Ohio's Research Initiative for Locals (ORIL) Research On-Call Task 1 – Tree Canopy

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16. Abstract

Premature deterioration of asphalt pavement has been observed in shaded areas, such as those under tree canopies or near tall buildings or hills. The shade slows or prevents drying of the pavement surface after rain or snow, and the prolonged presence of moisture leads to premature or increased stripping of the asphalt. One frequently used remedy is to trim or remove tree cover, but this is not always an option. This study was conducted to assess the current state of practice among local public agencies (LPAs) for mitigating and managing the damage to asphalt resulting from excess moisture presence. The scope of the investigation included the nature of moisture damage to asphalt and its causes, and various methods of prevention, mitigation, repair, and replacement.

The state of practice was ascertained via a literature review. Countermeasures may be applied at several stages, including at asphalt mix design (e.g. anti-stripping amendments), during construction (e.g. asphalt treated permeable base and permeable pavement), surface treatments after construction (e.g. fog seal, rejuvenator application, slurry seal, micro-surfacing, and chip seal), and in response to signs of damage (e.g. scrub seal, thin HMA overlay, or in extreme cases, full-depth replacement). Most of these treatments have been found effective in sealing the pavement and extending service life.

A survey of 67 LPAs in the Ohio examined current practices in the state, and follow-up interviews were conducted with some agencies to get a more in-depth view of practices. Nearly all LPAs encountered problems with shaded pavements, and most thought pavement service life was reduced by at least three years. Most common countermeasures included tree trimming and high-walling, sealing cracks, dura-patching, chip seal, rejuvenator application, Reclamite, or using a better surface course.

17. Key Words
Pavement condition; Tree canopy; Tree removal; Microclimate; Asphalt degradation; Pavement environment, chip seal, low traffic volume, county, township, city

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(°F-32)/9 or (°F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2 or psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8°C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2 or psi

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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Executive Summary

Premature deterioration of asphalt pavement has been observed in shaded areas, such as those under tree canopies or near tall buildings or hills. The shade slows or prevents drying of the pavement surface after rain or snow, and the prolonged presence of moisture leads to premature or increased stripping of the asphalt. One frequently used remedy is to trim or remove tree cover, but this is not always an option. This study was conducted to assess the current state of practice among local public agencies (LPAs) for mitigating and managing the damage to asphalt resulting from excess moisture presence.

The state of practice was ascertained via a literature review. A survey of LPAs in the Ohio examined current practices in the state, and follow-up interviews were conducted with some agencies to get a more in-depth view of practices.

The scope of the investigation included the nature of moisture damage to asphalt and its causes, and various methods of prevention, mitigation, repair, and replacement.

The literature review indicated freeze-thaw cycles are a major aggravating factor in moisture-related pavement deterioration, which is triggered by moisture migrating through voids in the asphalt. Specific mechanisms of asphalt damage include detachment between binder and aggregate, displacement of binder from aggregate, spontaneous emulsification, hydraulic scouring, and excess pore water pressure under compression from traffic. The damage progresses into the formation of visible surface distresses such as potholes and raveling.

Countermeasures may be applied at several stages, including at asphalt mix design (e.g. anti-stripping amendments), during construction (e.g. asphalt treated permeable base and permeable pavement), surface treatments after construction (e.g. fog seal, rejuvenator application, slurry seal, micro-surfacing, and chip seal), and in response to signs of damage (e.g. scrub seal, thin HMA overlay, or in extreme cases, full-depth replacement). Most of these treatments have been found effective in sealing the pavement and extending service life.

A survey of LPAs and other practitioners in Ohio generated 67 responses from county, city, ODOT, township, and village representatives. An overwhelming majority indicated they were aware of pavement problems related to tree canopies, hilly terrain, or tall buildings. The majority encountered these problems often (57%) or sometimes (40%), and over 90% said these problems shortened pavement life, predominately by more than three years (51%). Most (55%) had a treatment program for this issue, which typically included trimming or high-walling trees. Damage countermeasures cited included using better asphalt (ODOT 424 B Surface Course was mentioned), Dura-patching, chip seal, sealing cracks, applying rejuvenator, or Reclamite. Respondents overwhelmingly (81%) favored repair of pavement over replacement. Most popular repair methods were patching (90%), chip seal (25%), and rejuvenator (10%). Most agencies (56%) also had practices to mitigate and manage pavement damage, of which the most frequently cited approaches were trimming trees, chip seal, and using a better surface course.

Additional follow-up interviews were conducted by email and telephone with ten agencies, which confirmed many of the approaches mentioned in the survey responses.

Conclusions

Based on literature reviews and information from survey respondents, it is clear that tree canopies, geographic features, and tall structures that obscure sunlight promote retention of surface moisture in shaded pavement, which in turn leads to premature damage. To mitigate this damage on tree canopied sections, many local agencies have instituted programs, when possible, to remove or reduce canopies by trimming or high-walling the trees.

When these sections are present in rural areas, they are repaired by various methods, such as patching, and overlaid with a chip seal or similar surface treatment to prolong the life of the pavement at a relatively low cost. Local forces usually undertake this work and are able to add several years to the life of the pavement.

On the other hand, in urban areas, where population densities are higher, damaged pavement sections are usually repaired and overlaid with more expensive polymer modified treatments, or the pavement is replaced at with new asphalt containing polymer additives, which increases the price of the pavement by up to 5%.

Recommendations

Further study is recommended to address the following questions:

A more in-depth study of local practices can be undertaken to further assess the benefits of using various surface treatments to prolong pavement life.

A comparative evaluation of various repairs and treatments to determine which provide the most service life enhancement and value.

Whether polymer modified asphalt can be used effectively in rural as well as urban roads.

1 Project Background

Asphalt concrete pavement surfaces sometimes experience premature deterioration when placed in areas that receive a significant amount of shading (e.g., under tree canopies, excessively hilly terrain, and places with large, closely-spaced buildings such as downtown areas. At these locations, the shading impedes the sun's ability to dry the pavement surface, keeping the pavement damp which can cause premature or exaggerated stripping. Recently, ODOT completed a research project focused on impacts related to tree canopies and presented recommendations of removing or cutting down the trees to allow the road to get more sunlight to prevent moisture being held on the surface (SJN 135566). For local public agencies (LPA), the option of removing or substantially cutting existing trees is not always a viable option. Additionally, this project did not consider other sources of shade causing similar problems for LPAs, such as buildings and hilly terrain. It is possible that other research on this topic with proposed solutions exists.

2 Research Goals and Objectives

The goal of this task is to complete an in-depth literature review and survey to identify the current state of practice for LPAs around the country in dealing with the issue of asphalt concrete pavement deteriorating due to significant amounts of shading.

The objective of this project is to provide the LPAs with a method or methods to treat asphalt concrete pavement that are susceptible to moisture damage due to shading from trees, hills, buildings or other sources. This includes corrective measures to fix damaged pavement and preventative measures that limit damage. Recommendations on how to resolve this issue are provided.

3 Research Approach

To fulfill the objectives listed above, the following tasks were undertaken:

- Create a synthesis of current practice as determined by conducting a literature review.
- Survey local agency personnel in Ohio regarding best practices in managing tree cover over roads.
- Prepare this report.

3.1 Literature Search

Key literature was identified and searched to collect completed and active research information pertaining to pavement surface treatments used to mitigate damage due to tree canopies or other shading on local roadways. Search engines such as TRID, Google Scholar, and ScienceDirect were used for web-based queries to identify all relevant publications. OhioLINK, a consortium of Ohio's colleges and universities libraries, including the State Library of Ohio were used as necessary to obtain relevant publications. Information from pertinent is summarized and presented in this report.

3.2 Survey

A Qualtrics survey was created by the research team and reviewed by the TAC. Once the questionnaire was finalized and the survey approved by Ohio University's Institutional Research Board, it was emailed with the help of ODOT through LTAP to local agencies. The survey was sent on June 29, 2021, with follow-up requests on July 14 and August 13. The survey was closed on September 12, with 67 good responses. The research team followed up with selected local agency personnel with additional queries to elicit additional details. The questionnaire is reproduced in Appendix B: Ohio local agency survey.

4 Research Findings

4.1 Literature Review

4.1.1 Tree Canopy Effect

The various positive and negative effects associated to the presence of tree canopies on underlying pavement has been previously discussed by different authors. However, a good number of them have been focused on environmental aspects [Akbari, Pomerantz, and Taha, 2001; Taha, Change, and Akbari, 2000; Vailshery, Jaganmohan, and Nagendra, 2013; McPherson et al., 2005; Napoli et al., 2016; Gillner et al., 2015]; and of those that have been oriented towards asphalt pavement and its performance [Nowak et al., 1998; McPherson and Muchnik, 2005; Qiao et al., 2013]. Most of them have only considered tree canopies located inside urban areas [Nowak et al., 1998; McPherson and Muchnik, 2005] and in the dry, American West Coast climate. In such conditions, roadside trees have been found to be mostly beneficial for asphalt pavement integrity [McPherson and Muchnik, 2005; Qiao et al., 2013]. On the contrary, a recent research [Naik et al., 2017] have found a possible detrimental effect on the pavement surface, associated to the tree canopies in rural state roads located in the North Central region climate, including the State of Ohio. This literature review will be focused on the possible damage(s) associated to the tree canopies located in the latest condition and the different methods to prevent or repair such damages.

4.1.2 Tree Canopy Associated Damage

In recent studies [Naik et al., 2017; Naik et al., 2020], it was observed that in rural highways, segments of the road under a tree canopy required surface repairs (e.g. patching) due to localized damage (typically raveling), while adjacent open canopy sections did not [Naik et al., 2017]. The research team also noted the pavement surface under the shaded segments retained more moisture than that under the unshaded sections [Naik et al., 2020], indicating a potential relationship between moisture and pavement surface damage.

In the North Central region states such as Ohio, it is common to experience temperature fluctuations that induce several freeze-thaw cycles per year [Naik et al., 2017; Si et al., 2014]. During the warmest part of this cycle, rainwater and melted snow can find their way into the pavement; then, when the cools, this water freezes and expands, creating internal damage in the pavement structure [Wang et al., 2019]. This cycle is a likely mechanism to explain the degraded state of asphalt pavement observed under some tree canopies. This phenomenon, its damage mechanisms, and the resulting distress, have been widely studied [Wang et al., 2019; Taylor and Khosla 1983; Bonaquist 2014].

4.1.3 Moisture Damage

Moisture-induced damage in asphalt concrete can result in loss of adhesion between the asphalt binder and the aggregate, loss of cohesion within the mastic/asphalt binder, and/or degradation of the aggregates in the mix (especially when the mixture is subjected to freezing periods) [Bonaquist 2014]. The damage is induced by the water trapped in some of the voids of the asphalt concrete mixture after it has made its way through the interconnected voids within the asphalt [Taylor and Khosla 1983; Bonaquist 2014] and interacted chemically, physically or mechanically with the asphalt binder, producing the stripping of the asphalt film [Wang et al., 2019]. There are five failure mechanisms of moisture damage: detachment, displacement, spontaneous emulsification, hydraulic scouring, and pore water pressure, as shown in Table 1 [Wang et al., 2019; Taylor and Khosla 1983].

Table 1. Five mechanisms of moisture damage in pavement [Wang et al., 2019; Taylor and Khosla 1983].

Mechanism	Description
Detachment	Loss of adhesion. Separation between binder and aggregate without breaking the asphalt film, as a result of surface energies/tensions and interaction water-binder-aggregate [Taylor and Khosla 1983]
Displacement	Loss of adhesion. Separation between binder and aggregate produced by water that penetrates through a pinhole in the asphalt film. Also, as result of internal chemical reaction between water and mineral on the aggregate surface (change in pH) [Taylor and Khosla 1983]
Spontaneous Emulsification	Loss of adhesion. Separation between binder and aggregate result of a formation of an inverted emulsion (when asphalt and water get combined) [Kanitpong and Bahia, 2003]
Hydraulic Scouring	Loss of adhesion and cohesion. Stripping induced by changes in dynamic pore pressure created by the tire compression and pumping action of the surface runoff inside the cracks of the pavement surface [Wang et al., 2019]. The changes of dynamic pore pressure can cause rupture of the asphalt film [Taylor and Khosla 1983; Kanitpong and Bahia, 2003]
Pore Water Pressure	Loss of adhesion. Produced by an increase of a pore pressure of the entrapped water due to the densification generated under traffic [Kanitpong and Bahia, 2003]

Moisture-induced damage finally develops into surface distresses such as raveling and potholes [Naik et al., 2020; Si et al., 2014; Wang et al., 2019; Taylor and Khosla 1983; Bonaquist 2014; Kanitpong and Bahia, 2003; Kanitpong and Bahia, 2008]. As mentioned before, in recent research conducted in the state of Ohio, a greater need for patching of raveling and potholes was observed in pavement segments under a tree canopy than on sections with open canopy [Naik et al., 2017]. More importantly, it was later found that the prolonged presence of moisture on pavement surface under a tree canopy made those sections more prone to moisture damage [Naik et al., 2020]. When moisture damage has developed, it is necessary to evaluate the extent of the damage. Therefore, the different layers of the pavement structure should be subjected to tests for Tensile Strength Ratio (TSR) and Cantabro mass loss (ML%), as well as inspected for presence of stripping.

