Field Performance of Aramid Fibre Reinforced Pavements

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Abstract

The asphalt industry has a well-established track record of using new technologies and innovative materials such as polymers, fibres, recycled asphalt pavement (RAP), recycled asphalt singles (RAS) recycled tire rubber (RTR), and warm mix asphalt (WMA) with the objective of improving the performance and/or sustainability of the materials. The practice of using synthetic fibres to reinforce asphalt concrete pavements has been around since the 1980's. Since the 1980's, laboratory testing methods have improved to quantify an asphalt mixtures resistance to low temperature cracking, fatigue cracking, and permanent deformation. Also, plant operations have also improved since the 1980's and adapted to the incorporation of new technologies with minimal plant modifications. Numerous studies have been performed that quantify the benefits of using synthetic and aramid fibres in asphalt mixtures. Some of these studies are based on laboratory data while others are based on field data. Some background information will be provided from the older research (1980's to current) that quantify the field performance of synthetic fibres relative to a control section. The goal of this paper is to summarize recent/modern field projects using aramid fibres versus a control in terms of a pavement condition index (PCI) (manual and automated distress survey) so one can quantify the life-extension of the

pavement when using aramid fibre. Once the life extension is known, a life cycle cost analysis could be conducted to look at the cost savings.

Introduction

There are two types of fibres used in asphalt mixtures, reinforcement fibres (i.e. aramid, carbon, basalt, asbestos, other synthetic fibres) and non-reinforcement fibres (i.e. cellulose or paper)[1,2,3]. A survey conducted in 2014 showed that 30 out of the 48 U.S. states use some form of fibres in asphalt mixes[4]. The survey revealed that the most common application was non-reinforcement fibres (cellulose fibres) that are used in stone mastic asphalt (SMA) and open-graded graded friction courses (OGFC) to prevent asphalt binder drain down[4]. SMA and OGFC are prone to asphalt binder drain down due to the open (gapped) aggregate gradation and high asphalt binder content. Cellulose fibres help to prevent drain down but do not add structural reinforcement to the asphalt mixture.

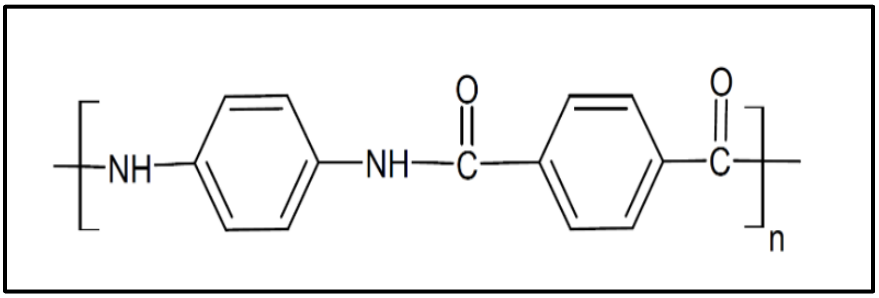
More recently, synthetic polymer engineered fibres have been developed to improve mixture performance. The resulting mixture type is known as fibre-reinforced asphalt concrete (FRAC) or fibre-reinforced asphalt pavement (FRAP). These engineered fibres have gained attention from state highway agencies and universities as an alternative or in addition to elastomeric polymers in asphalt to enhance asphalt concrete performance properties such as improved dynamic modulus, improved fatigue life as measured in the four-point beam fatigue test, improved cracking resistance as measured using the semi-circular bend test or indirect tensile cracking test (IDEAL CT) at intermediate test temperatures, and improved low temperature cracking resistance as measured using the disk-shaped compact tension test or low temperature indirect tensile creep and strength test.

Aramid fibres are a synthetically made, high performance dry polymer with molecules that are characterized by relatively rigid polymer chains. These molecules are linked by strong hydrogen bonds that transfer mechanical stress very efficiently, making it possible to use chains of relatively low molecular weight. This efficient stress transfer means that the force or load applied to one part of the fibre can be evenly distributed along the entire length of the polymer chains. This property helps prevent localized weak points and allows the material to handle stress without breaking. The fibre-forming substance is a long-chain synthetic polyamide in which at least 85 percent of the amide linkages are attached directly to two aromatic rings (see chemical structure below[5]). The structure contains benzene rings (hexagonal rings with alternating double bonds). These aromatic rings contribute to the rigidity and thermal stability of the polymer. The structure has amide linkages, indicated by the -CONH- groups.

