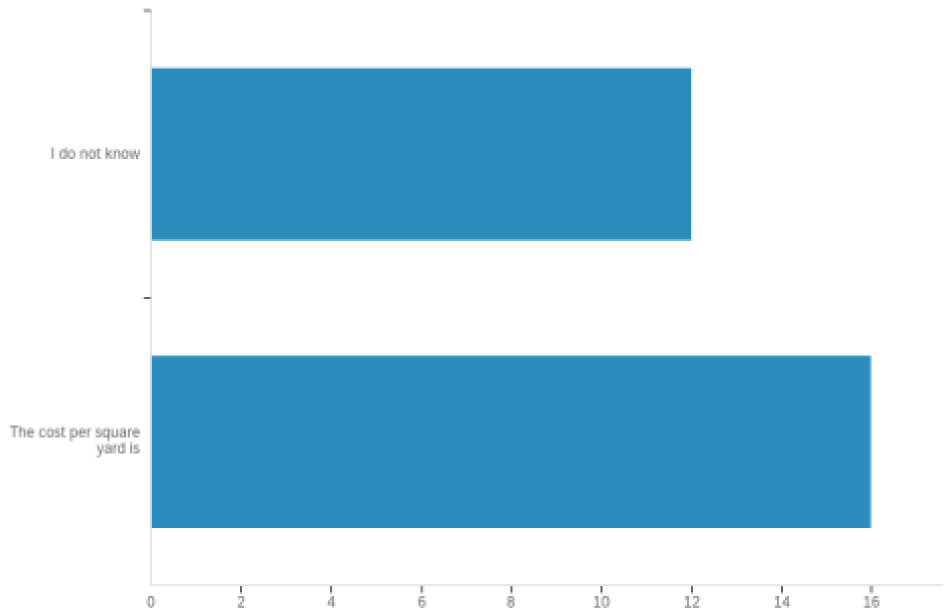

Figure B.9: The cost increase due using CSI

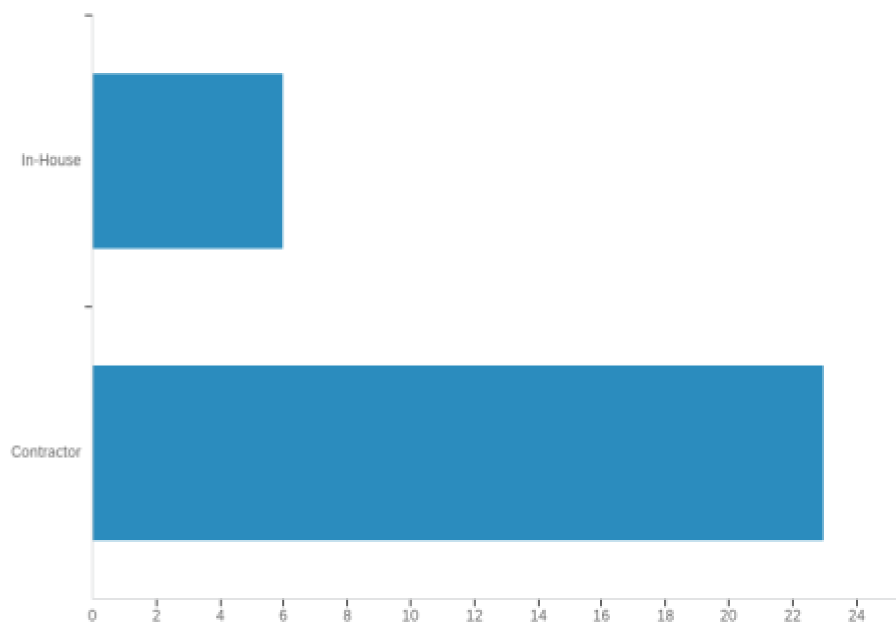

Figure B.10: In-house vs contractor installation of CSI

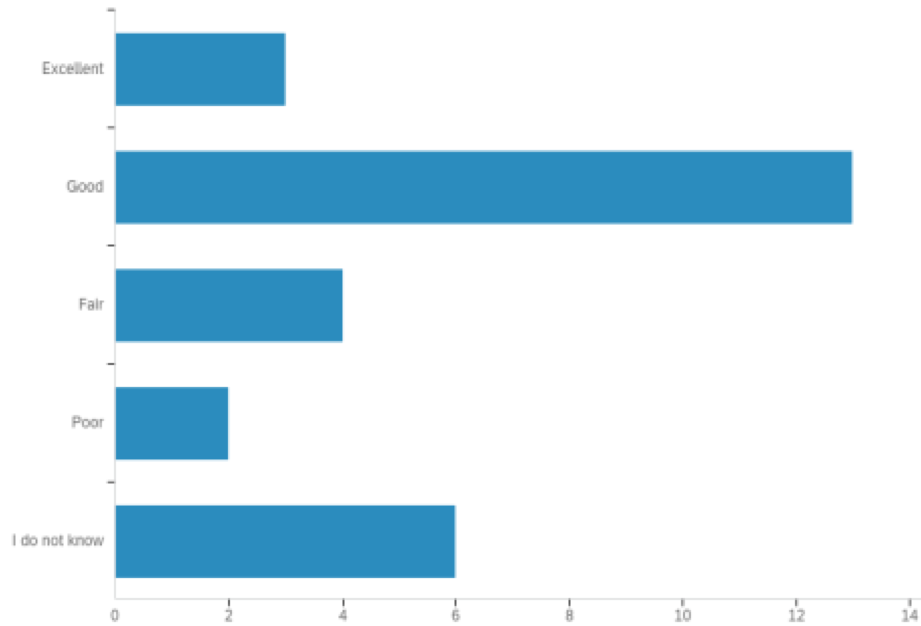

Figure B.11: Rate your experience with the performance of CSI in controlling reflection cracking

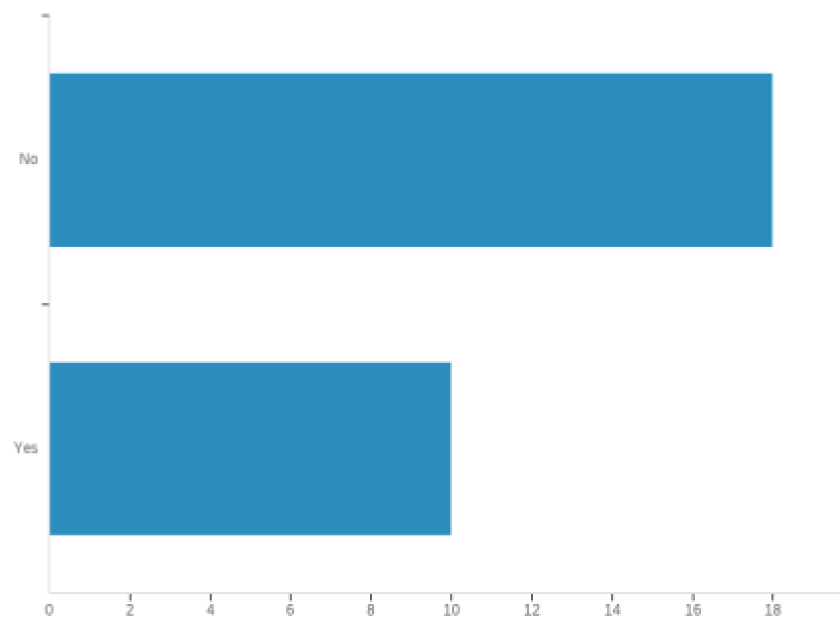

Figure B.12: Did your agency have any issues with using CSI?

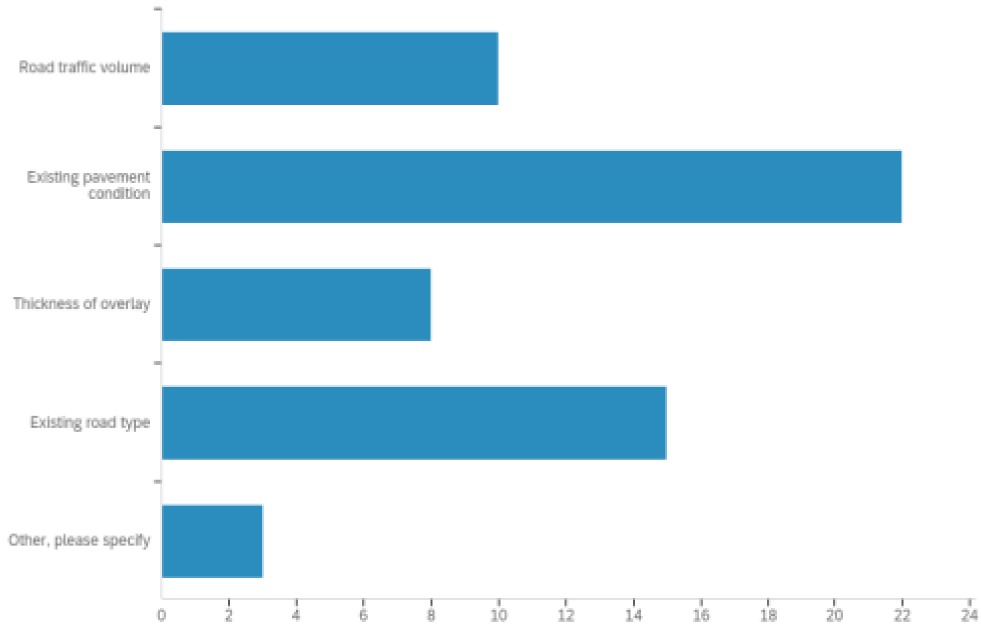

Figure B.13: The considered factors when using CSI

Figure B.14 illustrates the answers to the survey questions regarding the factors that affect chip seal interlayer effectiveness. It is noted that 30% of the responding agencies (15 responses) think that the existing pavement condition affects CSI effectiveness. Road traffic volume and existing road type were answered by 18% of the respondents (9 responses) for each factor. Almost the same 9% (4 responses) mentioned the thickness of overlay or chip seal properties. 16% (8 responses) indicated other factors that affect CSI effectiveness such as the summer heat.