4.1.4 Preventing Moisture Damage

Different measures can be taken to increase the asphalt mixture resistance to moisture damage or prevent the triggering of damage mechanisms. Some of these methods can be incorporated in the mix design, some can be incorporated in the pavement design and applied during construction, others after construction to prevent moisture damage, and still others once moisture induced damage has occurred. They are listed below according to these categories.

4.1.4.1 Methods Incorporated in the Mix Design

- Anti-stripping amendments:

  One of the most popular approaches for mitigating moisture susceptibility of asphalt mixes is using antistripping additives, of which there are numerous types in use. Antistripping additives are broadly classified into two categories: hydrated lime and liquid antistripping (LAS) additives. For many years, hydrated lime has been widely used by different agencies as an antistripping additive to reduce stripping in asphalt mixes. However, LAS additives have also been reported to produce comparable results, with easier application, safer operation and lower costs [Selim, 1997].

  Several studies have been conducted to evaluate the effectiveness of antistripping additives to prevent or mitigate moisture susceptibility of asphalt mixtures [e.g. Selim 1997; Do et al., 2019, Birgisson et al., 2005; Vargas-Nordcbeck et al., 2016]. Birgisson et al. [2005] found the inclusion of antistripping agents helps improve the moisture damage resistance of hot and warm asphalt mixes, while the improvement in rutting resistance was insignificant. For the majority of cases in this study, the use of lime as an antistripping agent was more beneficial than LAS for improving mixture performance in the HLWT. In addition, the benefits of adding antistripping agents were more pronounced for hot mix asphalt than warm mix asphalt. Do et al. [2019] evaluated using hydrated lime with 1.5% content by dry aggregate weight, and three different LAS additives with a content of 0.5% by weight of asphalt binder to improve the moisture damage resistance of different asphalt mixes. It was found that the mixes with antistripping additives showed significantly higher Tensile Strength Ratio (TSR) values than that those without additives. Vargas-Nordcbeck et al. [2016] evaluated antistripping additives in mixes with different nominal aggregate sizes. They found the improvement was more pronounced for mixtures with 9.5 mm nominal maximum aggregate size (NMAS) than for those with 12.5 NMAS.

4.1.4.2 Measures Applied During Pavement Design and Construction

- Asphalt Treated Permeable Base (ATPB):

  A base course can be considered a type of open-graded mixture. ATPB acts as a water-resistant barrier which facilitates drainage more efficiently than an unbound aggregate base [D'Angelo and Anderson, 2003], preventing infiltration of fine particles.
- Permeable Pavement Layers

  Considered a controversial alternative, permeable mixtures, such as open graded friction course (OGFC), allow water to move between the pavement surface and subgrade soil [Aseda and Ca, 1996]. These treatments might inhibit pore water pressure but can still be susceptible to raveling due to air voids and binder content [Arambula-Mercado et al., 2016; Sargand et al., 2020].

4.1.4.3 Surface Treatments Applied To Prevent Moisture Damage

- Fog Seal:

  Fog seal is a diluted asphalt emulsion used to seal surface voids and cracks and prevent water from entering the pavement, inhibit raveling and rejuvenate oxidized pavement in good structural condition [County of Santa Barbara Transportation Division, 2010]. While fog seal could restore some flexibility to the aged pavement, it could reduce skid resistance [Ali, Mehta, and Shackil, 2019; Lee and Shield, 2010]. To increase friction, some states, such as Minnesota, top the fog seal with a light coating of sand [MnDOT, 2020], while others, such as Indiana restrict fog seal treatment to pavements with a friction number of at least 30 [Johnson, 2000].

  Fog seal can be used on both low and high-volume roads [Lee and Shield, 2010; Johnson, 2000], and the road can be opened to traffic after about 2 hours of curing [Putman et al., 2016]. Fog seal can be applied on a clean (swept) and dry road surface at a rate of 0.05 to 0.20 gal/yd^2 (0.23 to 0.9 l/m^2) [County of Santa Barbara Transportation Division, 2010; MnDOT, 2020], at a cost of $0.13 to $0.60 per yd^2 ($0.16 to $0.72 per m^2) [MnDOT, 2020; Putman et al., 2016; Wilde, Thompson, and Wood, 2014]. Fog seal can extend pavement life between 1 and 4 years, depending on the pavement structural condition and sunlight exposure [County of Santa Barbara Transportation Division, 2010; MnDOT, 2020; Johnson, 2000; Buss, Claypool, and Bektas, 2019].
- Rejuvenator seal:

  In general, rejuvenators are cationic emulsions consisting of a maltenes blend modified with asphalt and polymer [MnDOT, 2020; Buss, Claypool, and Bektas, 2019; CalTrans, 2003]. Rejuvenators can be used on dense, gap, and open graded pavement surface mixtures [CalTrans, 2003] to correct or delay raveling, minor segregation, and new crack development [MnDOT, 2020; Buss, Claypool, and Bektas, 2019; CalTrans, 2003]. Their low viscosity allows rejuvenators to penetrate deep into pavement voids. They are applied at rates between 0.02 and 0.1 gal/yd^2 (0.09 to 0.45 l/m^2) at a cost range between \$0.85 to \$2.00 per yd^2 (\$1.02 to \$2.39 per m^2) [MnDOT, 2020].

- Slurry Seal:

  Slurry seal is a mix of asphalt emulsion and well graded aggregate in the size range 1/8 in (3.2 mm) to 3/8 in (9.5 mm). Slurry seal forms a new wearing surface on deteriorated pavement [County of Santa Barbara Transportation Division, 2010; Kucharek et al., 2010], preventing water penetration and correcting raveling while adding surface friction [Ali, Mehta, and Shackil, 2019; MnDOT, 2020; Johnson, 2000; Illinois DOT, 2018]. It is applied with spreader box or a squeegee [Putman et al., 2016; Illinois DOT, 2018]. If needed, patching is recommended before placing the slurry seal [MnDOT, 2020; Illinois DOT, 2018]. With an investment of \$2.5 to \$3.5 per yd^2 (\$2.99 to \$4.19 per m^2), slurry seal can add between 3 and 7 years to the pavement serviceability [MnDOT, 2020; Johnson, 2000; Putman et al., 2016; Wilde, Thompson, and Wood, 2014; Illinois DOT, 2018].

  Slurry seal can be placed only when temperature will stay above 50°F (10°C) and clear of rain or foggy conditions [MnDOT, 2020; Illinois DOT, 2018]. States like Nebraska and Illinois do not recommend it when the road has more than 0.5 in (13 mm) of rutting in the wheel path or structural issues [Illinois DOT, 2010; Illinois DOT, 2018; NDOR 2002]. Most roads can be opened to traffic about 2 to 4 hours after slurry seal application [MnDOT, 2020; Illinois DOT, 2018]

- Micro-surfacing:

  Micro-surfacing is like slurry seal but with polymer-modified emulsion and finely crushed stone added to improve surface friction properties [Ali, Mehta, and Shackil, 2019; Putman et al., 2016; Buss, Claypool, and Bektas, 2019; Kucharek et al., 2010]. Micro-surfacing inhibits water from entering the pavement, corrects raveling and low-severity cracking [Ali, Mehta, and Shackil, 2019; MnDOT, 2020; Putman et al., 2016; Illinois DOT, 2018], and can even reduce some hydroplaning [Lee and Shield, 2010]. Micro-surfacing can aggravate stripping and is thus not recommended where stripping is evident [Lee and Shield, 2010].

  The polymer-modified emulsion hastens hardening, allowing treated roads to reopen to traffic after about an hour [Lee and Shield, 2010; Putman et al., 2016; Illinois DOT, 2018]. However, an approved test strip is usually recommended to calibrate the equipment and verify the application rate [Lee and Shield, 2010; MnDOT, 2020]. States like Illinois recommend that micro-surfacing should be placed only at temperatures higher than 50°F (10°C) [Lee and Shield, 2010; Illinois DOT, 2018]. It is suitable for high volume roads [Lee and Shield, 2010;], creating a long-lasting surface on sound pavement [County of Santa Barbara Transportation Division, 2010; MnDOT, 2020] with a life expectancy between 4 and 7 years [County of Santa Barbara Transportation Division, 2010; Putman et al., 2016; Illinois DOT, 2018; PennDOT, 2019], at an average cost of \$3/yd^2 (\$3.59/m^2) [MnDOT, 2020].

- Chip Seal/Seal Coat:

  Chip seal is a type of seal coat consisting of an application of asphalt binder followed by a coat of aggregate chips compacted into the binder with at least three passes of a pneumatic-tire roller [MnDOT, 2020; Putman et al., 2016; Buss, Claypool, and Bektas, 2019]. The binder may contain added rubber, latex, or polymers [MnDOT, 2016]. Chip seal provides a cost-effective, waterproof, and friction-enhanced surface on existing pavement [Lee and Shield, 2010; MnDOT, 2020; Putman et al., 2016; MnDOT, 2016], while correcting raveling and minor bleeding [County of Santa Barbara Transportation Division, 2010; MnDOT, 2020; Buss, Claypool, and Bektas, 2019]. However, this treatment is not recommended for pavement with underlying stripping [Lee and Shield, 2010].

  Chip seal can be placed only when temperature is going to remain higher than 60°F and in clear weather without rain or fog [Lee and Shield, 2010; MnDOT, 2020]. The placement rate depends on the aggregate size (NMAS 3/8 in (9.5 mm) to No. 4 (4.8 mm)) and should be verified by doing a strip test where equipment calibration is conducted. The emulsion can be applied at a rate of 0.29 to 0.4 gal/yd^2 (1.31 to 1.81 l/m^2)), while the aggregate could be placed at a rate of 14 to 20 lb/yd^2 (7.6 to 10.8 kg/m^2) [Lee and Shield, 2010]. Some states like Pennsylvania and South Carolina only suggest its use on roads with low truck volume due to the potential for chips to be loosened [Lee and Shield, 2010; Putman et al., 2016; PennDOT, 2019] . For this reason, it is recommended to sweep the chip seal surface the day after placement to remove loose aggregate and if possible to apply a fog seal to reduce future chip loss [MnDOT, 2020]. With an average cost of $1.85/yd^2 ($2.12/m^2) [MnDOT, 2020], it can extend the pavement service life by 4 to 7 years [MnDOT, 2020; Putman et al., 2016; Buss, Claypool, and Bektas, 2019] (based on pavement condition).

  Several DOTs, including Minnesota DOT, have used chip seal and seal coat to provide a waterproof membrane for the asphalt pavement and slow down the oxidation process [Wood et al., 2009]. Several studies evaluated the effect of seal coat and chip seal on preventing moisture damage but the results were inconclusive [e.g. You et al., 2020; Zaniewski, 1996; Mousa et al., 2019]. This was attributed to the fact that the ground water table depth plays a major role in the development of moisture damage in asphalt pavements, including those with chip seal and seal coat [Mousa et al., 2019].

4.1.4.4 <u>Treatments Applied After Moisture Damage Has Taken Place</u>

- Scrub Seal:

  Scrub seal is the application of a polymer-modified emulsion which is scrubbed into the surface cracks by a one or more brooms dragged over the surface, followed by a layer of well-graded fine chips/aggregate also scrubbed with brooms [Lee and Shield, 2010; MnDOT, 2020; Putman et al., 2016; Wilde, Thompson, and Wood, 2014]. The completed scrub seal is compacted with a pneumatic-tire roller before it is opened to traffic, typically in less than an hour [Lee and Shield, 2010; MnDOT, 2020]. The application rate for the emulsion is in the range of 0.12 to 0.16 gal/yd^2 (0.54 to 0.72 l/m^2) and that for the aggregate is 10 to 15 lb/yd^2 (5.4 to 8.1 kg/m^2) [County of Santa Barbara Transportation Division, 2010; Lee and Shield, 2010]. This treatment can be used on low to moderate volume roads [Lee and Shield, 2010; MnDOT, 2020; Buss, Claypool, and Bektas, 2019], but is vulnerable to snow plow operation [Lee and Shield, 2010; Buss, Claypool, and Bektas, 2019].

Scrub seal can ensure better sealing of the road by filling cracks and voids, inhibiting water intrusion and reducing raveling [Lee and Shield, 2010; Putman et al., 2016; Buss, Claypool, and Bektas, 2019]. Scrub seal also adds flexibility and rejuvenates oxidized pavements, increasing durability and surface friction [Lee and Shield, 2010; MnDOT, 2020; Buss, Claypool, and Bektas, 2019]. In terms of performance and cost, some states found scrub seal to last between 1 and 3 years, with an average cost of $1.00/yd^2 ($1.20/m^2) [Putman et al., 2016]; others have estimated a service life of about 6 years, at a cost between $1.40 and $2.80 per yd^2 ($1.67 to $3.35 per m^2) [MnDOT, 2020]; while still others anticipate a service life of up to 10 years, at a cost of 30% of that of a regular overlay [County of Santa Barbara Transportation Division, 2010].