- The carbonyl group (C=O) is bonded to a Nitrogen atom (NH), forming the amide bond and
- These amide linkages are responsible for the strong hydrogen bonding between polymer chains, which contributes to the material's high tensile strength.

The structure shown is a repeating unit, which means it is repeated many times to form a long polymer chain. The "n" at the end of the structure indicates that this unit can repeat multiple times, where "n" represents the number of repeating units in the polymer chain.

Figure 1 Chemical Structure of Aramid Fibres[5]



General characteristics of aramid fibres are:

- High strength and high strength to weight ratio,
- Good resistance to abrasion,
- Good resistance to organic solvents,
- Non-conductive,
- No melting point,
- Low flammability, and
- Good fabric integrity at elevated temperatures[5].

The properties above make aramid fibre an excellent product to improve the performance of asphalt concrete pavements in terms of cracking (low temperature, fatigue, longitudinal, block) and rutting resistance. Aramid fibres have been used in many high-tech applications such as aerospace and military applications for "bullet-proof" body armor fabric. Reinforcing fibres such as aramid fibre, natural fibres, steel fibre, glass fibres, polypropylene fibre, and carbon fibre have been used by the Portland cement concrete industry since the 1960's to improve the tensile strength and strain capacity[6]. Generally, the fibres are not added to concrete to increase the strength but rather to control the cracking of concrete to provide post-cracking ductility (the fibres bridge across cracks as they begin to open). In recent years, aramid fibre have found its way into asphalt pavement applications as an asphalt mixture modifier added locally (manual and automatic metered systems depending on job size) at the hot mix plant to improve the overall properties of the asphalt mixture by enhancing the fatigue resistance, improving permanent deformation, and resistance to reflective cracking[7,8]. Typical properties of the aramid fibres are shown below in Table 1[9]. In some instances, the fibres are coated with a wax based additive to prevent the fibres (which are light weight) from blowing away due to wind.

Table 1. Typical Aramid Fibre Physical Properties

Length (mm)	19 or 38
Form	Cut Fibre Clips
Acid/Alkali Resistance	Inert
Specific Gravity (g/cm^3)	1.44
Linear Density (dtex)	>3200
Fibre Decomposition Temperature (°C)	>425
Tensile Strength (MPa)	>2700
Young's Modulus (GPa)	>80

Background

Field Trials

Field trials are critical when it comes to the adoption of new technologies. This data is critical for decision-makers concerning cost-benefit of new additives and processes. One of the earliest uses of a fibre-reinforced asphalt concrete occurred in 1980 on a composite pavement (continuously reinforced concrete with 100 mm of HMA on top) on I-65 in Indiana[4,10]. The existing HMA overlay was severely deteriorated after six (6) years of service. The Indiana Department of Highways placed a test section consisting of 50 mm binder course mixture with a 50 mm surface mixture (with and without fibre reinforcement) to determine the benefit. Approximately 472 m of polypropylene fibre reinforced mixture (0.3 percent fibre by total mix weight or about 454g per ton (0.9 metric tonne) of mix) was placed while the remaining portion of the project served as the control section. After 2.5 years of service, the control section exhibited twice the cracking than observed in the fibre section. In addition, the severity of the cracks in the control section were more intense (moderate and high, 6 to 9.5 mm wide) as compared to the fibre section at 0.8 mm crack width. In terms of rutting resistance, the control section had severe rutting (as deep as 57 mm) while the fibre section was all less than 9.5 mm deep.