Figure B.15 shows that about 86% of the respondents (24 responses) answered yes when they were asked whether their agencies use similar design method and specifications for chip seal interlayer as that used for typical chip seal treatment. Just about 14% (4 respondents) answered no. some of them mentioned that when they use interlayer, they specify type A. Others use type B fiber-mat.

Figure B.16 shows what type of emulsion the agencies use for CSI. Approximately 30% (8 responses) are using CRS-2P. Both agencies that use CRS-2 or HFRS-2P represent 15% of the total respondents (4 responses) for each. RS-2 is used by around 19% of the respondents (5 responses). Moreover, about 22% of the answerers (6 responses) mentioned other types of emulsion that they are using with CSI such as type SBS, MC-3000, CRS2 latex modified, or polymer modified bituminous emulsion.

Figure B.17 shows that about 60% of the total respondents (20 respondents) use limestone aggregate. About 18% (6 responses) are using Crushed gravel. Others indicated that they are using gravel or dolomite with a percentage of about 12% (4 responses) and 9% (3 responses) respectively. Only about 3% of the total answerers (1 respondent) is using slag for CSI.

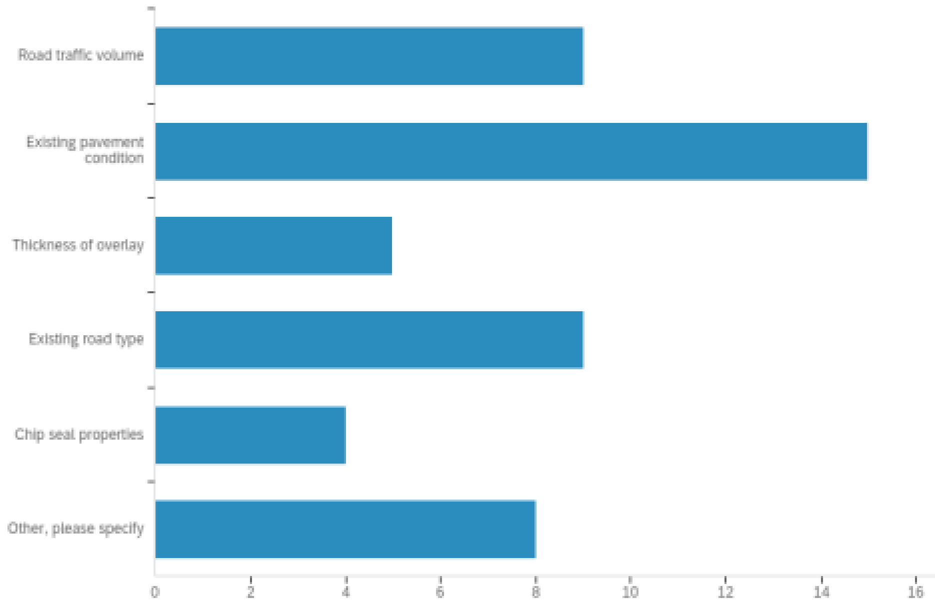

Figure B.14: Factors that affect CSI effectiveness

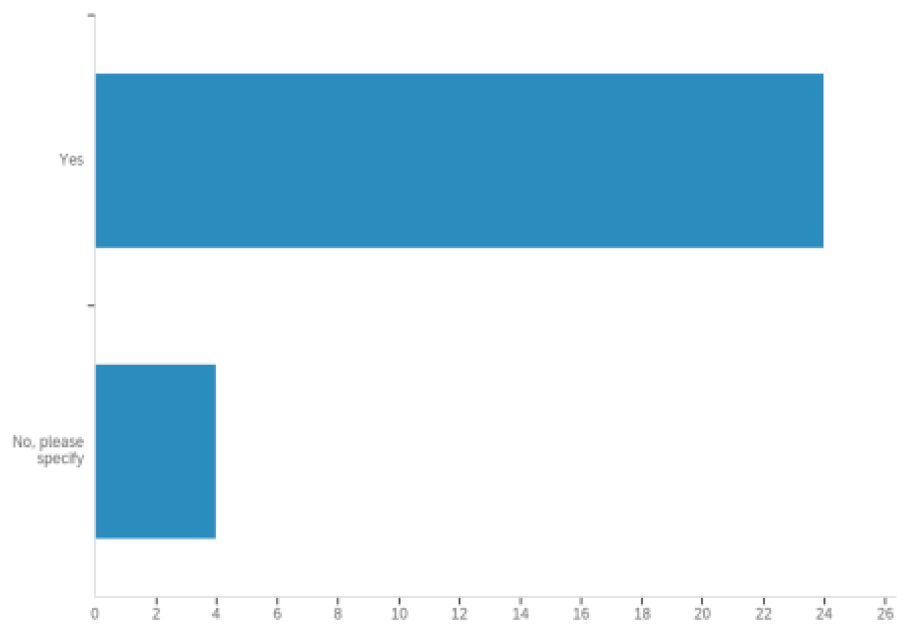

Figure B.15: Does your agency use similar design method and specifications for CSI as that used for typical chip seal treatment?

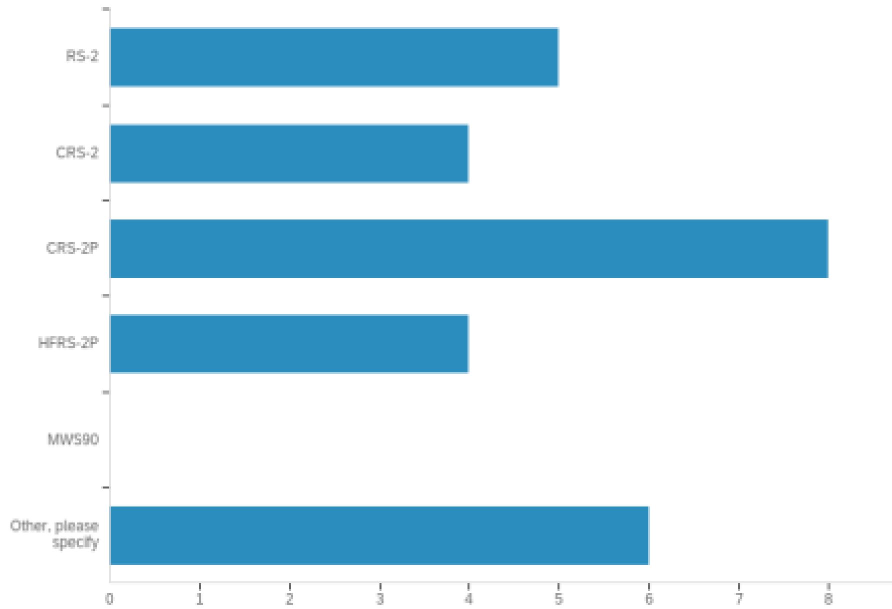

Figure B.16: Type of emulsion you use for CSI

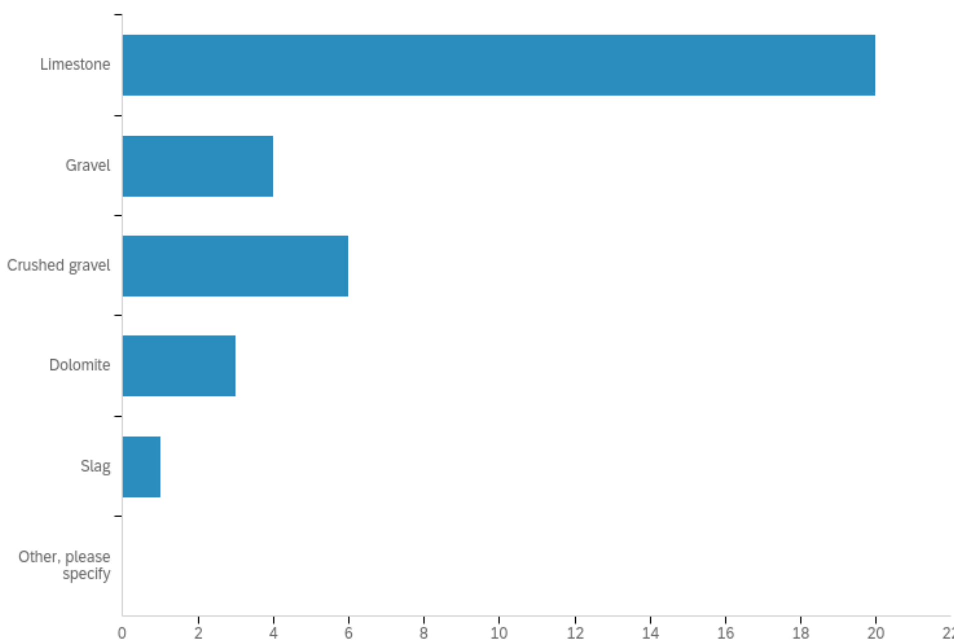

Figure B.17: Type of aggregate you use for CSI

Figure B.18 shows the answers when the respondents were asked about the nominal maximum aggregate size (NMAS) used for CSI in their agencies. Approximately 54% (14 respondents) were using 3/8". A percentage of 11.5% (3 respondents) mentioned 1/4" and another 11.5% mentioned No.4. Around 15% of the respondents (4 responses) are using 1/2". Only about 8% of the answerers (2 responses) indicated using other sizes of the aggregate such as ODOT spec and No.8.