- Thin HMA Overlay:

Thin overlays are usually a hot mix asphalt (HMA) layer between 3/4 in (19 mm) to 1/2 in (13 mm) thick [Ali, Mehta, and Shackil, 2019; Putman et al., 2016; Wilde, Thompson, and Wood, 2014; Buss, Claypool, and Bektas, 2019; Illinois DOT, 2018], that can be placed on the top of profile-milled, structurally sound pavement [Lee and Shield, 2010; MnDOT, 2020; Illinois DOT, 2018; PennDOT, 2019]. An overlay improves surface drainage while reducing water intrusion [Putman et al., 2016; Wilde, Thompson, and Wood, 2014] and hydroplaning [Lee and Shield, 2010; Buss, Claypool, and Bektas, 2019; Illinois DOT, 2018]. It also corrects profile irregularities, improves ride quality, and increases surface friction [Lee and Shield, 2010; MnDOT, 2020; Putman et al., 2016; Wilde, Thompson, and Wood, 2014; Buss, Claypool, and Bektas, 2019; Illinois DOT, 2018].

When properly designed and placed over pavement in sound structural condition, an overlay can improve the pavement structural capacity [County of Santa Barbara Transportation Division, 2010; Putman et al., 2016; Buss, Claypool, and Bektas, 2019;] and extend the service life [County of Santa Barbara Transportation Division, 2010; MnDOT, 2020; Illinois DOT, 2018] by as much as 7 to 10 years [Ali, Mehta, and Shackil, 2019; MnDOT, 2020; Putman et al., 2016; Illinois DOT, 2018] The cost of an HMA overlay is about $4.00 to $7.00 per yd^2 ($4.78 to $8.37 per m^2), which includes milling of 1 in (25 mm) to 1.5 in (38 mm) before applying a 1.5 in (38 mm) overlay [MnDOT, 2020]. A tack coat is recommended to improve the bond between the overlay and the milled surface [Lee and Shield, 2010; MnDOT, 2020; Illinois DOT, 2018].

- Full-Depth Asphalt Replacement

A full-depth asphalt replacement is necessary when structural capacity of the pavement system has been compromised. Usually, this will be the result of damage in the asphalt base layer or the subgrade [Green et al., 2018] .

4.1.4.5 Summary of literature

The studies found of micro-surfacing, chip seal, and overlays and the effects of moisture and tree canopies can be summed up as follows.

- Most of these treatments are effective in sealing the pavement and preventing the infiltration of moisture through the pavement surface and sublayers, most likely improving the performance of the whole pavement and extending service life.
- Moisture entering from the ground water table or from rainfall events will always get into the bottom layers of a pavement unless there is sufficient drainage.
- Micro-surfacing, chip seal, or overlays where there is a shallow water table will entrap water since they do not permit the normal evaporation process. This will eventually produce moisture damage in the underlying asphalt layers [Bashar et al. 2019 on micro-surfacing; Mousa et al. 2020 on chip seal; Estakhri and Ramakrishnan 2006 on underseal].
- Shatnawi and Van Kirk [1993] could not find clear evidence that a chip seal or overlay will have the greatest impact on stripping, particularly when the stripping can be attributed to the moisture susceptibility of the aggregate.
- Finally, Wood [2013] went the other way around and attributed the higher susceptibility to moisture damage to lower density from higher air voids as a result of a poor compaction effort, which would end up reducing the life of the chip seal.

4.2 Survey of Practitioners

County, township, and municipalities in Ohio were surveyed to obtain details about the use and performance of chip seals within their jurisdiction, and to select agencies for follow up interviews. An online survey was developed using the Qualtrics survey platform. The survey questions are presented in Appendix C. A link to the survey, as well as hard copies, for local agencies without access to the internet, was distributed by the County Engineer Association of Ohio (CEAO), the Ohio Township Association (OTA), the Ohio Municipal League (OML), and the Ohio Local Technical Assistance Program (LTAP) through their respective newsletters and/or email posting. The distribution of the survey began June 29, 2021 with follow-up emails in July and August. The survey was closed by September 12, 2021.

The survey generated 67 usable responses by the deadline, including city, county, ODOT, township, and village personnel. The breakdown is in Figure 1 and a list of the counties, cities, and other entities responding is given in Table 2.

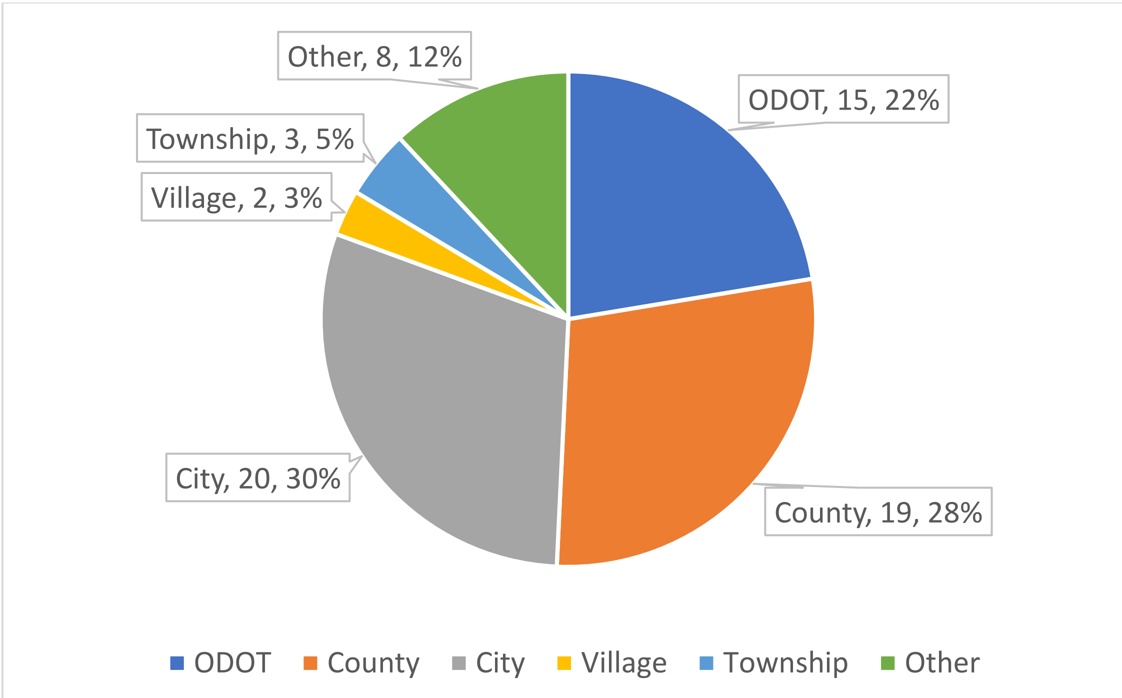

Figure 1. Breakdown of survey respondents by jurisdiction.

Table 2. List of jurisdictions represented by survey respondents.

Counties	**Cities**	**Township**	**ODOT/Village/Other**
Butler County	Cincinnati	Beavercreek	ODOT (15 respondents)
Carroll County	Berea	Sycamore Township	ODOT District 10
Columbiana County	Lebanon	Swancreek Township	Village of Crestline
Coshocton County	Springdale		Village of Gambier
Geauga County	Columbus		Summit Metro Parks
Greene County	Garfield Heights		Five Rivers Metro Park
Lorain County	Lorain		State Highway Patrol
Lucas County	Marysville		Burgess & Niple
Mahoning County	Monroe		ODOT Retired Engineer
Mercer County	Monroe		Arborist
Pickaway County	Moraine		Graduate Student
Scioto County	Mount Vernon		Ohio Office of Information Technology
Summit County	Oberlin		
Tuscarawas County	Oberlin		
Warren County	Ravenna		
Washington County	Walnut Creek		
Wayne County			
Williams County			
Wyandot County			

The survey contained 17 questions on the topic and an eighteenth question regarding permission to follow up with respondents for additional information. Five questions requested typed responses, eight multiple choice questions, and four Yes/No questions (some requesting explanations or specifics) (including the follow up request). A few choices in the responses included a request to specify (typically if the choice was "other").

Question 1 asked if the responding agency was aware of any pavement issues related to tree canopy, hilly terrain, or tall buildings. More than one response could be selected. Responses are shown in Figure 2. Percentages are based on 67 respondents.

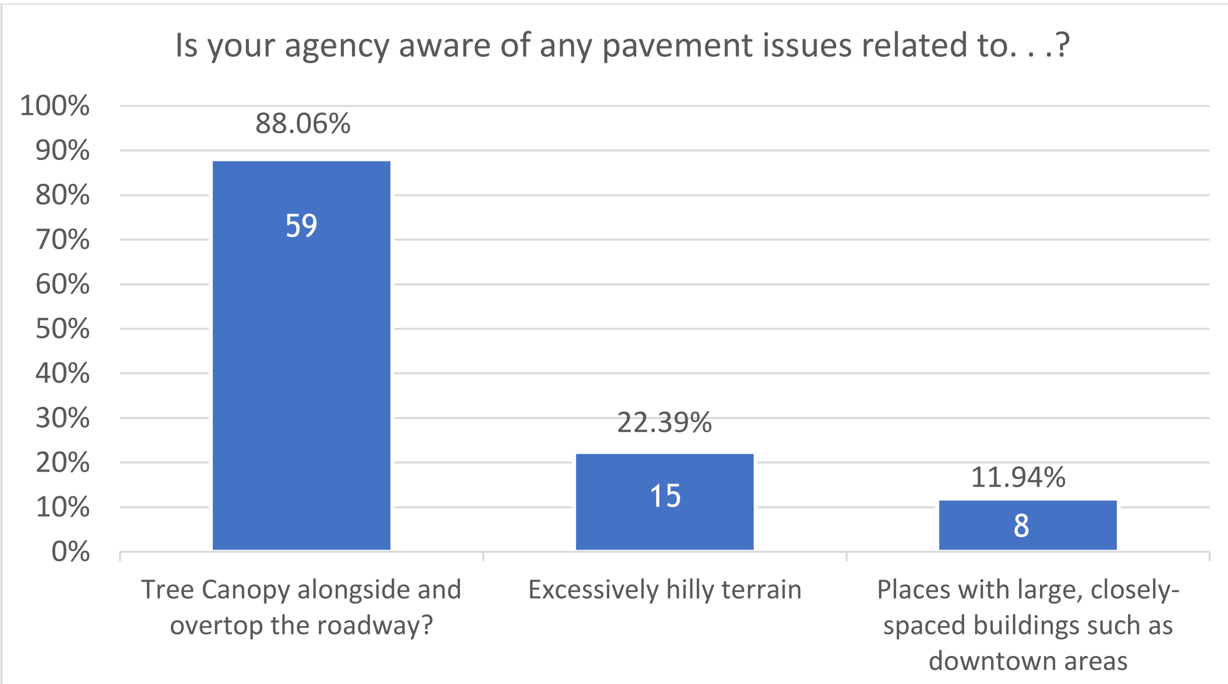

Figure 2. Responses to Question 1 of survey, "Is your agency aware of any pavement issues related to" the conditions related to tree canopy, hilly terrain, or tall buildings, as listed at bottom. White numbers in bars are number of responses, and percentages are based on 67 total respondents.

Respondents to Question 1 were asked to provide additional details in Question 2. These are summarized below and provided in their entirety in Appendix D: Survey Responses, under Q8. In general, most respondents indicated that they have seen premature deterioration and increased raveling, cracking and in some cases alligator cracking in areas that are shaded. Most respondents indicated that they have experienced excessive moisture accumulation and potholes in areas that are covered with tree limbs heavily shaded by trees or around hilly terrain. Some also indicated that poor drainage in those areas contributed to excessive moisture in these areas.

Question 3 inquired about the frequency that pavement issues were encountered, with choices being "often", "sometimes", and "rarely". Responses are plotted in Figure 3.

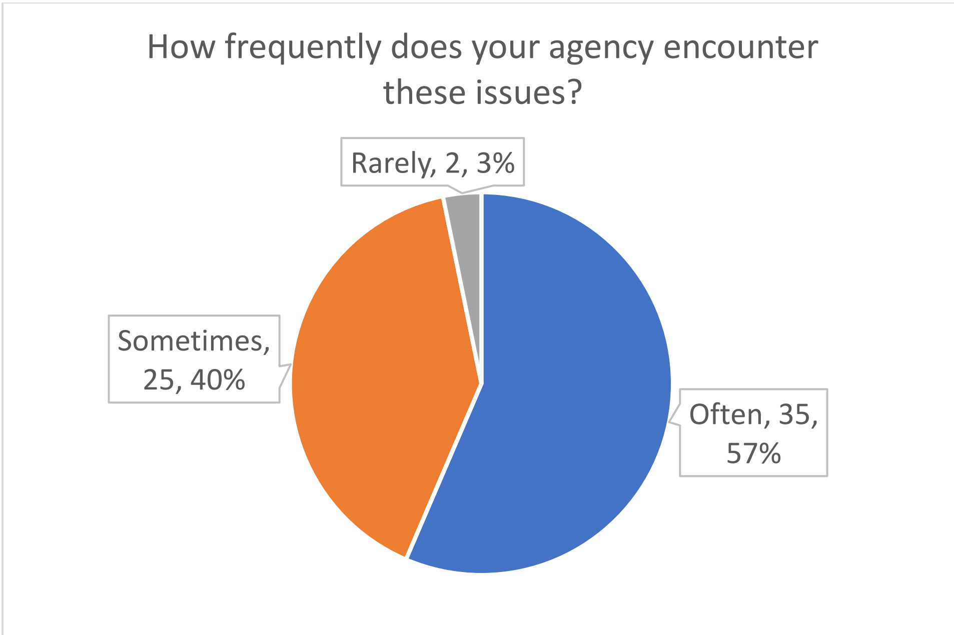

Figure 3. Responses to Question 3 regarding frequency pavement issues were encountered.