In the 1980's Pennsylvania started to see excessive rutting in their heavy-duty pavements[11]. A task force was assembled to discuss options (gradation changes, volumetric changes, construction changes, aggregate quality changes). One of these options was several types of binder modification techniques. A test project was conducted on I-80 in Clearfield County from mile marker 120 to 128 in 1989. This was an overlay (75 mm base mix, 63.5 mm binder course, and 38 mm surface mix) on an existing conventional jointed Portland cement concrete pavement. The base asphalt was an AC-20 (a PG 64-22 today in today's binder specification) with six experimental sections with various modifiers that included polyethylene, ethylene vinyl acetate, polyester fibres, SB-reacted, Gilsonite, and SBS 4141. After ten years of service, the fibre-modified and elastomer modified mixtures were in excellent condition with little to no secondary cracking at the sawn joints with little raveling and minimal rutting[11].

Around 1990, the Strategic Highway Research Program (SHRP) was implementing binder specifications. Indiana Department of Transportation conducted a field trial to look at various asphalt modification techniques, one of them being synthetic fibres. The field trial was conducted in September of 1990 on I-465 (ring road) around Indianapolis[12]. This stretch of road would see 150,000 vehicles per day with 30 percent trucks. Paving was completed in September of 1990. The existing pavement was Portland cement concrete (PCC). Three (3) lifts of HMA were placed on top of the PCC. The base asphalt used was an AC-20. For additional details on the project and test sections, see McDaniel et al[12]. Over the course of eleven (11) years, pavement surveys were conducted. The following information that was collected was rut depth, transverse cracking, and longitudinal cracking. Table 2 shows the rutting summary and Table 3 shows the cracking summary. The rutting values vary from year to year due to slight differences in measurement location. It is important to note that the rutting is quite minimal, i.e.

only 1.6 mm (1/16th in) of rutting or less has occurred in each test section after 11 years. These are abbreviated tables to show comparisons of the control mixture (AC-20), polymer modified mixture (PAC20), and fibre modified mixture. In terms of rutting resistance, the fibre and polymer modified mixture were comparable to the control. Where you see increased performance is in the cracking resistance of the fibre and polymer modified mixtures; particularly in later years (1996 and 2001). By 2001 the control mixture was overlaid, whereas the polymer and fibre modified mixtures were still performing satisfactorily.

Table 2. *Pavement Condition Survey - Rutting Summary*[12]

Section	Rut Depth in 1/16th of an inch			
	Left 1993	Right 1993	Left 1996	Right 1996
A – Control	1.0	0.8	0.3	0.9
B – PAC20	1.0	0.4	0.4	0.5
C – Fibre	0.8	0.2	0.2	0.8

Table 3. *Pavement Condition Survey - Cracking Summary*[12]

Section	Sum Transverse Cracking, (lineal ft)			Sum Longitudinal Cracking, (lineal ft)		
	1993	1996	2001	1993	1996	2001
A – Control	174	416	NA[3]	142	507	NA
C – Fibre[1]	144	150	178	30	70	370
B – PAC20[2]	24	87	186	15	198	665

[1] Polyester fibre supplied by BoniFibres.

[2] PAC20 Sulfur cross-linked SBS (Styrelf) supplied by Koch Materials.

[3] NA = not available, section overlaid.

Another important study was conducted in 2002 and finished in 2008[13]. This occurred at the Federal Highway Administration (FHWA) accelerated loading facility (ALF). This study looked at various asphalt modification techniques. Multiple test sections were designed and constructed to look at permanent deformation and fatigue cracking. The permanent deformation test sections were tested at 64°C with a 44-kN wheel load and 689-kPa tire pressure. The fatigue test sections were tested at 19°C with a 71-kN wheel load and 827-kPa tire pressure. Both the permanent deformation and fatigue test sections included wheel wander as part of the experiment. The styrene-butadiene-styrene linear grafted (SBS-LG) and fibre modified mixture behaved similar in terms of resistance to permanent deformation initially, up to approximately 30,000 cycles. At 64°C, the fibre section went to just approximately 120,000 cycles until failure whereas the control and SBS-LG section were terminated at approximately 50,000 cycles (12 mm rut depth). At 74°C both the SBS-LG and fibre section went to 100,000 cycles until the test was terminated (12 mm rut depth). The fibre modified mixture not only outperformed the control mixture in total cracking by eight times (8x), but it outperformed by SBS-LG test section by 1.5x. This set of data shows the benefit of the fibre in mitigating and bridging cracks thus providing a mixture that can extend the life of a pavement.