Few of the responding agencies recommend steps that they have used and found to enhance the performance of chip seal interlayer. The main recommendation was allowing traffic to run on the chip seal for a week or two before doing the tack coat or the trackless tack.

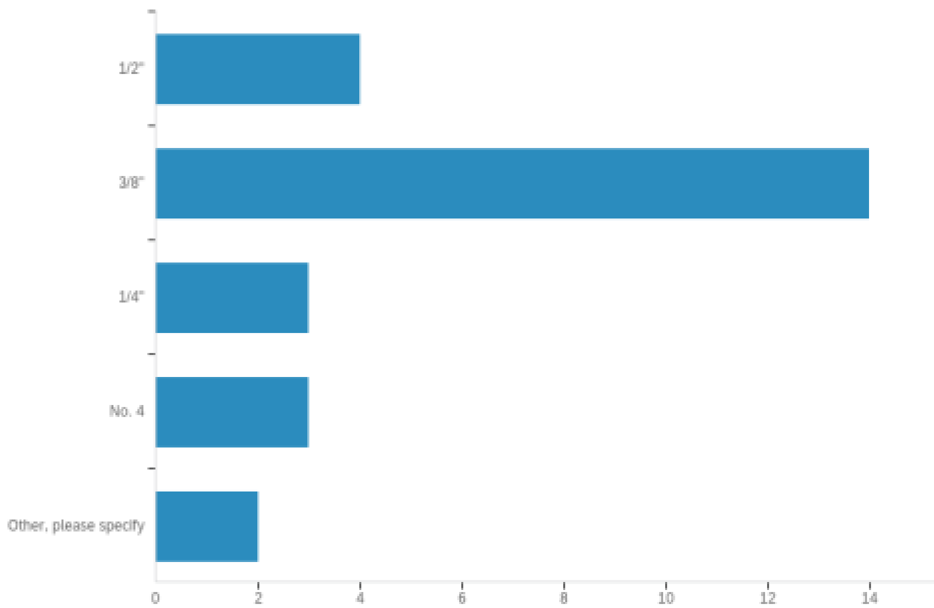

Figure B.18: What is the NMAS used for CSI?

Appendix C Nationwide Survey Results

A nationwide survey of LPAs in the US was conducted to document their current practices and experiences with using Chip Seal Interlayer (CSI) to reduce and control reflection cracking. A draft survey questionnaire was prepared by the research team and sent to the TAC. Modifications were made and some questions were added/deleted based on comments received from the TAC. The survey was sent by Ohio LTAP to all LPAs in the US on June 7, 2021.

The survey included 21 questions which investigated the following information:

- The extent of use of CSI.
- Experience with using CSI.
- Effectiveness of CSI in reducing reflection cracking.
- Properties of CSI layer.
- Performance data on record for overlays with CSI.
- Factors that were found to affect CSI effectiveness.
- Factors used to select the projects for using CSI.

Over 55 respondents were received from different types of LPAs in different states in the US as shown in the following figure. The results were analyzed and compiled for each.

Figure C.1 Locations of LPAs that responded to the national survey

Figure C.2 summarizes the answers when the respondents were asked about the type of LPAs for their agencies. Approximately 66% (37 responses) of the respondents answered "county". About 25% of the respondents (14 responses) are in cities. However, neither township nor village were mentioned by the respondents. Only 5 respondents (about 9% of the answerers) specified other answers. Furthermore, the respondents were asked whether their agencies have used chip seal interlayer to control reflection cracking before. Figure C.3 shows that 35 respondents answered no, which represent around 66% of the respondents. On the other hand, about 28% (15 responses) indicated that the chip seal interlayer is used by their agencies to control reflection cracking. Only about 3 respondents (about 5.7%) indicated that they were using CSI to control reflection cracking in the past, but currently they are not.

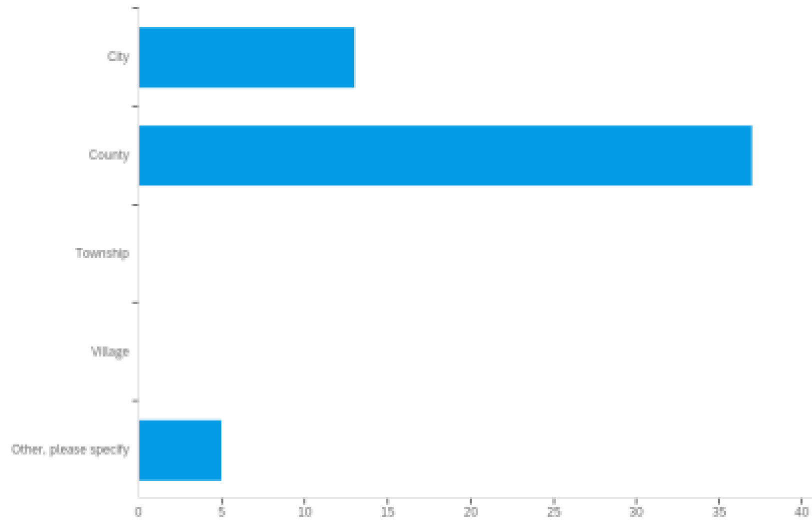

Figure C.2: Agency type

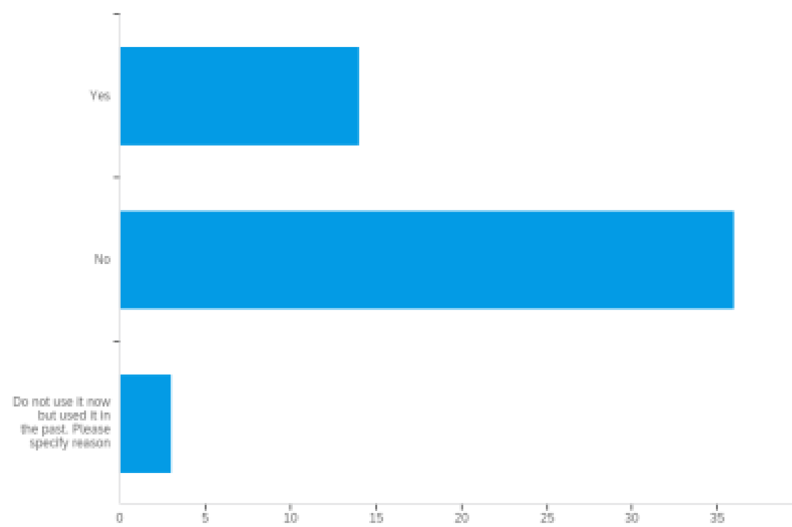

Figure C.3: Have your agency used CSI to control reflection cracking?

Figure C.4 summarizes the answers for how often each agency use chip seal interlayer to control reflection cracking. Just 1 out of the answerers answered rarely, and another 1 answered sometimes, which represent about 10% of the respondents for each answer. Other respondents selected (always, often, or never) with a percentage of about 20% of the respondents (2 responses) for each. The remaining 2 answerers specified other answers.

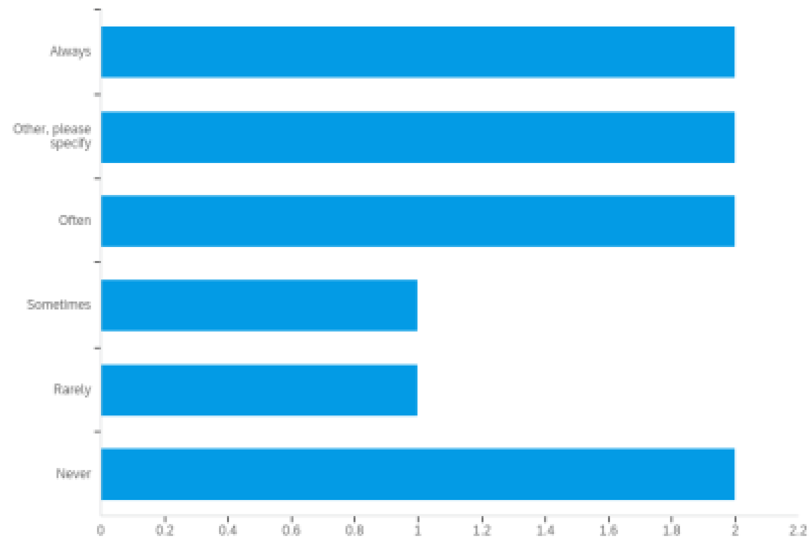

Figure C.4: How often does your agency use CSI to control reflection cracking?