The next question asked if the respondent thought these issues reduced pavement life. An overwhelming majority of responses (90.77%) were yes, and the remainder (9.23%) were no. Question 5 then asked for an estimate of the service life reduction, with options of one year, one to three years, or more than three years of service life reduction, and an additional option of "I do not know". Responses are shown in the pie graph in Figure 4, with "more than three years" being the most popular response (51%)

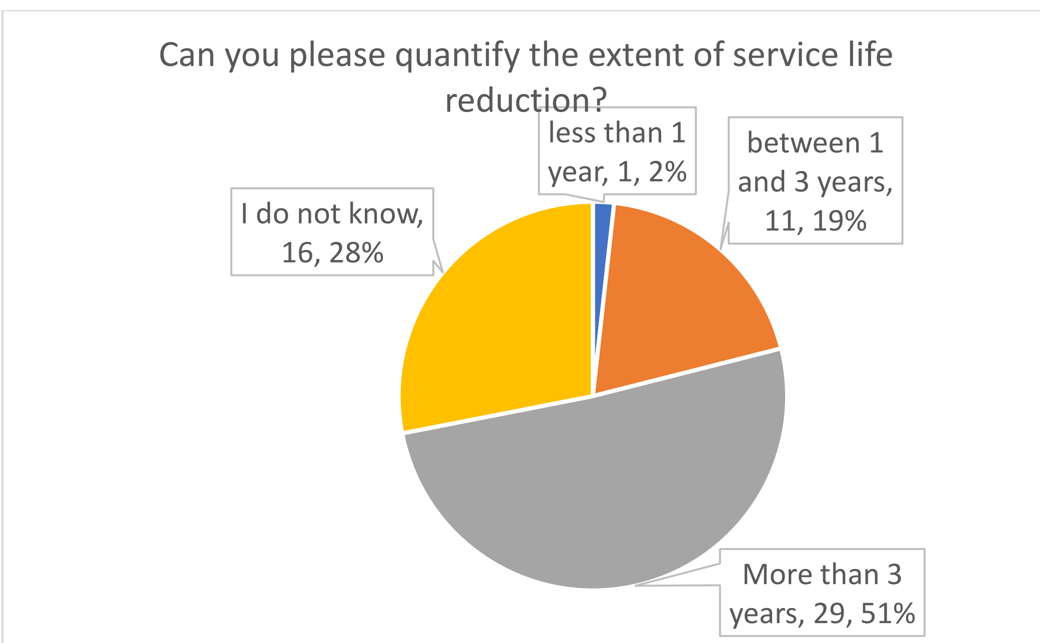

Figure 4. Responses to Question 5 of the survey, regarding service life reduction caused by tree canopy or related issues.

Question 6 asked if the respondent had a program in place to address pavement problems caused by tree canopy. Most (36, 54.55%) had a program, and the rest (30, 45.45%) did not. Those that did were asked to describe their program.

Responses to Question 7 included specifics on the programs used to address pavement issues. The full set of answers to this question is in Appendix D: Survey Responses, under Q13.

In summary most cities, and counties that responded had a program to deal with overhanging trees, by either trimming the trees or high-walling them depending on the situation. Most counties and cities that responded indicated that they deal with the damage depending on the situation in various ways listed below:

1. Use better asphalt specification - ODOT 424 B Surface Course
2. Dura patching and chip seal as needed
3. Crack seal any cracks that develop in the asphalt
4. Use pavement rejuvenators
5. Use of Reclamite, surface treatment

Treatment of problem pavements was the subject of Question 8, with the response options being repair or replacement of the pavement. Repair was by far the most common option, selected by 51 (81%) respondents, while replacement was the choice of the remaining 12 (19%).

In the next question, the respondents who repaired pavements were asked which repair methods they used, with the possibility of selecting more than one and/or selecting "other" writing in the name of the treatment. Responses are shown in Figure 5.

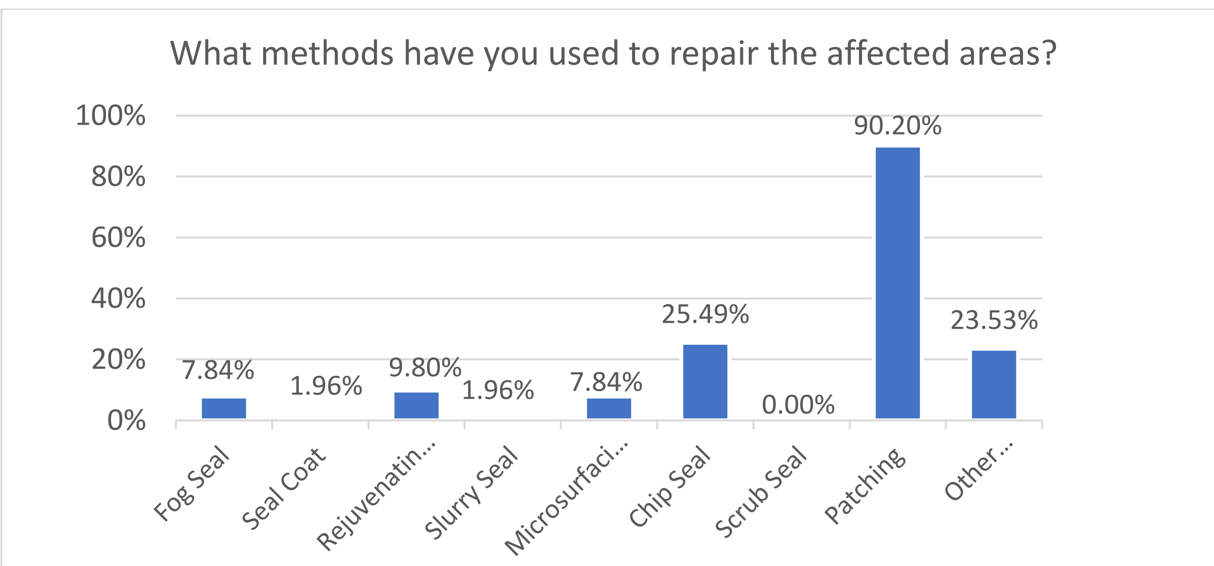

Figure 5. Responses to survey Question 9 regarding pavement repair methods used. Percentages are of the 51 respondents who selected "repair" in Question 8.

The "Other" category for pavement repair was selected by 12 respondents, who were then asked to describe their other method in Question 9. This included mill and fill or inlays, selected by 5 respondents. Other "other" treatments included edge paving, Dura-patching, 1.5 in (38 mm) overlay, patching, and fixing drainage. The original responses are in Appendix D: Survey Responses, under Q15_12_TEXT. Respondents universally declined to provide cost estimates in Question 10.

Those who repaired pavement were asked in Question 11 whether replacement consisted of surface grinding and repaving (presumably similar to mill and fill noted under repair methods) or full-depth reclamation. The responses to this question broke down as 7 (63.64%) choosing "surface grinding and repaving", and 4 (36.36%) choosing "full depth section replacement", with one other respondent who selected "replacement" in Question 8 not answering this question. Question 12 requested cost estimates, and again these were not provided by respondents.

Question 13 asked if the agency had any practices in place to mitigate or manage the pavement damage due to shading. Of those responding, 34 (55.74%) did and the other 27 (44.26%) did not. Those who did have a process were asked to elaborate on the measures in Question 14. A full set of responses is in Appendix D: Survey Responses under Q18. The most typical and relevant responses are summarized below.

- Using a better surface course of asphalt (ODOT 424 B) has been shown to be effective. The added cost is less than 10% to the job. The added service life is significant.
- Use of chip seal.
- Tree trimming

How projects were identified or prioritized for adoption of a practice (Question 15, with options "due to pavement serviceability" (same as condition, presumably), "due to public feedback" or "Other, please specify"), whether the process is continuous or periodic (Question 16), and how often the process was reviewed (Question 17, with options "as needed", "every month", every 6 months", "once a year", or "other").

The response to these questions from the in-person interviews conducted indicated that deteriorated road sections were repaired due to pavement serviceability issues as needed. Sections that were damaged due to shading represented a small fraction of the road repair inventory.

Question 18 asked if respondents could be contacted by the research team for further information. The vast majority (51, 86.44%) agreed, and the rest (8, 13.56%) said no. Information from interviews with agencies is discussed in a separate section.

4.3 Interviews with local agency personnel

Several jurisdictions were contacted to follow up on the survey, or in some cases encourage them to complete the survey (City of Columbus). A summary of these contacts, by telephone or email, is in Table 3. Notes from more extensive interviews with County Engineers from Carroll, Pickaway, Warren, and Franklin Counties are given in Appendix E: Local Agency Interview Summary.

Table 3. Summary of responses from follow-up contacts with agencies.

Agency(s)	Comments
Warren County, Lucas County	Use of asphalt rejuvenator, clearing tree canopy in some areas, trying to begin compaction of asphalt as soon as possible after asphalt is placed.
Pickaway County, Scioto County, Carroll County	Chip seal, patching
City of Kirtland	Rejuvenators and fog seal at construction
City of Berea, City of Cincinnati	Reclamite, Surface Treatment. 2" (50 mm) Mill and Fill Patching if beyond a Reclamite Application. Rejuvenating Seal.
City of Garfield Heights	Chip Seal
Swancreek Township	Dura Patching, Chip Seal

5 Primary Findings

Tree canopies, geographic features, and tall structures that obscure sunlight from pavement lead to excess damage to roadways caused mainly by the retention of surface moisture. Past research [Naik et al., 2017 and Naik et al., 2020] confirmed that excessive moisture is present under tree canopies. In addition, excessively hilly terrain and high building create a similar effect to trap moisture on the pavement surface resulting in premature damage to the pavement surface.

Based on the responses to the survey conducted with the assistance of ORIL and ODOT, the following has been noted:

- Local agencies try to mitigate the damage from trees by high-walling or trimming them in the right-of-way when possible.
- Local agencies, especially in rural counties, have successfully used chip seal as a means to prolong the life of damaged pavement sections.
    - This was the most cost-effective method for those counties
- Local agencies in urban areas have preferred the use of polymers or other additives to pavement mixes to mitigate damage due to moisture.
    - This adds a 5% premium to the per mile cost of resurfacing pavements
- Other respondents have used rich AC mixes to prolong the life of chronically shaded roads.

6 Summary and Conclusions

6.1 Summary

Premature deterioration of asphalt pavement has been observed in shaded areas, such as those under tree canopies or near tall buildings or hills. The shade slows or prevents drying of the pavement surface after rain or snow, and the prolonged presence of moisture leads to premature or increased stripping of the asphalt. One frequently used remedy is to trim or remove tree cover, but this is not always an option. This study was conducted to assess the current state of practice among local public agencies

(LPAs) for mitigating and managing the damage to asphalt resulting from excess moisture presence.

The state of practice was ascertained via a literature review. A survey of LPAs in the Ohio examined current practices in the state, and follow-up interviews were conducted with some agencies to get a more in-depth view of practices.

The scope of the investigation included the nature of moisture damage to asphalt and its causes, and various methods of prevention, mitigation, repair, and replacement.

The literature review indicated freeze-thaw cycles are a major aggravating factor in moisture-related pavement deterioration, which is triggered by moisture migrating through voids in the asphalt. Specific mechanisms of asphalt damage include detachment between binder and aggregate, displacement of binder from aggregate, spontaneous emulsification, hydraulic scouring, and excess pore water pressure under compression from traffic. The damage progresses into the formation of visible surface distresses such as potholes and raveling.

Countermeasures may be applied at several stages, including at asphalt mix design (e.g. anti-stripping amendments), during construction (e.g. asphalt treated permeable base and permeable pavement), surface treatments after construction (e.g. fog seal, rejuvenator application, slurry seal, micro-surfacing, and chip seal), and in response to signs of damage (e.g. scrub seal, thin HMA overlay, or in extreme cases, full-depth replacement). Most of these treatments have been found effective in sealing the pavement and extending service life.

A survey of LPAs and other practitioners in Ohio generated 67 responses from county, city, ODOT, township, and village representatives. An overwhelming majority indicated they were aware of pavement problems related to tree canopies, hilly terrain, or tall buildings. The majority encountered these problems often (57%) or sometimes (40%), and over 90% said these problems shortened pavement life, predominately by more than three years (51%). Most (55%) had a treatment program for this issue, which typically included trimming or high-walling trees. Damage countermeasures cited included using better asphalt (ODOT 424 B Surface Course was mentioned), Dura Patching, chip seal, sealing cracks, applying rejuvenator, or Reclamite. Respondents overwhelmingly (81%) favored repair of pavement over replacement. Most popular repair methods were patching (90%), chip seal (25%), and rejuvenator (10%). Most agencies (56%) also had practices to mitigate and manage pavement damage, of which the most frequently cited approaches were trimming trees, chip seal, and using a better surface course.

Additional follow-up interviews were conducted by email and telephone with ten agencies, which confirmed many of the approaches mentioned in the survey responses.