An aramid fibre demonstration project was conducted on State Route 3036 in Lancaster County Pennsylvania in 2011[14]. Two test sections were constructed; with and without aramid fibre to quantify performance. The mixtures were designed identically using the Superpave gyratory compactor except one mixture used aramid fibre and the other did not. In July 2015 the performance of the pavement was quantified using ASTM D6433, Standard Practice for Roads and Parking Lots Pavement Condition Index

Surveys to calculate the pavement condition index (PCI). After 4 years of in-service pavement life, the control section had a PCI of 69.08 while the aramid fibre section had a PCI of 93.46[14]. The aramid fibres appear to be extending the service life of the existing road by nearly 5 years.

A demonstration project in a cold weather region was paved in Dickinson County, which is located in the Upper Peninsula of Michigan in October 2018[15]. Two mixtures were placed; a control mixture and a fibre modified mixture to quantify the field application and the performance (field and laboratory). The mixtures were designed identically using the Superpave gyratory compactor except one mixture used aramid fibre and the other did not. No differences in the volumetric properties were seen and there was no absorption of the asphalt into the aramid fiber. The pavement condition was assessed before construction and after one year, two years, and three years of service. After two years, minimal cracking was observed in the control mixture while no cracking was observed in the fibre section[14].

Advanced Pavement Condition Index (PCI) Rating

Recently, a deep machine learning approach was developed and implemented to predict pavement condition index (PCI) of asphalt surfaced roadways[16, 17, 18], also known as a smart pavement monitoring (SPM) algorithm. The approach uses a combination of you look only once (YOLO) and U-net deep learning models to automatically classify and quantify the severity of distresses in pavement images. The output of the models is used to develop a comprehensive pavement condition tool that rates each pavement image according to the type and severity of distress extracted. This technology uses a video camera mounted on a vehicle and driven at highway speeds to capture the images of the pavement. Historically, pavement distress surveys have been performed using complex collection vehicles, often combined with boots-on-the-ground surveys for verification/validation. This technology is useful from two aspects; safety and bias through human judgement. The images are captured via a camera and the YOLO and U-Net deep learning framework is used to train the model. The distress classification can be checked to ensure the model correctly identified the distress. the proposed approach is a promising new method for developing PCIs. This new approach can automate the PCI assessment process, which can save time and money. Additionally, the approach is more accurate and robust than traditional PCI methods. Additional information on the SPM technology can be seen in Buttlar et al. 2023[17].

Blankenship Asphalt Tech and Training (BATT) Vision pavement imaging system includes a high-resolution 360-degree camera, high-definition action camera, a GPS unit tied to the video, and accelerometers to capture pavement roughness. The video frames is labeled with GPS information, which is processed by Tiger Eye Engineering (TEE) software to extract images at specified intervals to remove duplication and to cover the pavement network continuously at a spacing of 5 feet (Figure 1). The Insta 360 camera is used to collect a 360-street image like Google Street View to allow viewing of the local area as it relates to the pavement distress.

Figure 2. Video Data Collection System

Pavement condition assessment provides critically needed information allowing owner-agencies to make more cost-effective and consistent decisions as they manage their network of urban and/or rural pavements. Generally, pavement distress inspections are performed using sophisticated data collection vehicles and/or very limited foot-on-ground surveys. In either approach, the process of distress detection is sub-optimal, as it inherently contains human bias, is very costly and can be inefficient, and can introduce on-site inspector safety risks. TEE automated pavement evaluation software suite was developed by coding and integrating several machine learning and deep learning techniques for distress detection and pavement condition assessment (Figures 2). Examples of detections from 28 distinct distress types on both flexible and rigid pavement are displayed. The AI models have annotated the images, indicating the type and extent of each distress. (Figure 3).