The respondents were asked whether their agency observed any improvement in the overlay service life when using a CSI. Figure C.5 shows that there are 5 respondents answered yes (50% of the respondents). The figure shows that 3 respondents (30%) don't know. Only 2 of the answerers (20%) indicated that their agencies did not observe any improvement in the overlay service life when using a CSI.

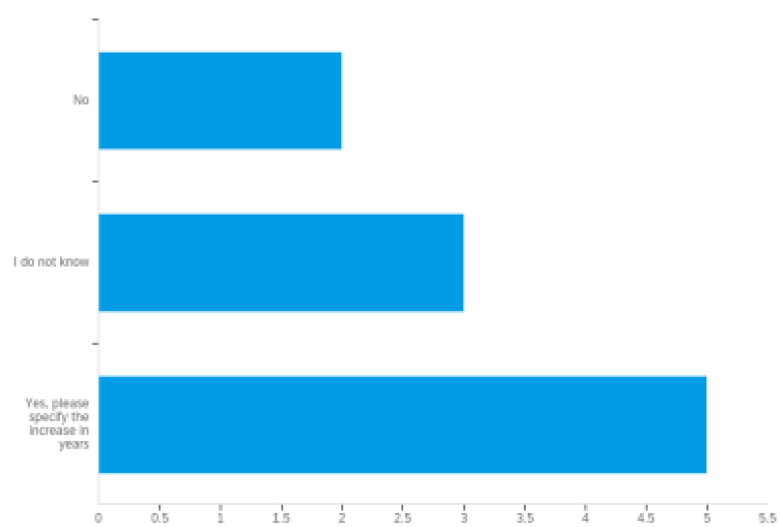

Figure C.5: Did your agency observe any improvement in the overlay service life when using a CSI?

Figure C.6 illustrates the answers when the respondents were asked, what is the typical overlay design thickness used when using a CSI. Most of the answerers answered 1.5-2 inch or 1 inch with a percentage of around 44% (4 respondents) and 33% (3 respondents) respectively.

The rest answered 1-1.5 inch or more than 2 inches with a percentage of around 11% of the total respondents (1 respondent) for each answer.

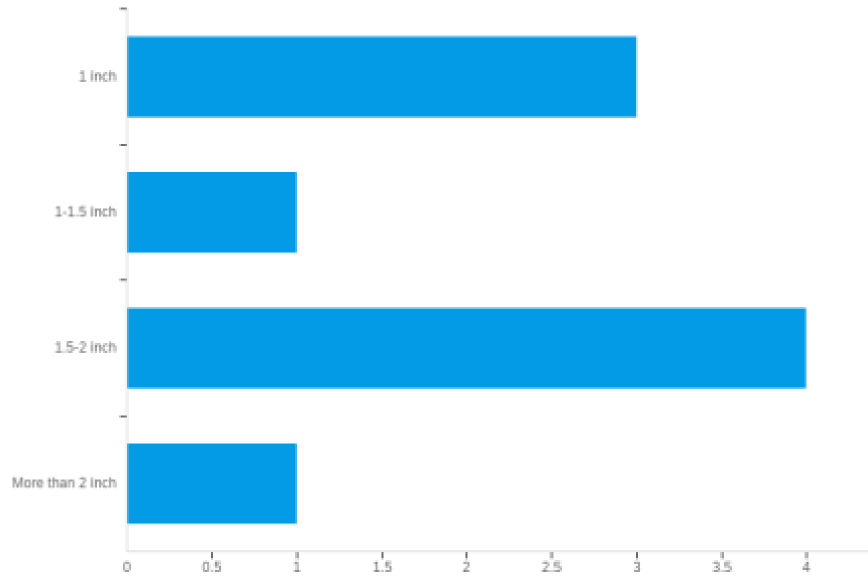

Figure C.6: Overlay design thickness used when using a CSI

The respondents were asked, does a CSI allow for a reduction in the design overlay thickness. Figure C.7 shows that 5 respondents (55.5% of the respondents) answered yes. The remaining 4 answerers (44% of the respondents) answered no.

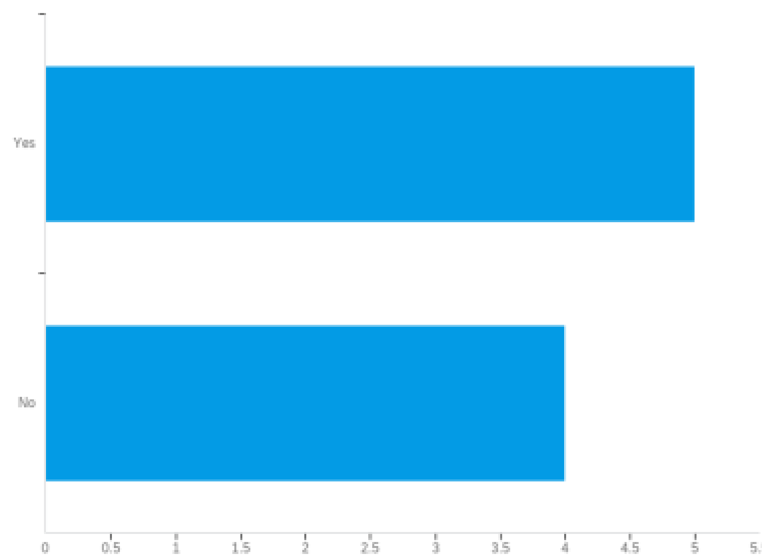

Figure C.7: Does a CSI allow for a reduction in the design overlay thickness?

Figure C.8 shows that 60% of the total respondents (6 responses) think that using chip seal interlayer is cost effective. They specified multiple reasons such as, the reduction in reflection cracking will reduce future crack sealing needs and extend the overlay life. Other respondents mentioned that related to their experience, using chip seal interlayer will double the life of the overlay. In addition, the CSI helps to keep water out of the asphalt which lead for saving in base asphalt. About 20% (2 responses) answered that they don't think using CSI is cost effective. 2 respondents (20% of the responses) don't know whether using CSI is cost effective or not.

Moreover, the respondents were asked, in general, how do they rate their experience with the performance of CSI in controlling reflection cracking. Figure C.9 shows that 4 respondents answered "Good" (which represent 40% of the responses). The remaining respondents answered (excellent, fair or I don't know) with a percentage of 20% for each answer (2 responses for each answer).

The responding agencies were asked whether they did have any issues with using CSI. Figure C.10 shows that most of the respondents answered no, their agencies did not have any issue, with a percentage of around 78% of the respondents (7 responses). Only 2 respondents (about 22%) answered yes, and they specified that provisions in the specs must be enforced in controlling the speed of traffic and the duration the chip seal is exposed to traffic. Others have issues during placement.