6.2 Conclusions

Based on literature reviews and information from survey respondents, it is clear that tree canopies, geographic features, and tall structures that obscure sunlight promote retention of surface moisture in shaded pavement, which in turn leads to premature damage. To mitigate this damage on tree canopied sections, many local agencies have instituted programs, when possible, to remove or reduce canopies by trimming or high-walling the trees.

When these sections are present in rural areas, they are repaired by various methods, such as patching, and overlaid with a chip seal or similar surface treatment to prolong the life of the pavement at a relatively low cost. Local forces usually undertake this work and are able to add several years to the life of the pavement.

On the other hand, in urban areas, where population densities are higher, damaged pavement sections are usually repaired and overlaid with more expensive polymer modified treatments, or the pavement is replaced at with new asphalt containing polymer additives, which increases the price of the pavement by up to 5%.

7 Recommendations

Further study is recommended to address the following questions:

A more in-depth study of local practices can be undertaken to further assess the benefits of using various surface treatments to prolong pavement life.

A comparative evaluation of various repairs and treatments to determine which provide the most service life enhancement and value.

Whether polymer modified asphalt can be used effectively in rural as well as urban roads.

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9 Appendix B: Ohio local agency survey questionnaire

Dear fellow transportation engineering professional,

You are receiving this email to solicit your professional insight(s) regarding management of pavement sections damaged due to significant shading from tree canopies, excessively hilly terrain, and places with large, closely-spaced buildings such as downtown areas. This is part of a research project sponsored by the Ohio Department of Transportation under the Ohio's Research Initiative for Locals (ORIL). This project aims to understand current practices for local public agencies (LPA) around the country in dealing with the issue of deteriorating asphalt concrete pavement due to excessive moisture from significant amounts of shading.

Please click on the following survey link to participate in the survey: https://ohio.qualtrics.com/jfe/form/....

Your participation in this survey is voluntary and your responses will be kept as confidential as legally possible. All data will be reported in the aggregate. We are only interested in your local public agencies' management practices and the research team will not identify you by name in any published reports.

We would greatly appreciate your response by August 30 2021

If you feel that you are not the correct individual for this request, please forward our message to the correct individual(s) within your organization.

If you have any questions about this survey, please feel free to contact principal investigator for this study, Dr. Issam Khoury, Phone: 740-593-0010, email: khoury@ohio.edu,

We sincerely appreciate your assistance with this survey.

Thank you.

Respondent Demographics:

Name:
Position:
Agency: (DOT/County/City/Village/Township/Other)
Phone Number:
Email:

Survey Questions:

1. Is your agency aware of any pavement issues related to?
   a. Tree canopy alongside and overtop the roadway?
   b. Excessively hilly terrain
   c. Places with large, closely-spaced buildings such as downtown areas

2. For the pavement issues identified above, can you please provide additional details

   ____

3. How frequent does your agency these encounter these issues?
    a. Often
    b. Sometimes
    c. Rarely

4. Do you think that these issues resulted in reducing the service life of the pavement? on text
    a. No
    b. Yes

5. Can you please quantify the extend of service life reduction
    a. less than 1 year
    b. between 1 and 3 year
    c. More than 3 years

6. Is there any program(s) that you have in place to address these issues specifically?
    a. No
    b. Yes

7. Can you please specify the type of program in place

    ____

8. How have you addressed these issues?
    a. Repair of affected areas
        i. How/ what method/s
    b. Replacement of affected areas
        i. How/ what method/s

9. What methods have you used to repair the affected areas?
    a. Fog Seal
    b. Seal Coat
    c. Rejuvenating Seal
    d. Slurry Seal
    e. Microsurfacing
    f. Chip Seal
    g. Scrub Seal
    h. Pot-hole Patching
    i. Other (please specify) ______________________

10. Can you provide an estimate for the cost of these repair methods

    ____

11. What methods have you used for the replacement of affected areas?

a. Surface grinding and repaving
b. Full Depth section replacement

12. Can you provide an estimate for the cost of the replacement sections?

    ____

13. Are there any measures or practices in place that your agency has adopted to mitigate/manage these effects from pavement damage due to excessive shading?
    a. Yes
    b. No

14. Would you please elaborate on these measures?

    ____

15. How are projects identified (or prioritized) for adoption of any practices?
    a. Due to pavement serviceability
    b. Due to public feedback
    c. Other, please specify: _________________

16. Is this a continuous or periodic process?
    a. Continuous
    b. Periodic

17. How often is this process reviewed
    a. As needed
    b. Every month
    c. Every 6 months
    d. One a Year
    e. Other: ____________

Follow up Availability

18. If the need arises for the researchers to contact you for further information/clarifications, are you willing to speak to them?
    a. Yes
    b. No

10 Appendix D: Survey Responses

This is a raw data report from Qualtrics before final processing and plotting. The survey questions, starting with Question 1 above, begin here at Q7.

Default Report

ORIL TASK#1: Tree Canopy

September 10th 2021, 4:28 pm EDT

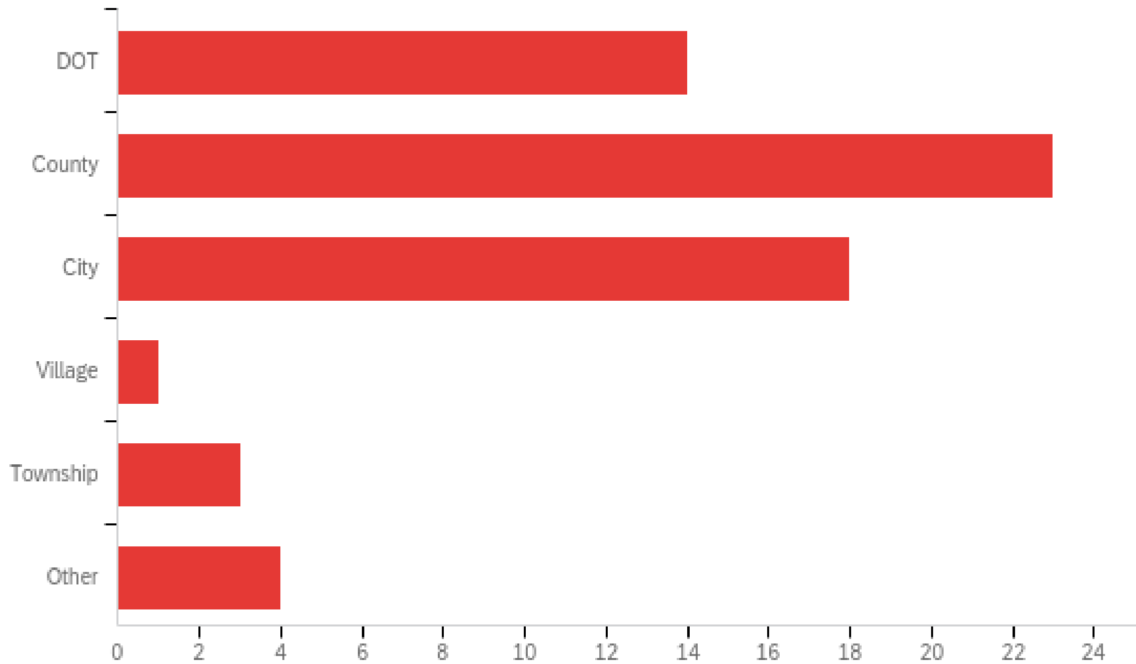
Q3 - Position:

Position:
Transportation Manager/ISA Certified Arborist
Director of Administration
Engineering Project Manager
Chief Deputy Highway Engineer
Supervising Engineer
SENIOR ENGINEER
Design Tech
Highway Superintendent
Warren County Engineer
Village Administrator
City Engineer
City Engineer
City Engineer
Pavement/Scoping Engineer
HT 3 C/M Certified Arborist
Traffic Engineer
Street Superintendent
Operations Deputy
Director of Engineering

County Engineer
Maintenance Supervisor
Tuscarawas County Engineer
Highway & Drainage Engineer
Pavement & Roadway Engineer
Retired
Deputy Engineer
HPRD
City Engineer
Associate Engineer
Deputy County Engineer
Engineer IV
Eng Tech Inspector
Area Engineer
auto mechanic
Assistant Public Works Director
Deputy Engineer
Municipal Arborist
Highway Patrol
Executive Director
Graduate Student
Citizen/Tree Board
Director of Facility Inspection, Principal
Public Works Director
Pavement Engineer
Public Works Director
Superintendent
County Engineer

Project Manager
Warren County Engineer
Highway Management Administrator
Road Superintendent
Washington County Engineer
Operations Services Manager
Mobility & Construction Manager
Chief Deputy Engineer
Sr Project Coordinator
Highway Maintenance Supervisor
Operations Manager
HT-3C-Inspector
Eng Tech - inspector
Transportation Manager
Assistant City Engineer/Service Dept. Superintendent
Village Council
Retired Civil Engr.
Assistant Superintendent
Project Manager
Assistant Engineer
City Engineer

Q4 - Agency Represented :



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Agency Represented : - Selected Choice	1.00	6.00	2.49	1.33	1.77	63

#	Answer	%	Count
1	DOT	22.22%	14
2	County	36.51%	23
3	City	28.57%	18
4	Village	1.59%	1
5	Township	4.76%	3
6	Other	6.35%	4
	Total	100%	63

Q4_1_TEXT - DOT

DOT - Text
ohio DOT
x
Ohio Department Of Transportation
ODOT
ODOT
ODOT D10
ODOT

Q4_2_TEXT - County

County - Text
Summit
Lucas
Columbiana
Greene
Warren
Butler
OH
Wayne County Engineer's Office
Wyandot County Engineer
Geauga
Pickaway County
Carroll
Scioto
Summit Metro Parks
Mahoning
Williams

Mercer County Engineer's
Mahoning
Pickaway County Engineer Dept

Q4_3_TEXT - City

City - Text
Yes
CINCINNATI
City of Lebanon, Ohio
Mount Vernon
Lorain
Oberlin
Walnut Creek
Monroe
City of Springdale
Oberlin
Marysville
Garfield Heights
Monroe
City Of Berea
Ravenna
Moraine
Columbus

Q4_4_TEXT - Village

Village - Text
Gambier

Q4_5_TEXT - Township

Township - Text
Sycamore Township
Swancreek Township

Q4_6_TEXT - Other

Other - Text
State Highway Patrol
Ohio Office of Information Technology
Burgess & Niple
Five Rivers MetroParks

Q5 - Phone Number:

Phone Number:
740-323-5323
3306438103
6143599388
330 424 1740
513-352-6235
513-352-5284
5137927258
937-562-7500
513-695-3307
740-427-2063
513-228-3130
7403939528
4402042005
740-833-8228
740-238-2364
216-581-2100
937 535 1041
513-678-6330
3308412973
7406222135
(419)822-5641
3303396648
330-287-5500
216-584-2121
419-294-2330

4407760037
9259435899
4404789360
440-329-5586
330-786-3112
6143482992
5133465520
7404743360
5137857556
419-423-1414
6147280890
7403310586
937-403-3383
614-459-2050
440-775-7204
740-568-3945
4407995019
330/627-2345
740-259-5541
513-695-3307
(740)568-4392
937-429-3672
7403767430
3304750477
330-799-1581
330-913-1050
419-636-2454 ext. 2143
419-586-7750

13308053670
5137278953
440.826.5824
419-564-0760
419-522-4422
7404743491
937-277-4825
3302965666
9375351031

Q6 - Email:

Email:
Charles.dawson@dot.ohio.gov
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srowland@co.lucas.oh.us
bhelscel@cceng.org
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JOE.FLADING@CINCINNATI-OH.GOV
sreutelshofer@sycamoretownship.org
ermiller@co.greene.oh.us
Neil.Tunison@co.warren.oh.us
villageadministrator@villageofgambier.org
dbicknell@lebanonohio.gov
engineer@mountvernonohio.org
Dale_Vandersommen@cityoflorain.org
LAURA.WRIGHT@DOT.OHIO.GOV
joseph.thompson@dot.ohio.gov
keith.hamilton@dot.ohio.gov
bcampbell@moraineoh.org
bresslers@bceo.org
pmakosky@warren.org
fredwachtel@coshoctoncounty.net
Roads@swancreektwp.org
tcejoe@yahoo.com
rpm@wayne-county-engineer.com
eric.kallio@dot.ohio.gov

twright@wyandotcountyengineer.com
clraugh@dps.ohio.gov
rroberts@cityofoberlin.com
wong@walnut-creek.org
ngorris@co.geauga.oh.us
sduffala@loraincounty.us
bodikerj@monroeohio.org
brian.olson@dot.ohio.gov
Brad.Shannon@dot.ohio.gov
mhuxsoll@springdale.org
aneff@pickawaycountyohio.gov
dave.bienemann@hamilton-oh.gov
AHYoung@dps.ohio.gov
David.Blackstone@das.ohio.gov
bi663220@ohio.edu
moggieandyoggie@yahoo.com
ed.cinadr@burgessniple.com
jbaumann@cityofoberlin.com
matthew.first@dot.ohio.gov
Jfornaro@kirtlandohio.com
mbryan@carrollcountyohio.us
darren.lebrun@sciotocountyengineer.org
Jason.Lutz@dot.ohio.gov
Neil.Tunison@co.warren.oh.us
bert.tooms@dot.ohio.gov
tparks@beavercreektownship.org
rwright@wcgov.org
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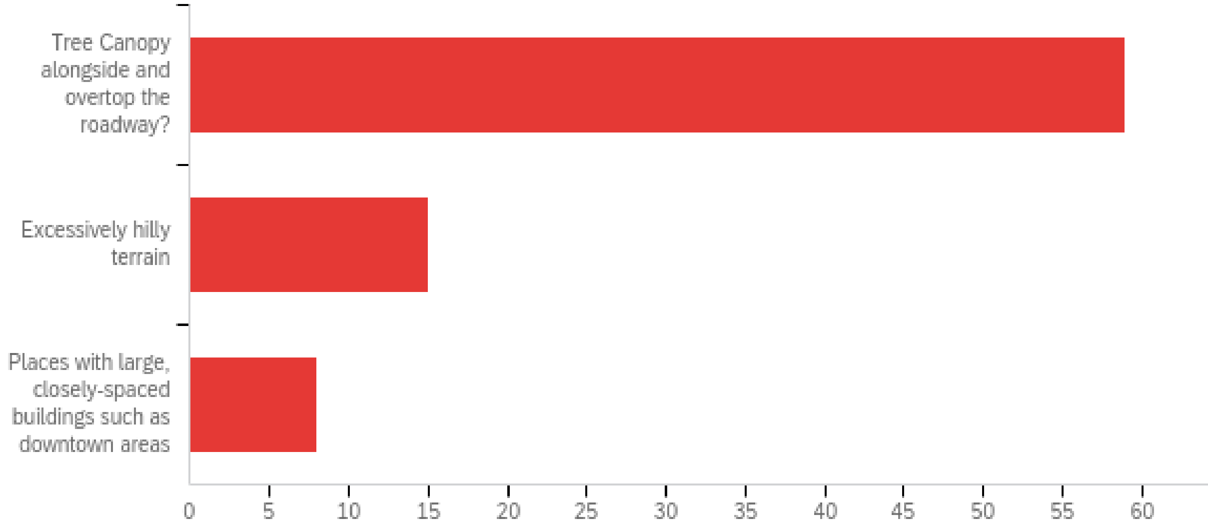
bdurbin@mahoningcountyoh.gov
james.sickels@ohm-advisors.com
stevenhumphrey@wmscoengineer.com
brad.laffin@mercercountyohio.org
William.Kusior@dot.ohio.gov
bodikerj@monroeohio.org
rtheberge@cityofberea.org
crestlinelaferty@gmail.com
ryarger4422@yahoo.com
lboyer@pickawaycountyohio.gov
joseph.zimmerman@metroparks.org
patrick.jeffers@ravennaoh.gov
aburcham@moraineoh.org

Q7 - Is your agency aware of any pavement issues related to?



#	Answer	%	Count
1	Tree Canopy alongside and overtop the roadway?	71.95%	59
2	Excessively hilly terrain	18.29%	15
3	Places with large, closely-spaced buildings such as downtown areas	9.76%	8
	Total	100%	82

Q8 - For the pavement issues identified above, can you please provide additional details

For the pavement issues identified above, can you please provide additional details
Over grown trees
Tree canopy over the roadway has always been an issue. The roads stay wet longer and if there is certain trees along the roadway we have noticed more issues with pavement deterioration. Maples seem to be more of a problem with breaking the road down but all areas with shade all the time show issues with pavement issues.
There is excessive raveling and the surface deteriorates at a much faster rate. This is the biggest problem in park areas.
Excessive tree canopy does not let the pavement dry out and contributes to pavement deterioration. Excessive hilly terrain enables the canopy to grow to excessive heights which make trimming by conventional means very difficult
It's not just the shade from the tree canopy, it is more significantly from the tree blossom/seed debris. Certain trees should not be planted next to the road. The small blossoms/seeds have a tendency to stick to the roadway and hold moisture causing premature deterioration of the pavement. Excessively hilly terrain can become destabilized and landslides can form, tearing pavements apart. Need to make sure that downtown pavements are graded with both longitudinal and cross slopes that will drain correctly. Flat areas in shady zones will deteriorate at a much faster rate.
STREET TREES CREATE CANOPIES THAT HINDER THE DRYING PROCESS FOR ASPHALT PAVEMENTS.
Extensive level of surface disintegration, severe surface fatigue & map/alligator cracking, potholes and base failures. The severe fatigue & alligator cracking is indicative of general structural failures of the underlying base course, which is caused by high moisture content of the sub-grade. The pavement cracks have increased year over year which allows for more and more moisture to infiltrate into the sub-grade. This in turn leads to increased alligator cracking and sub-grade failure. The existing pavement is in extremely poor condition. The targeted and extensive partial and full depth pavement repairs by maintenance forces are no longer a viable cost effective option. The numerous attempts at repairing and patching the pavement are short lived because most of the areas do not have enough structural integrity left to hold the repair.
creates shady areas that deteriorate the pavement
Surface deterioration including debonding and heavy raveling under tree canopy.
Shade from tree canopy is related to much more pavement deterioration than unshaded areas.
some area have shading problems. Often we have drainage problems in addition to shading.
Accelerated deteriation in shady areas, closely spaced buildings not as much
The area stays fairly shaded and didn't have a noticeable crown to facilitate drainage
Shade and moisture are issues

Excessive pavement deterioration in areas with tree canopy.
Premature deterioration of pavement.
Tree canopy causing pavement deterioration
Shading accelerates pavement deterioration and inhibits proper curing of chip seal emulsions
Several roads that wind through heavily shaded valleys.
Trees being cut back on State Routes.
In some cases where the tree canopy is over the road, the pavement is a bit more distressed than at other locations along the same roadway.
Subgrade water freeze thaw
Pavement cracks and breaks up quicker along wooded areas that do not get as much sun light in order to dry the pavement
Significant cracking of pavement in canopy areas.
There are more paving irregularities and subsurface variations in hilly terrains.
Shaded Areas do not permit the pavement to drain/dry .. Also increase posibility of ice conditions in winter
We often see deterioration in roadways where large canopies are present and when resurfaced, base failures are generally located here which are then repaired
tree canopy issues creating areas of surface asphalt not drying under the canopy outline, creating early pavement surface failure Hilly areas creating shoving at stop locations
In shady areas, potholes and raveling develop before the rest of the pavement
When the tree canopy is over the roadway, the surface coarse deteriorates faster than areas without the tree canopy.
Work mostly around and adjacent to bridges. Trees encroach on structures and cause sight distance safety issues but rarely affect structures.
Water is slow to evaporate. Pavement in these areas deteriorates more quickly.
Accelerated surface deterioration due to moisture.
Canopy causes premature deterioration of pavement; hilly terrain causes roadway slips/landslides
Tree canopy over roadways keep pavements wet longer causing accelerated deterioration through raveling and requires proper subgrade drainage to mitigate which is rare on older two-lane roadways and usually requires pavement repair prior to the next resurfacing cycle.
We tend to see alligator cracking much sooner than in unshaded areas.
Excessive shade causing roadway issues
Some areas remain shaded for the entire day due to tree canopy and steep surrounding terrain the trees are growing on.
We have parkways that are heavily shaded in many areas.

Pothole are always located under areas with a tree canopy. They can also be found in some locations near a single large tree that has branches over the pavement.

The pavement takes much longer to dry out.

We notice increased cracking of pavement where a wooded area are close to the pavement.

Pavement deterioration in shaded areas. Very poor drainage for roadway. Shoulders are higher than roadway surface. Need graded down.

areas of dense tree canopies such as silver maples and elms, create areas where the roadway surface does not dry and create life span of the surface course issues

Pavements remain wet longer than open areas. Pavements tend to pothole faster in these location and retain snow and ice longer due to not getting sunlight.

Raveling, Bleeding, surface cracking, alligator cracking

Ice build up due to shade.

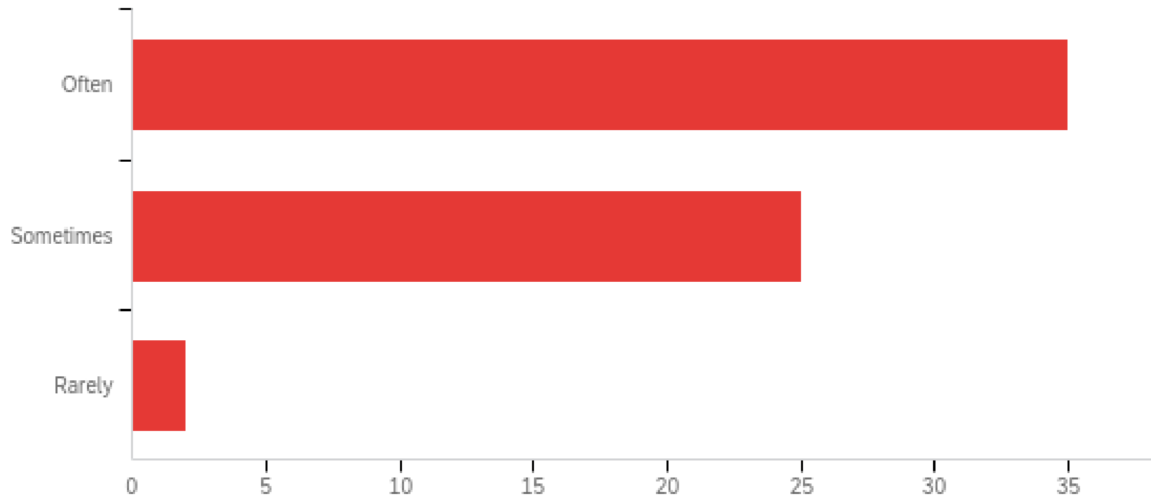
Mainly tree shaded pavement areas create raveling of asphalt pavemet.

We actually part of the budget set aside to go around roads the what we call "high Wall" trees along the road and go about 5 ft off the edge of pavement and go strait up and we have a local contract with a bucket truck and high wall trees. and then we chip the brush. We have noticed in shaded areas of where the trees canopy over the road we see raveling sooner than we do on a road that gets mostly shade.

As a park district, we prioritize tree cover, especially over many of the miles of paved bikeways we operated, as well as park roads and parking areas. Particularly on the bikeways, we find that this can lead to both short-term problems with slippery surfaces causes by the accumulation of sediment and algae on the surface, and also long-term issues with surface degradation from cement loss.

Pavement cracking in areas shaded by trees

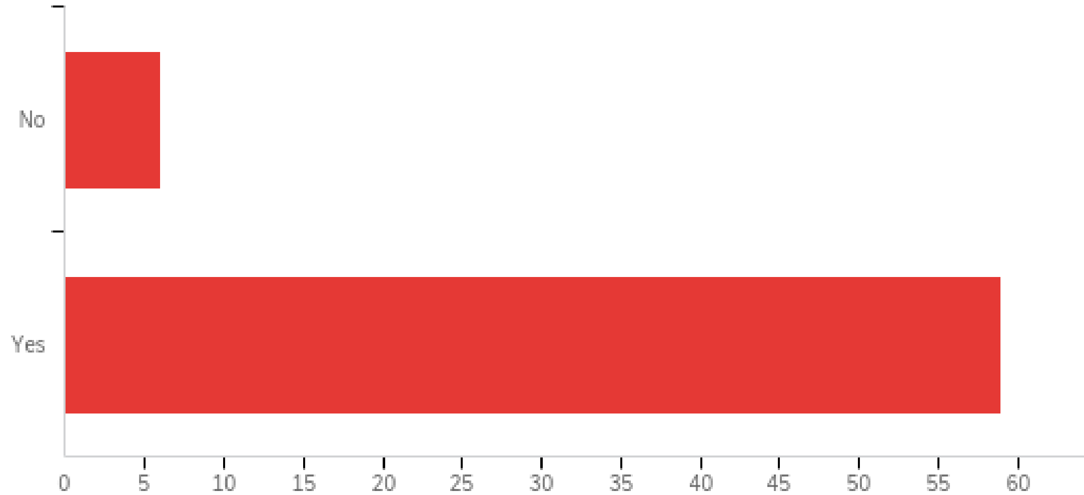
Q9 - How frequent does your agency encounter these issues?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How frequent does your agency encounter these issues?	1.00	3.00	1.47	0.56	0.31	62