Figure 3. Application of AI to Detect Type, Extent and Severity of Distresses

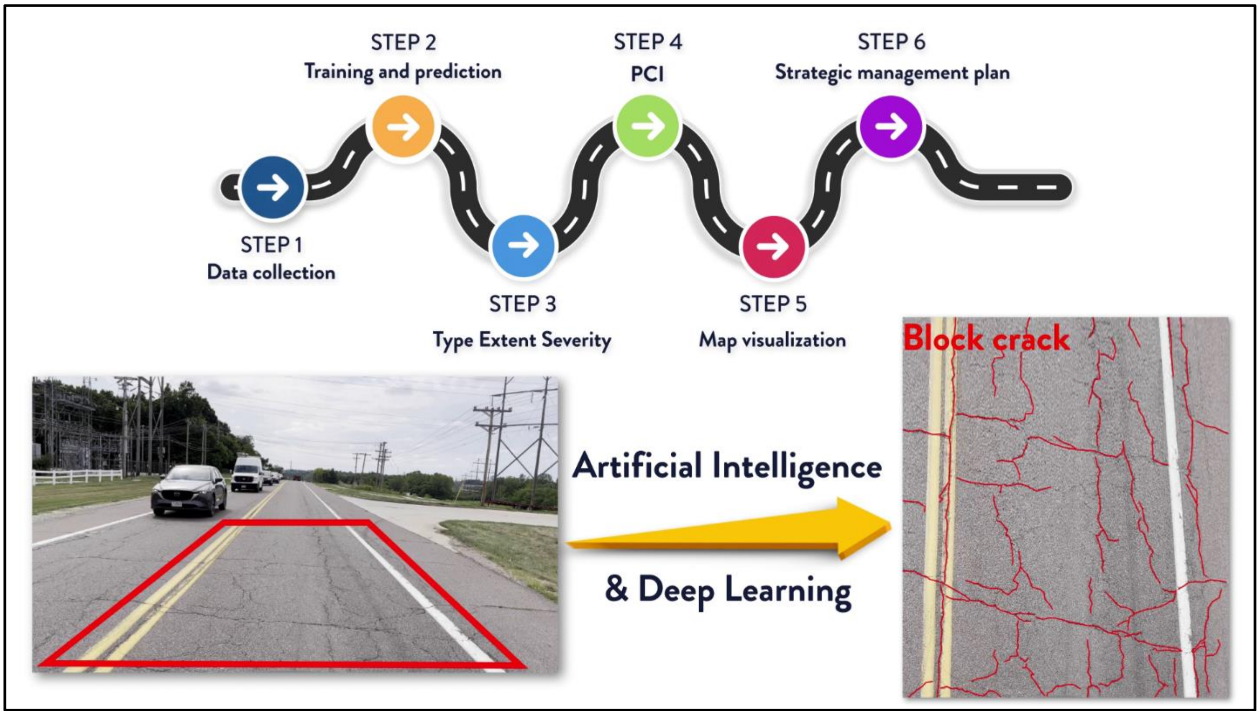