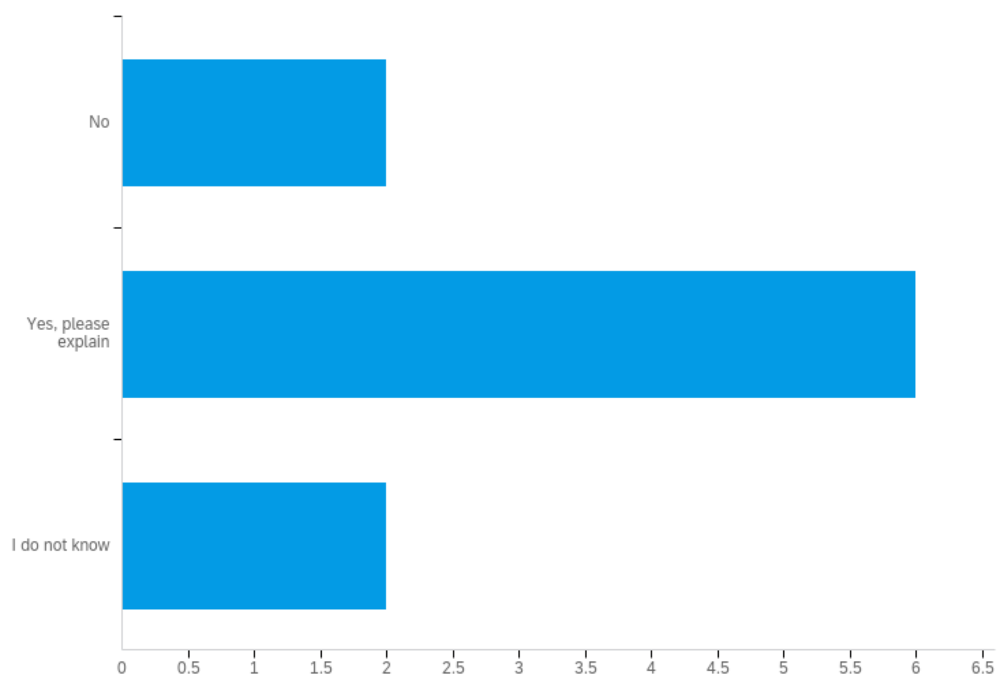

Figure C.8: Whether using CSI is cost effective

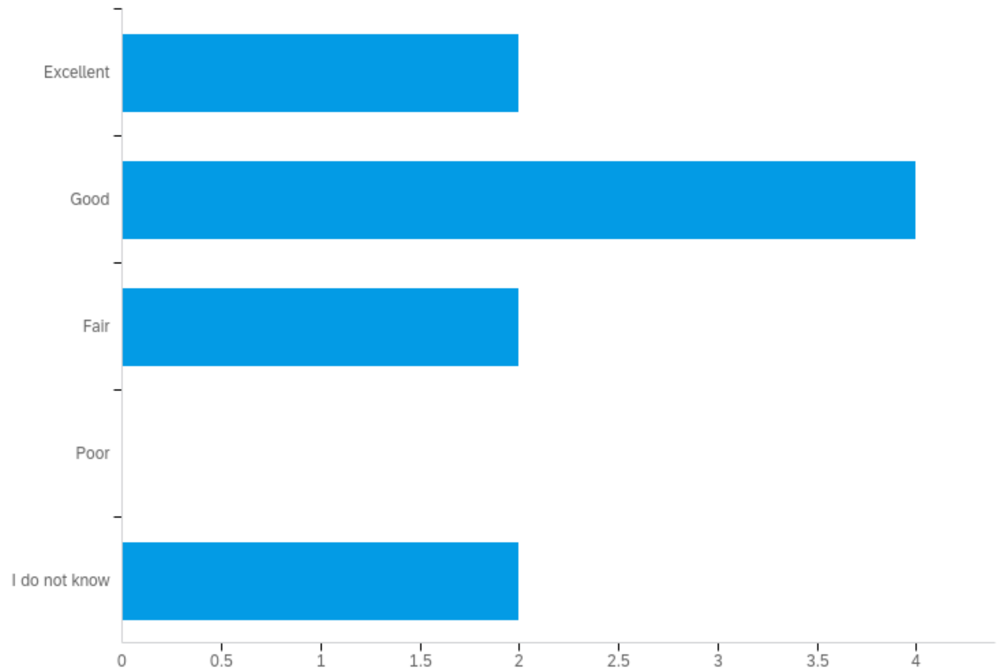

Figure C.9: Rate your experience with the performance of CSI in controlling reflection cracking

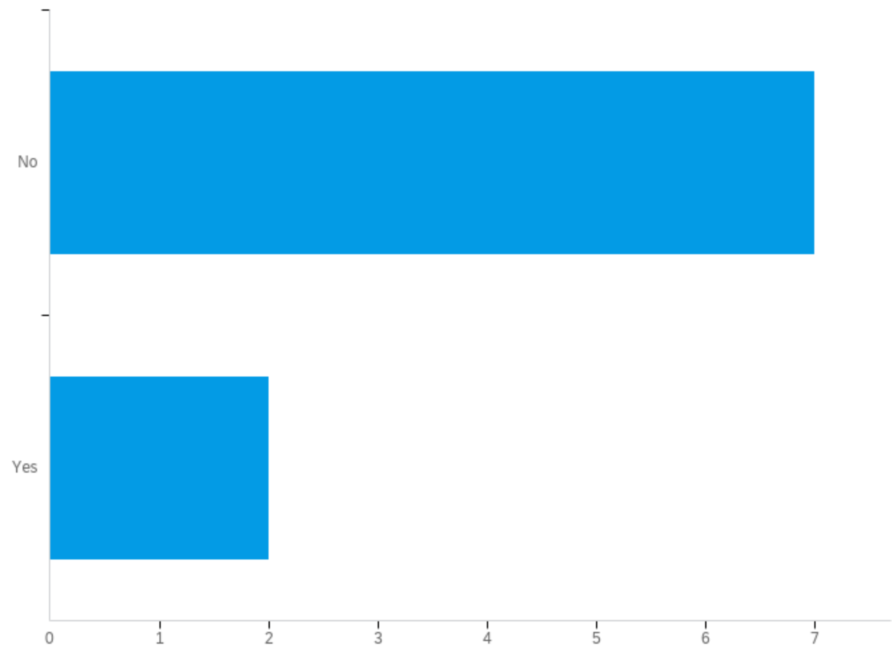

Figure C.10: Did your agency have any issues with using chip seal interlayer?

Figure C.11 summarizes what factors each agency consider when using the CSI. About 41% of the respondents (7 responses) indicated that the existing pavement condition is considered. Moreover, the existing road type and road traffic volume were mentioned with a percentage of 23.5% (4 responses) and 17.6% (around 3 responses) respectively. Just 1 respondent (around 6% of the respondents) indicated that the thickness of overlay factor is considered when using CSI. In addition, around 12% of the respondents (2 responses) mentioned other factors.

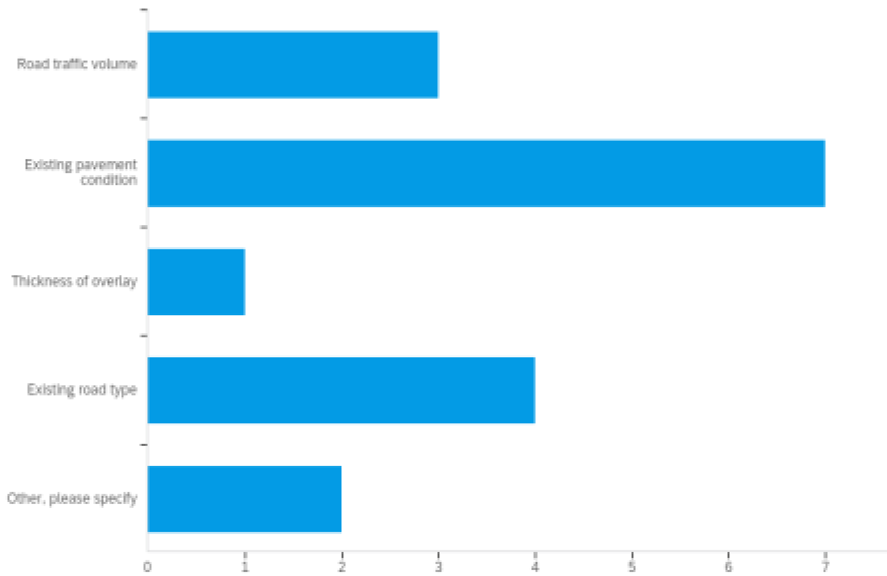

Figure C.11: The considered factors when using the CSI

The respondents were asked, what factors were found to affect CSI effectiveness. Figure C.12 shows that 5 respondents indicated that road traffic volume affect the effectiveness of CSI and other 5 respondents mentioned the existing pavement condition with a percentage of about 28% of the respondents for each. Approximately 17% (3 responses) of the respondents found that the properties of chip seal affect the effectiveness of CSI. Moreover, thickness of the overlay and existing road type were mentioned by 2 responses (around 11%) for each.

Figure C.13 shows that few of the responding agencies (4 responses, around 17% of the respondents) recommend steps or measures that they have used to enhance the performance of CSI. Some respondents recommend applying enough emulsion. Others recommend to chip seal when the weather is hot. In addition, using the Idaho transportation department supplemental specification for CSI is recommended by some respondents. Others think it is better to crack seal 1 year minimum prior to chip seal. Providing pilot car to control the speed of traffic was recommended.