#	Answer	%	Count
1	Often	56.45%	35
2	Sometimes	40.32%	25
3	Rarely	3.23%	2
	Total	100%	62

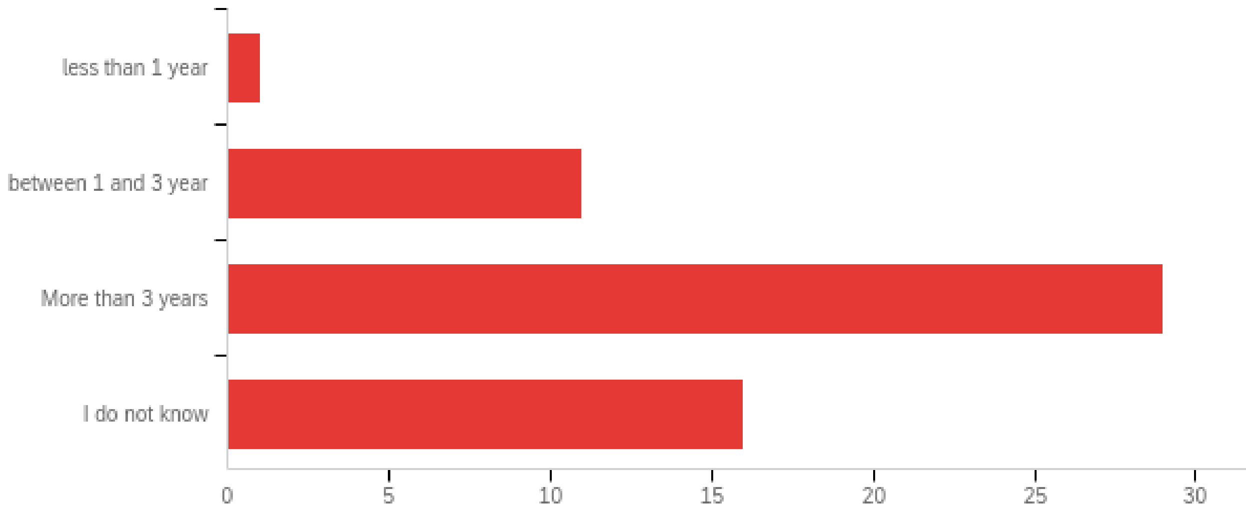
Q10 - Do you think that these issues result in reducing the service life of the pavement?on text



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you think that these issues result in reducing the service life of the pavement?on text	1.00	2.00	1.91	0.29	0.08	65

#	Answer	%	Count
1	No	9.23%	6
2	Yes	90.77%	59
	Total	100%	65

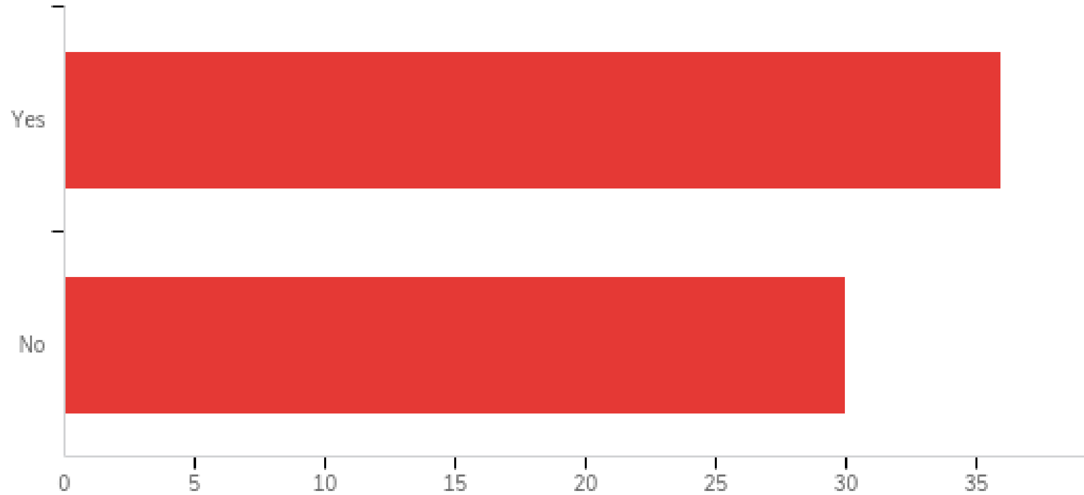
Q11 - Can you please quantify the extend of service life reduction



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Can you please quantify the extend of service life reduction	4.00	7.00	6.05	0.74	0.54	57

#	Answer	%	Count
4	less than 1 year	1.75%	1
5	between 1 and 3 year	19.30%	11
6	More than 3 years	50.88%	29
7	I do not know	28.07%	16
	Total	100%	57

Q12 - Is there any program(s) that you have in place to address these issues specifically?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is there any program(s) that you have in place to address these issues specifically?	1.00	2.00	1.45	0.50	0.25	66

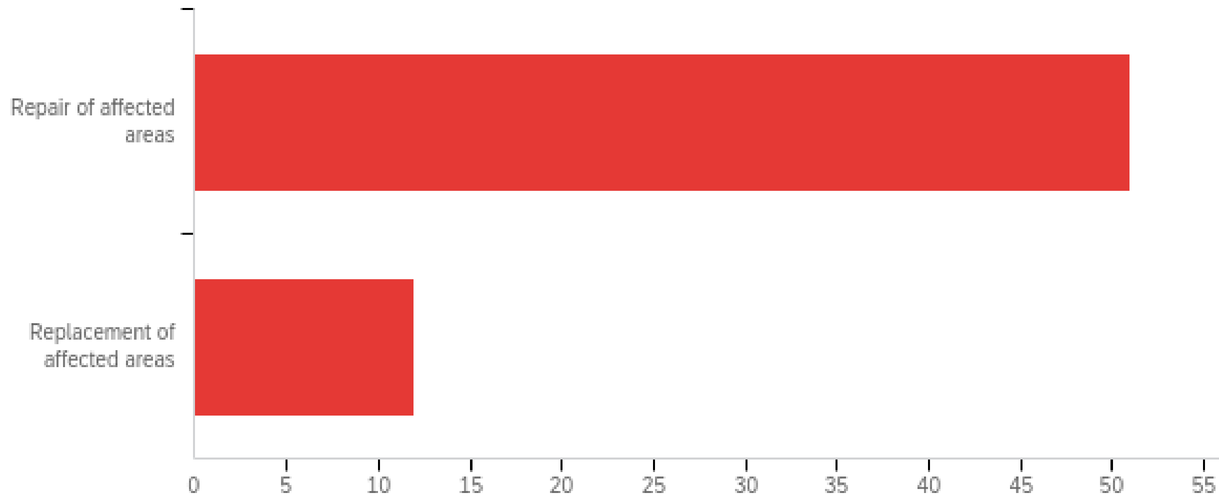
#	Answer	%	Count
1	Yes	54.55%	36
2	No	45.45%	30
	Total	100%	66

Q13 - Can you please specify the type of program in place

Can you please specify the type of program in place
Grinding down trees
We try to keep up with are pruning and not having limbs or trees hanging over the roadway. We try to get as much sun in on the roadway as possible, with pruning back to the edge of the right of way (30') this seems to really help. Or in some cases we'll remove the tree completely.
We put asphalt rejuvenating agent on pavements that are heavily shaded.
Annual tree trimming with various pieces of specialized equipment such as a bucket truck and a jarraff boom cutter
Street Rehabilitation Program/Street Improvement Program/Public Services Spot Repair
WE USE THE ASPHALT REJUVENATION AGENT CALLED RECLAMITE ON OUR LOW VOLUME STREETS UPON THE COMPLETION OF PAVING WORK. WE DON'T NECESSARILY TARGET STREETS WITH TREE CANOPIES WITH THE RECLAMITE, BUT WE BELIEVE IT PROVIDES ADDED PROTECTION AS A SECONDARY BENEFIT. WE ALSO HAVE OUR CITY MAINTENANCE CREWS INSTALL SURFACE PATCHES OVER THE RAVELLED PAVEMENT.
tree cutting program
these items are identified annually and dealt with during the annual resurfacing program
fix drainage and do limited tree maintenance
We prohibit trees in the public right of way
repave with added crown to assist water run off of the paved area
Use better asphalt specification - ODOT 424 B Surface Course
Dura patching and chip seal
Crack seal any cracks that develop in the asphalt
Removal of Canopy
We are trying to removed the trees in areas to open the pavement up to sunlight. This is easier on freeways.
We try to cut back trees as much as possible.
County maintenance forces, mill and fill spot paving.
Pavement rejuvenators
chip seal as needed.
For canopy, we clear right of way to "unshade" the roadway; for slips we repair as needed.
County crews perform tree cutting to over hanging limbs

We utilize "sky trim" operations throughout the district to open up the canopy areas.
Tree trimming along roadways
We do tree trimming to increase the distance between the roadway & the tree
Tree trimming ,removal of trees if additional right-of-way is available.
Canopy removal with bucket truck, Jarraff all terrain saw and chippers.
Reclamite, Surface Treatment. Pruning Trees as needed. 2" Mill and Fill Patching if beyond a Reclamite Application
Spot pave.
We try and do a road or area of a road a year to high wall the trees.

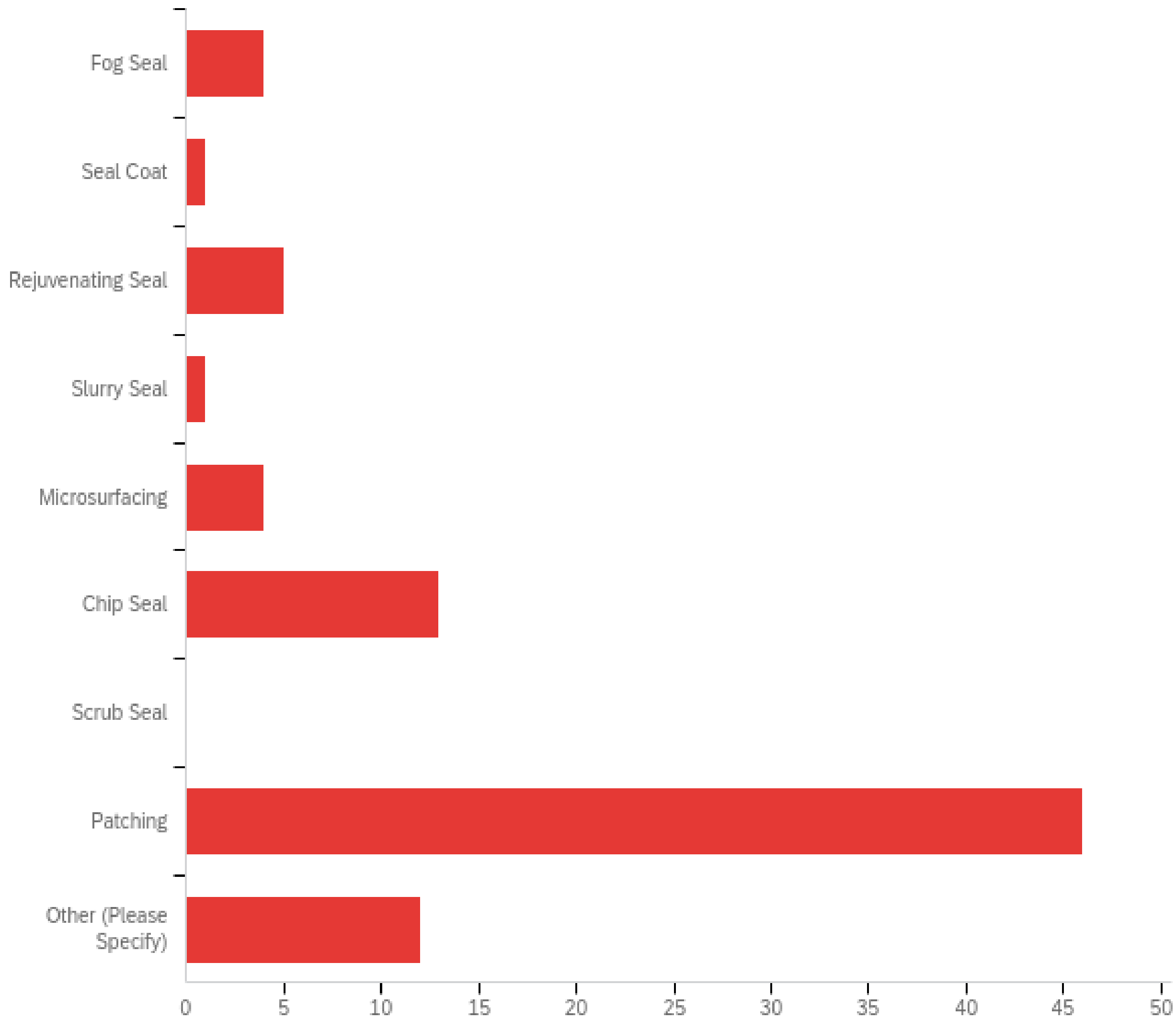
Q14 - How have you addressed these issues



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How have you addressed these issues	1.00	2.00	1.19	0.39	0.15	63

#	Answer	%	Count
1	Repair of affected areas	80.95%	51
2	Replacement of affected areas	19.05%	12
	Total	100%	63

Q15 - What methods have you used to repair the affected areas? (Check all that apply)



#	Answer	%	Count
4	Fog Seal	4.65%	4
5	Seal Coat	1.16%	1
6	Rejuvenating Seal	5.81%	5
7	Slurry Seal	1.16%	1
8	Microsurfacing	4.65%	4
9	Chip Seal	15.12%	13
10	Scrub Seal	0.00%	0