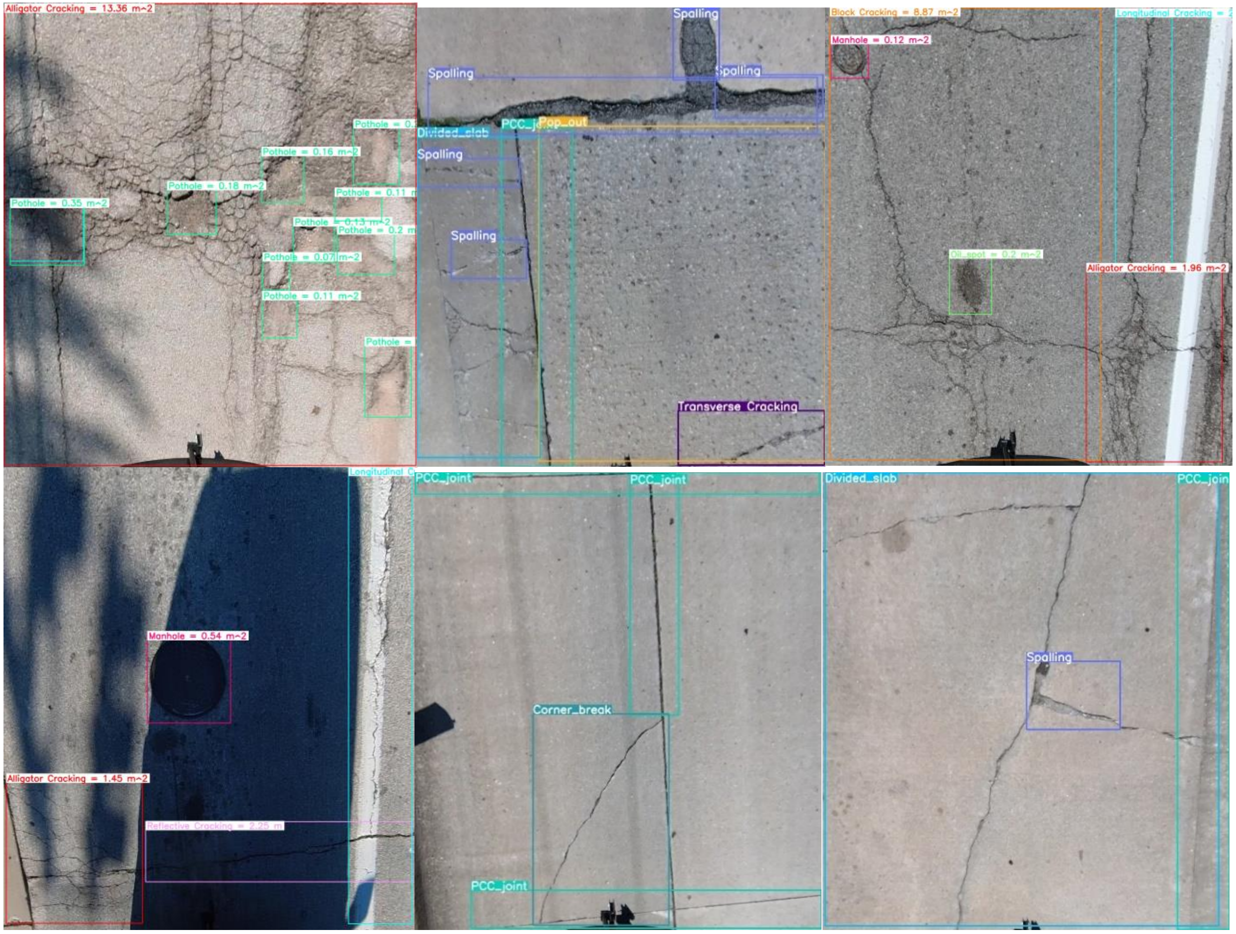
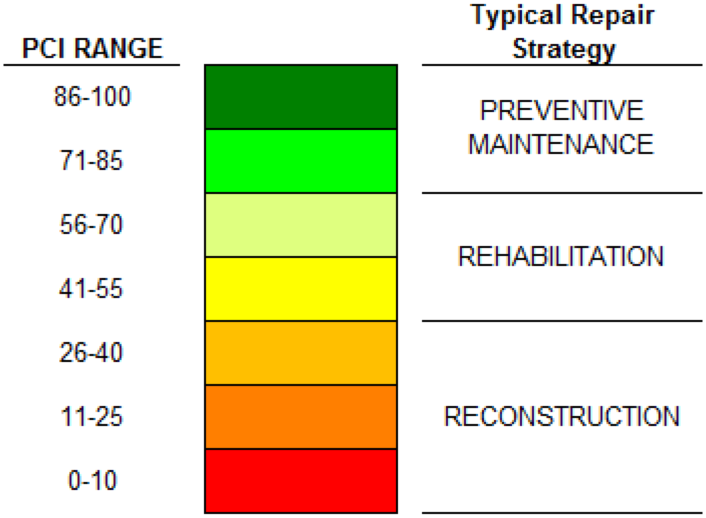