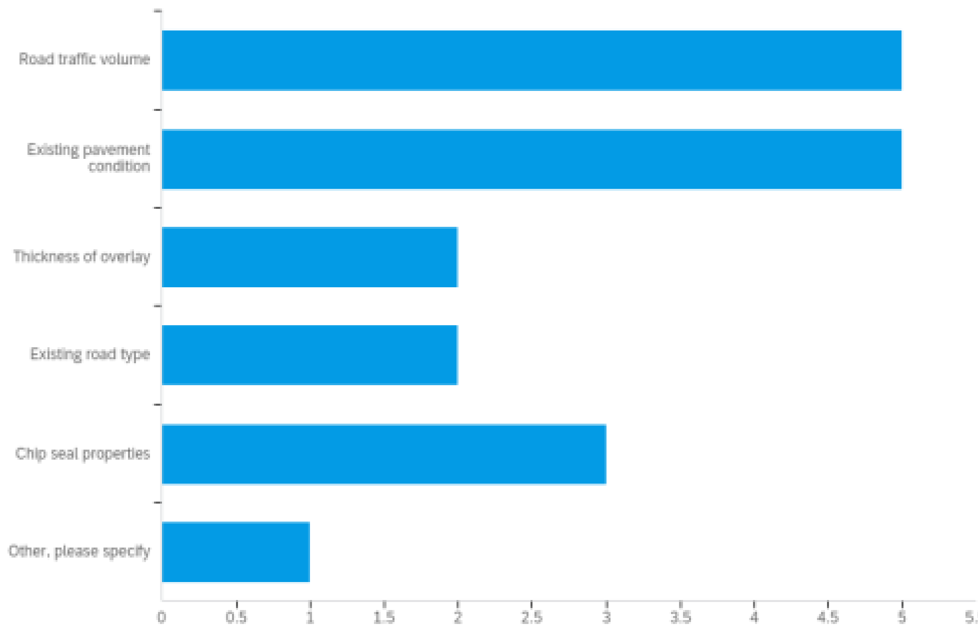

Figure C.12: Factors that affect CSI effectiveness

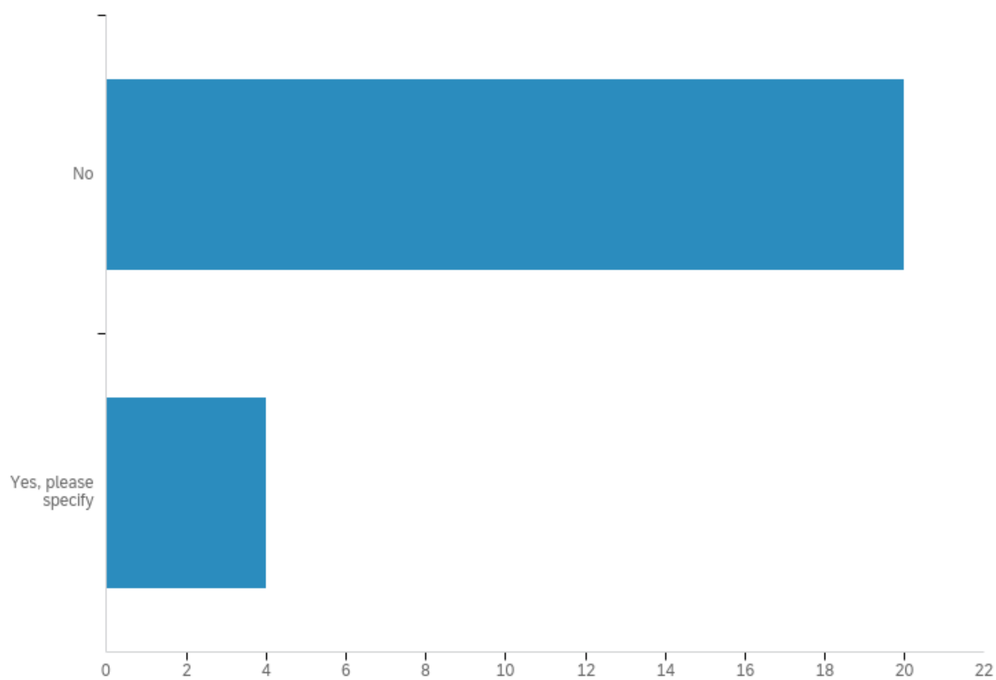

Figure C.13: Do you recommend steps or measures that you have used to enhance the performance of CSI?

Appendix D Results of Interviews with Selected LPAs and Evaluation of Roads with CSI

D.1 Introduction

Several interviews were conducted with LPAs that have used CSI. The interviews were one-hour interview that were conducted using Microsoft TEAMS. Follow-up emails were made to obtain more information based on the interview. All interviews were recorded and the transcript of these interviews was saved. A set of questions were developed that were used in the interview. However, based on the conversation other questions were asked. The interviewed LPAs included

- Licking County Engineering: Jared Knerr, (County Engineer)
- Delaware County: John Huffman (Pavement Engineer)
- Scioto County: Darren LeBrun (County Engineer)
- City of Wooster: John Rice (City Engineer)
- City of Chardon: Paul Hornyak (Director of Public Works) and the City Engineer.

In addition, an online meeting was held with the Mr. Jim Marszal from the Flexible Pavements of Ohio about the use of CSI in Ohio. The following sections summarizes the results of these interviews.

D.2 Licking County Interview Summary

The Licking County engineer indicated that CSI was used in all resurfacing projects in the county since. The county resurfaces between 12 miles and15 miles of roads a year; so, they have about 60-72 miles with CSI since 2014. The main reason for including CSI is that the county uses thin overlays (1 inch) and they think that CSI can help to delay reflection cracking in such overlays. The first road they did was in 2014, was close to across culvert, and it had a lot of alligator cracking. The interlayer stopped the alligator cracking from being reflected on the surface. The county leave the CSI for about 5 days before placing the overlay. In addition, they use very low rate of tack coat (0.02-0.03 gsy) and they think it is good enough. The cost of CSI is about $13,000-$15,000 a mile. So it comes to be about $1.25/SQY. Licking County indicated that they are happy with using CSI so far and believe it delays the occurrence of reflection cracking particularly since they are using 1-inch overlay.

D.3 Delaware County Interview Summary

Delaware County has been using CSI with their overlays for over 10 years. The county uses CSI on older surfaces that was not repaired before applying the overlay, which typically has raveling and low-temperature cracks. The county believe it seals the cracks and provides a water proof layer. It is typically used when resurfacing rural roads with low to medium. Delaware County believes that CSI is beneficial as it allows to use thin overlays (1 inch) instead of using a 2 in. thick asphalt overlay (3/4 leveling and 1.25 surface) 2 in. As CSI costs $1.80/SQY; thus, it might cut the cost by more than $2/SQY. Delaware County open the road for traffic between 2- 7 days after installing the CSI before paving. No tack coat is applied on top of chip seal. Delaware County uses No. 8 limestone with RS-2 emulsion for the CSI. The county indicated that they have some concerns with CSI when placed on curby road and road along a cord de-sac.

D.4 Scioto County Interview Summary

Scioto County started using CSI in 2018. The decision to use CSI in the county depends on the PCR and the percentage of cracking in the pavement to be resurfaced. Typically, CSI is used when Scioto County is not able to seal the cracks for any reason. Therefore, the CSI helps in sealing the cracks and helps in delaying and recuing reflection cracking. The county uses No. 8 limestone aggregates and with HFMS-2 emulsion for CSI. The CSI is done it in-house. It costs 10,000 to 12,000 per centerline miles (Average = 18 foot wide). Therefore, the CSI costs less than $1/SQY. They have used the CSI in 2 projects. The CSI seems to be delaying the development of reflection cracking so far. They are monitoring the performance these sections.

D.5 City of Wooster Interview Summary

The City of Wooster started using CSI in 2018 and has been using it every year since then. The city uses CSI in two main situations: 1- overlay on rigid or composite pavement, and 2- overlay on low volume roads with thin asphalt pavement structure, which the city does not want to mill too much asphalt because they are not sure how much is there. The City of Wooster indicated that they see several benefits for CSI so far, these include:

- It gives a cushion and a layer of separation just underneath the new asphalt overlay.
- Chip seal does a pretty good job of creating a barrier that keep any cracking in the existing pavement from coming up or at least delaying it for quite a while.

The City of Wooster indicated that they haven't seen any reflection cracking in the street they did in 2018 with CSI. However, they have seen reflection cracking in other streets without CSI within a few years.

After placing CSI, they typically open the road for traffic for a week or two before they pave it. As for using tack coat, the City of Wooster specify a 0.02 gsy tack coat application rate, but sometimes they do not apply tack coat. It depends on what the chip seal looks like, how long it's been down, what the weather is like. If the road was open for longer time after placing CSI they typically use the tack coat, but if it's shorter they don't. The City of Wooster typically uses 1.25-1.5-inch-thick overlay on asphalt pavements. For CSI they use CRS-2P emulsion. Sometimes they use MC3000 cutback because they do the paving in the spring and they run into temperature issues. They use No. 8 limestone aggregate for CSI. To date they haven't had any bad feedback or any complaints from their contractors.

D.5 City of Chardon Interview Summary

The City of Chardon has been using CSI for over 15 years. As shown in Figure D.1, the city uses CSI in all of their resurfacing and full depth repairs. The city indicated that they had seen more success when using CSI on flexible pavement as compared to rigid pavements. The main advantage of using CSI is that there is no thickness requirement for the overlay when using it. The city noticed that at intersections there was some pushing under the asphalt. Therefore, the City of Chardon typically do not use CSI around the intersections to avoid any pushing. The city uses CRS-2P emulsion and number 8 aggregates for CSI. The city does not use tack coat. In addition, they let the CSI set a day or two prior to paving; typically, they pave 48 hours after installing of the CSI.