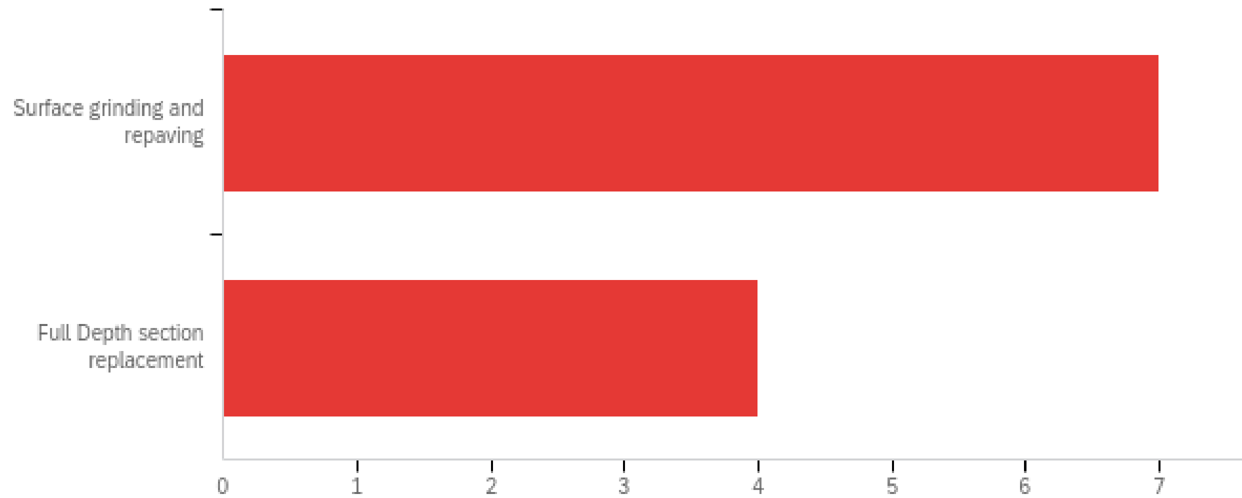
11	Patching	53.49%	46
12	Other (Please Specify)	13.95%	12
	Total	100%	86

Q15_12_TEXT - Other (Please Specify)

Other (Please Specify) - Text
Edge paving
milling out bad areas and paving back in
Fix drainage in area
Durapatching
We do not fog seal / seal coat / rejuv / slurry / microsurface / chip or scrub seal in our agency
Inlays if a large area
Mill/fill spot paving.
1.5 inch overlay
Mill and fill paving operations to repair asphalt.
Patch roadway, But couse of problem is not addressed....High shoulders
milling and repair

Q19 - Can you provide an estimate for the cost of these repair methods
Can you provide an estimate for the cost of these repair methods

Q16 - What methods have you used for the replacement of affected areas?



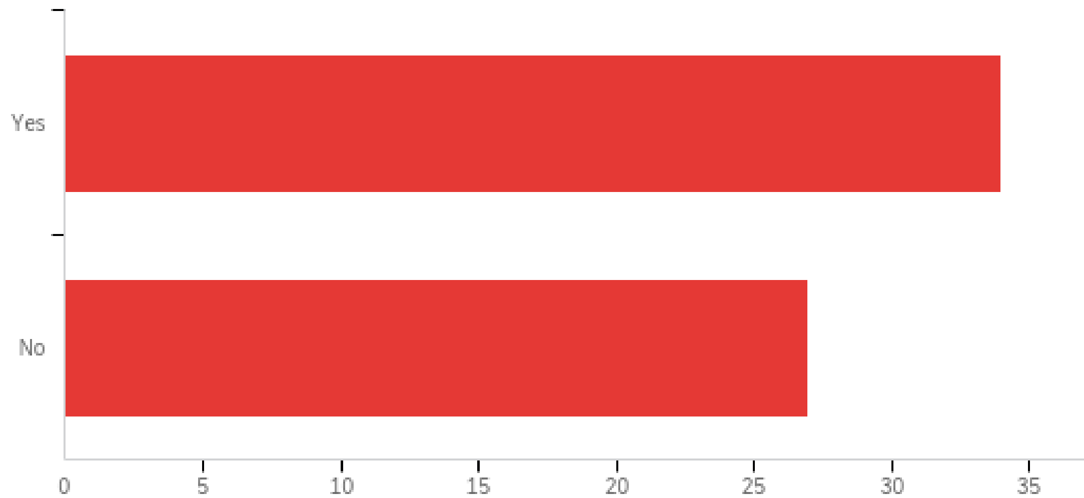
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What methods have you used for the replacement of affected areas?	4.00	5.00	4.36	0.48	0.23	11

#	Answer	%	Count
4	Surface grinding and repaving	63.64%	7
5	Full Depth section replacement	36.36%	4
	Total	100%	11

Q20 - Can you provide an estimate for the cost of the replacement sections?

Can you provide an estimate for the cost of the replacement sections?

Q17 - Are there any measures or practices in place that your agency has adopted to mitigate/manage these effects from pavement damage due to excessive shading?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Are there any measures or practices in place that your agency has adopted to mitigate/manage these effects from pavement damage due to excessive shading?	1.00	2.00	1.44	0.50	0.25	61

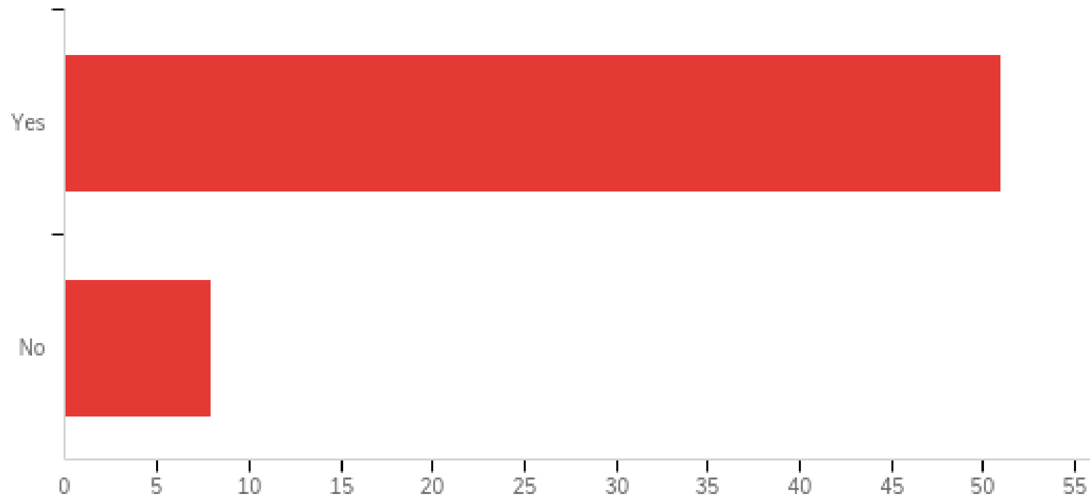
#	Answer	%	Count
1	Yes	55.74%	34
2	No	44.26%	27
	Total	100%	61

Q18 - Would you please elaborate on these measures?

Would you please elaborate on these measures?
Using Jarraffs, bucket trucks, aerial lifts and felling from the ground when need be. If the tree is perfectly healthy we'll just trim back to the the edge of the ROW or base of the tree. If the whole top is over the roadway we will remove it completely along with any dead or ash trees.
we have an active tree trimming program
No trees, better grading, better drainage structures, more drainage structures, correcting pavement areas with maintenance programs
as stated before, tree trimming and removal program
Use of asphalt rejuvenator, clearing tree canopy in some areas, trying to begin compaction of asphalt as soon as possible after asphalt is placed.
Thank about using concrete or brick for road vs asphalt. Plant trees in lawn on the homeowners side of the sidewalks.
Tree trimming
Using a better surface course of asphalt (ODOT 424 B) has been shown to be effective. The added cost is less than 10% to the job. The added service life is significant.
Tree trimming program every year to get more sunlight to the road surface
when able we try to cut back trees as far off the pavement as possible
Removal of canopy
Tree clearing
Routine tree trimming and planting the right tree in the right place.
cut back trees as much as possible when funding allows
Previous answer choices are somewhat oversimplified. Pavement shading is generally not the driver in selecting streets for re-construction, re-surfacing or pavement maintenance activities. What we will do as opportunities arise - is to install underdrain to reduce pavement and soil saturation. We have not cut down trees or altered species selection as a result of this issue.
Maintenance forces trim trees within the right of way to open the canopy.
Rejuvenators and fog seal at construction
surface treatment as needed.
Tree cutting has been most effective method but ditch maintenance is also necessary to allow water to escape from roadway
Trying to get roller compaction during resurfacing operations started as soon as possible.
Tree trimming operations.

Trim trees along roadways as needed
Tree clearing and cut back to the right of way line when the trees are reachable. In some areas the canopy is above current capabilities.
Recently added Urban Forester to staff. Established routine scheduled trimming of street trees.
We have purchased a bucket truck so we can trim trees in areas with issues. However, this work is secondary in nature to our other highway work and is only done on a limited basis as time and manpower permit.
tree trimming to increase distance between roadway & trees to increase sun to area.
Tree trimming or removal of the canopy. Clearing of trees to the limits of the right-of-way.
Trim trees. Need to hire outside contractors to do this more efficiently and quickly.
Chip seal or use a rubberized asphalt pavement.
We high wall a road where we have a local contractor come in with a bucket truck and high wall the trees and try and eliminate the canopy over the roads. We have done about 3 roads the last four years.
Short-term effects (slippery) are mitigated in selected areas where conditions and trail geometry have created safety hazards by installing a polymer asphalt mix with a higher coefficient of friction. Long-term pavement degradation is typically addressed as part of our scheduled pavement restoration program.

Q24 - If the need arises for the researchers to contact you for further information/clarifications, are you willing to speak to them?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If the need arises for the researchers to contact you for further information/clarifications, are you willing to speak to them?	1.00	2.00	1.14	0.34	0.12	59

#	Answer	%	Count
1	Yes	86.44%	51
2	No	13.56%	8
	Total	100%	59

11 Appendix E: Local Agency Interview Summary

11.1 Overview

- Contacted City of Columbus
  - Columbus filled out the survey
- Contacted other respondents
  - Warren County, Lucas County
    - Use of asphalt rejuvenator, clearing tree canopy in some areas, trying to begin compaction of asphalt as soon as possible after asphalt is placed.
  - Pickaway County, Scioto County, Carroll County
    - Chip Seal, patching
  - City of Kirtland
    - Rejuvenators and fog seal at construction
  - City of Berea, City of Cincinnati
    - Reclamite, Surface Treatment. 2" (50 mm) Mill and Fill Patching if beyond a Reclamite Application. Rejuvenating Seal.
  - City of Garfield Heights
    - Chip Seal
  - Swan Creek Township
    - Dura Patching, Chip Seal
  - Received responses from Carroll and Scioto, Warren, Pickaway and Franklin County Engineers
  - Other emails sent and telephone calls were not returned

11.2 Notes from Interview with Scioto County Engineer

- County has limited miles with tree/hill moisture damage
- Scioto County has a 5-year Chip-Seal program,
  - with a clearing the right of way of trees
  - and fixing drainage problems if found,
  - then Chip and Seal
- Scioto County uses a cold mix paving or drag patching first
- Then Chip-Seal the pavement top after repairs when needed
- Scioto County uses local forces to help with clearing the right of way
- Scioto County indicated that they would use chip seal as a preventative measure when they recognize tree damage and not wait, to limit the damage potential.
- Indicated that the use of any other additives would be too cost prohibitive to the amount of damage seen (few miles)

11.3 Notes from Interview with Carroll County Engineer

- County has limited miles with tree/hill moisture damage

- Depends on severity
- Local forces clear the right-of way
  - No dedicated program
  - Will use it in conjunction with a road repair program
- Most damage to roads which were overlaid
- Used Dura Patch with limited success
- Use Type 1 Hot mix to fix the limited miles (0.5 miles /year or less)
- Use Chip-Seal to seal the hot mix scratch coat
- Chip-Seal does helps with durability (Indicated that it is necessary)
- Indicated that the use of any other additives would be too cost prohibitive to the amount of damage seen (few miles)

11.4 Notes from Interview with Pickaway County Engineer Anthony Neff

- County has limited miles with tree/hill moisture damage
- Response based action
- Local forces high wall trees
  - No dedicated program
  - Will use it in conjunction with a road repair program
- Paved areas under the trees
- Pickaway County uses Chip Seal to mitigate damage to tree Canopy damage on roads with up to 1500 vehicles per day, any larger traffic volume they will pave.
- Chip Seal is a cost-effective method for them, it costs around $20,000/mile versus the $100,000/ mile for paving.
- They do conduct some high walling of trees when needed, at a cost of $10,000 to $40,000 per year depending on the volume.
- Anthony indicated that Chip Sealing the roads with tree canopy damage "buys them time" and would recommend it when possible.

11.5 Notes from Interview with Warren County Engineer Neil Tunisson

- Warren County has some 260 miles of road, half of which is tree covered
- Where possible dying trees were removed
- They have used Reclamite on a "moist" road 12 years ago and the moisture still beads
- Additive showed promise in beading water and reducing cracking
- Decided to use more Reclamite
- They have some newer pavements with the additive and are seeing some benefit
- Reclamite adds 4 to 5% cost to the road
- They have used Dura Patcher on some areas with good results
- Have not used Chip Seal under tree Canopies
  - Warren County is urban and did not want to deal with dust issues.

11.6 Notes from Interview with Franklin County Engineer Jamie Tickle

- County has minimal roads with tree canopies and tree cover
- County does not deal with pavement damage due to moisture
- Some suburbs like Bexley and Upper Arlington do
- They used some pavement with Reclamite
- In general, they use a “rich” AC mix (6%)
- Have had good results with that
- Used some Polymer additives to mitigate rutting
- Cost is usually not an issue for them, they will pave what needs to be paved
- Will not use Chip Seal
    - Franklin County is urban and did not want to deal with dust issues.

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