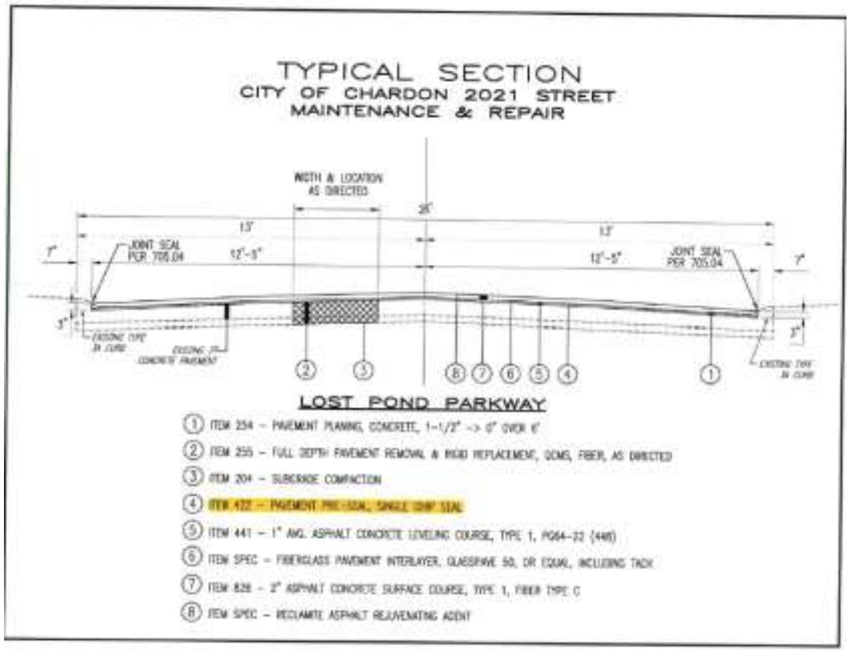

Figure D.1 Typical pavement section used in resurfacing of roads in the City of Chardon

D.6 Flexible Pavement of Ohio Interview Summary

An online meeting was also held with Mr. Jim Marszal from the Flexible Pavements of Ohio to get information about the use of CSI by LPAs in Ohio. Mr. Marszal indicated that several LPAs in northeast Ohio have been using CSI and they had good experience so far. For example, the City of Aurora has done multiple projects. The city experience with CSI were inconsistent. In the first job they had, the city noticed good improvements with using the CSI. The second job they did, it wasn't as good as the first job. So, they are noticing different performances based on the condition of the existing pavement. If the roads are too deteriorated, there will be limitations to how well the CSI is going to work. Therefore, their decision to use CSI depends on the existing pavement conditions. Based on workshops attended, Mr. Marszal thinks that using chip seal with coarser aggregate will be better for interlayer. It is noted that ODOT specification for chip seal has two different aggregates gradations: Type A, and Type B. Type A has coarser aggregates. Also, using a thicker interlayer might have better results. He indicated that there is City of Westlake has done one project using double chip seal interlayer. In this case, the second chip seal would be with the smaller stone. Mr. Jim Marszal thinks a tack coat layer should applied on top of CSI prior to placing the overlay. However, a lower application rate (0.03-0.04 gsy) can be used.

D.7 Evaluation of Selected Local Roads with CSI

Selected local road sections that were paved with and without CSI were evaluated in Licking County, Delaware County and Scioto County. The sections in Licking County were constructed in 2015 and was part of a resurfacing project on Morse road, Figure D.2. The project was 2 miles in length. The first portion of the project had a 0.75-mile section that had a 1.75-inch asphalt overlay:

3/4-inch intermediate course and 1 inch of surface course. In addition, the second portion of the project had a 1.25-mile section that had CSI interlayer but a thinner overlay (1-inch overlay). Both sections were evaluated in September 2021, more than 5 years after construction. Two types of cracks were pronounced in both the sections including longitudinal and reflection cracks (transverse crack). In general, the frequency of reflection cracks was similar for both sections. The extent of longitudinal cracks was almost similar in both of the sections. In some places in section 2, alligator cracking was observed which was not observed at all in section 1. Figures D.3 and D.4 presents pictures that were taken during the evaluation of sections 1 and 2, respectively.

Figure D.2 Locations of sections in Licking county with and without CSI

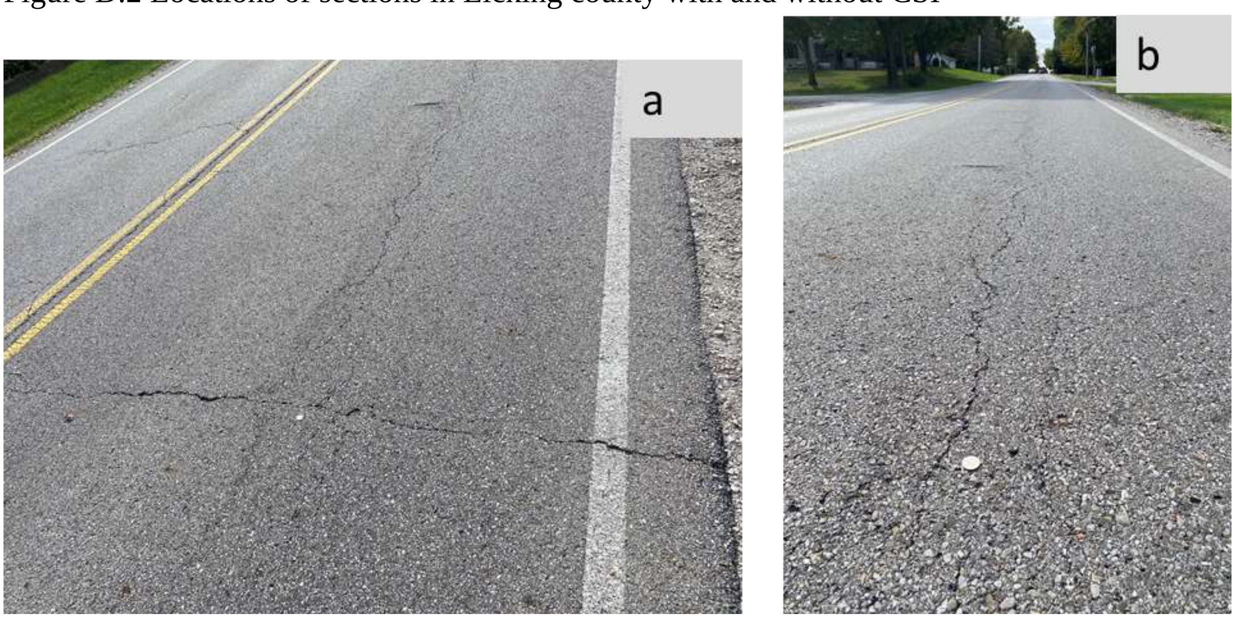

Figure D.3 Pictures taken during evaluation of Licking County section 1 (a) Transverse cracks, (b) Longitudinal cracks

Figure D.4 Pictures taken during evaluation of Licking County section 2 (a) Transverse cracks, (b) Longitudinal cracks (c) Alligator crack

The CSI sections that was evaluated in Delaware County was part of resurfacing project on Bunty station road between South Section Line Road and Ford Road, Figure D.5. The section was 1-mile in length and was constructed in 2006. CSI layer was installed prior to placing a 1-inch overlay. The road and evaluated in September 2021, more than 15 years after construction. The section had longitudinal cracks on the edge wheel path and the center of lane and some scattered transverse cracks. The cracks were sealed with a crack sealant. Figure D.6 shows pictures that were obtained of section during the evaluation. In general, the section had good performance for a 15-years old pavement.

Figure D.5 Locations of sections in Licking county with and without CSI

Figure D.6 Pictures taken during evaluation of Delaware County section

Scioto County had constructed several sections with CSI during the last 2 years. Three sections were evaluated in November 2021.Two sections had CSI installed prior to placing overlay and one did not include using CSI. In general, all road sections had similar pavement condition rating with PCR ranging between 62-67 prior to resurfacing. Those roads had mostly low-temperature transverse cracking and had some alligator cracking. Figure D.7 shows the locations of the different sections evaluated.

The first section was on County Road 168 (Bonser Run Road). The section was 3.5-mile-long and was constructed in 2019, Figure D.8. The section was first chip sealed and after 30 days a 1.5-inch overlay consisting of Type 1 surface course layer was placed. The CSI was done by the county were paving was done by a contractor. As shown in Figure D.9, some very low severity reflection cracking was occasionally observed in this section. The cracks were hairline cracks. No longitudinal cracks were observed throughout the entire section.

The second section with CSI was on Turkey Foot Road. The section was 2.7 miles in length, Figure D10. In this section the CSI was installed in 2019 but the 1.5-inch overlay was placed in 2020. As shown in Figure D.11 this section exhibited excellent performance with no visible crack observed throughout the entire section.

The third section evaluated did not have CSI. This section was part of a resurfacing project on Bussey Road, Figure D.12. In this section a 1.5-inch overlay consisting of Type 1 surface course layer was placed in 2020. The evaluation of this section showed that there were medium severity reflection cracks throughout the section, Figure D13. The reflection cracks occurred frequently. In addition, the width of these cracks was between ¼ to ½ inch, Figure D.14. Some hairline longitudinal cracks were also observed on rare occasions. This section performed significantly worse than sections with CSI on Turkey Feet Road and Bonser Run Road.

Figure D.7 Locations of evaluated sections in Scioto County

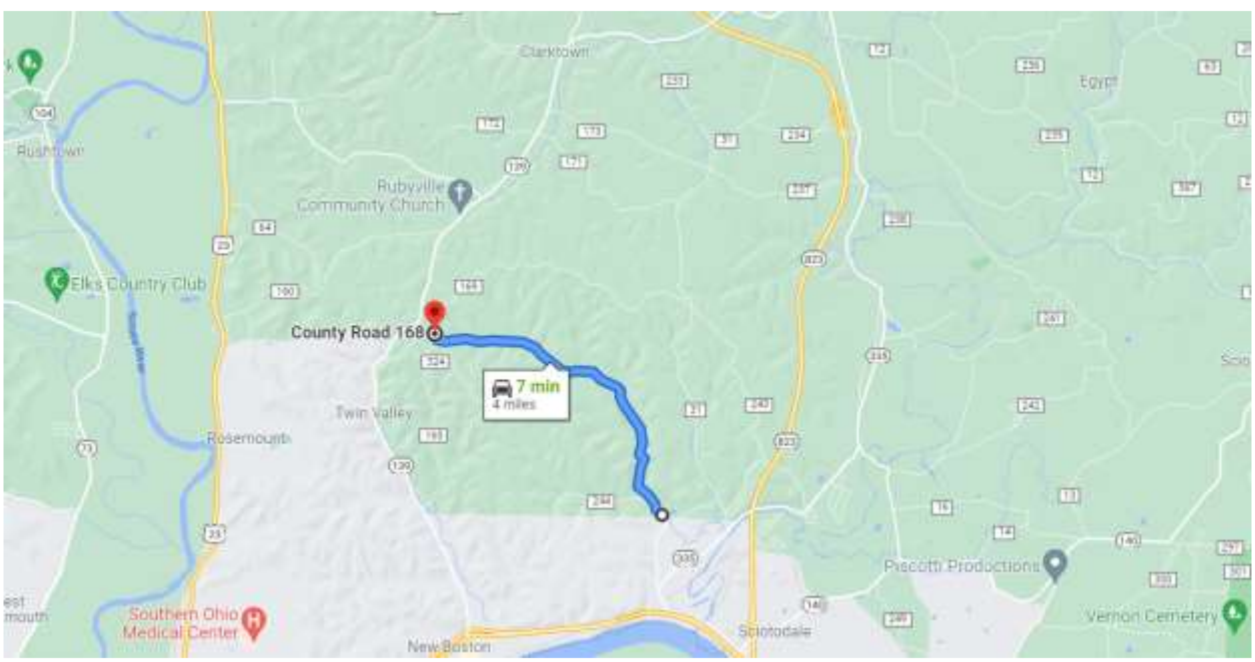

Figure D.8 CSI section on County Road 168 (Bonser Run road) in Scioto County

Figure D.9 Pictures taken during evaluation of Bonser Run Road

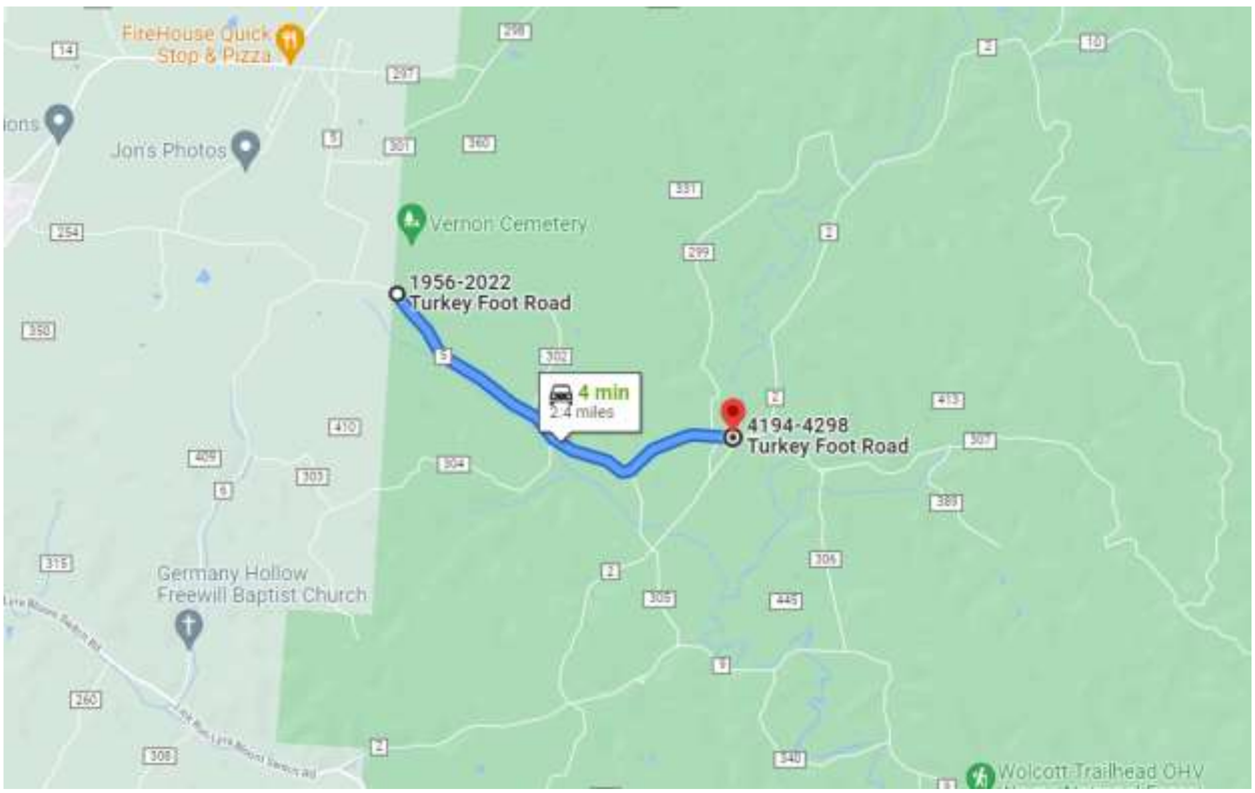

Figure D.10 CSI section on Turkey Foot Road in Scioto County

Figure D.11 Pictures taken during evaluation of Turkey Foot Road in Scioto County

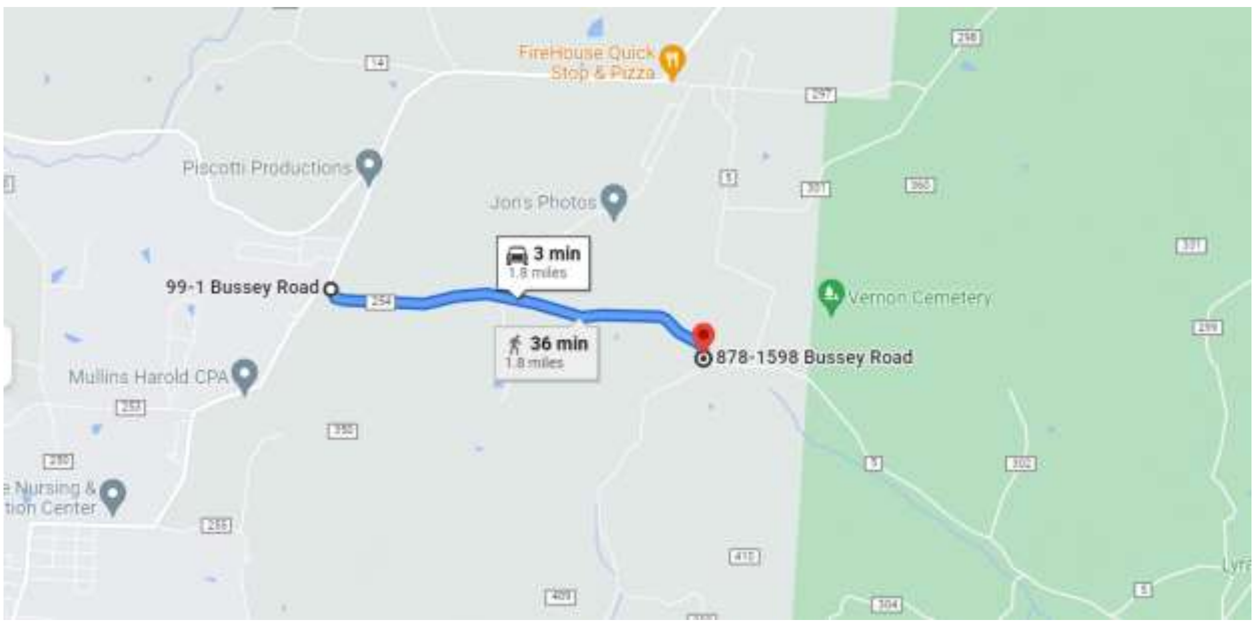

Figure D.12 CSI section on Bussey Road in Scioto County

Figure D.13 Pictures taken during evaluation of Bussey Road in Scioto County

Figure D.14 Pictures taken of cracks on Bussey Road a) Reflection crack, b) longitudinal crack