Figure 4. Representative Images and Automated Distress Detection Results for Flexible and Rigid Pavement (Generic photos not representative of from this project)



Pavements are divided into sections such as streets, direction, and/or test sections. Through the automated and consistent AI-based pavement evaluation, pavement distress types are assigned a severity and density (quantity in relation to the section measured). The PCI is then calculated using standardized equations. PCI is represented on a scale ranging from 0 to 100, where higher values signify a superior condition of the pavement. The ASTM standard defines these ranges where treatment type is subjective to the pavement owner (Figure 5).

Figure 5. Pavement Condition Index (PCI) Scale and Potential Strategy



PCI RANGE		Typical Repair Strategy
86-100	🟩	PREVENTIVE MAINTENANCE
71-85	🟩	
56-70	🟨	REHABILITATION
41-55	🟨	
26-40	🟧	RECONSTRUCTION
11-25	🟧	
0-10	🟥	

Study Objectives

The objective of this paper is to show modern, recent research on the performance of aramid fibre asphalt concrete mixtures in terms of short term and long-term field performance. In all pavement sections, the aramid fibre will be compared to a control test section. In this case, the mixture design for the control section is the same as the aramid fibre mixture except for no fibre in the control mixture (i.e. same optimum asphalt binder content). Field performance is quantified using a manual distress survey (lineal feet of cracking) and an automated approach using the advanced pavement condition index (PCI) method that is briefly described above. The PCI is a numerical indicator that rates the surface condition of the pavement based on the severity and extent of the observed distresses. It provides an objective and rational basis for determining maintenance and repair needs and priorities.

Field Projects

The following sections will discuss more recent field performance on the use of aramid fibre reinforced asphalt concrete relative to a control section. PCI data was not gathered before the construction of the projects. While manual transverse crack counts (ignoring the longitudinal construction joint) were performed annually, full section video PCI data was not gathered until 2023. The PCI was to supplement the manual crack counts and add consistency in the measurements.

Beckley Station (East Louisville, Kentucky)

The first aramid fibre project placed in Kentucky was on Beckley Station Road in 2015. The city wanted to evaluate the use of aramid fibre to reduce cracking on this lower volume road. The aramid fibre section was constructed as a typical mill and fill process with approximately a 50 mm overlay. The overlay is usually 12 mm of a leveling course and 38 mm of a final surface. Aramid fibre was dosed at 65.6 g per tonne of mixture into a PG 64-22, 9.5 mm NMAS asphalt mixture. The control section was built the following year, adjacent to the 2015 project. The results of this road are shown in Table 4. Note the control section that is 1 year newer than the control has a PCI of 74 as compared to fibre section with a PCI of 82.5.

Table 4. Beckley Station Field Performance

Road (Location with Year Constructed	Control – 2023 PCI	Fibre – 2023 PCI
Beckley Station (East Louisville, Kentucky, 2015)	74	82.5

Dixie Highway (Louisville, Kentucky)

The existing pavement for this project was a 180 mm thick Portland cement concrete (PCC) pavement that the Kentucky Transportation Cabinet (KYTC) chose to evaluate the use of aramid fibres to mitigate reflective cracking. The control section consisted of a 25-mm leveling course followed by 76 mm of base mix followed by a 32-mm surface mix. The aramid fibre section had the same cross-section but used 65.6 g per metric tonne mixture. The aramid fibre pavement was 1.8-km long and placed in the north bound direction while the control mixture was 1.7 km long and placed in the south bound lane. Paving was completed in 2016. Traffic for this pavement had an average annual daily traffic of 27,400 vehicles with the percent trucks being 12.4. Figure 6 shows a manual survey of lineal feet of cracking versus time. The data shows how the use of aramid fibre delays the onset of cracking compared to the control section (no fibre). The predominate mode of distress for this pavement is reflective cracking because this was an overlay on a PCC pavement. Table 5 shows the field performance for the aramid fibre section and the control section after eight years of service. After eight years, the aramid fibre section has significantly outperformed the control section Figure 6.

Figure 6. Manual Survey of Lineal Feet of Transverse/Reflective Cracking vs Time for Dixie Highway

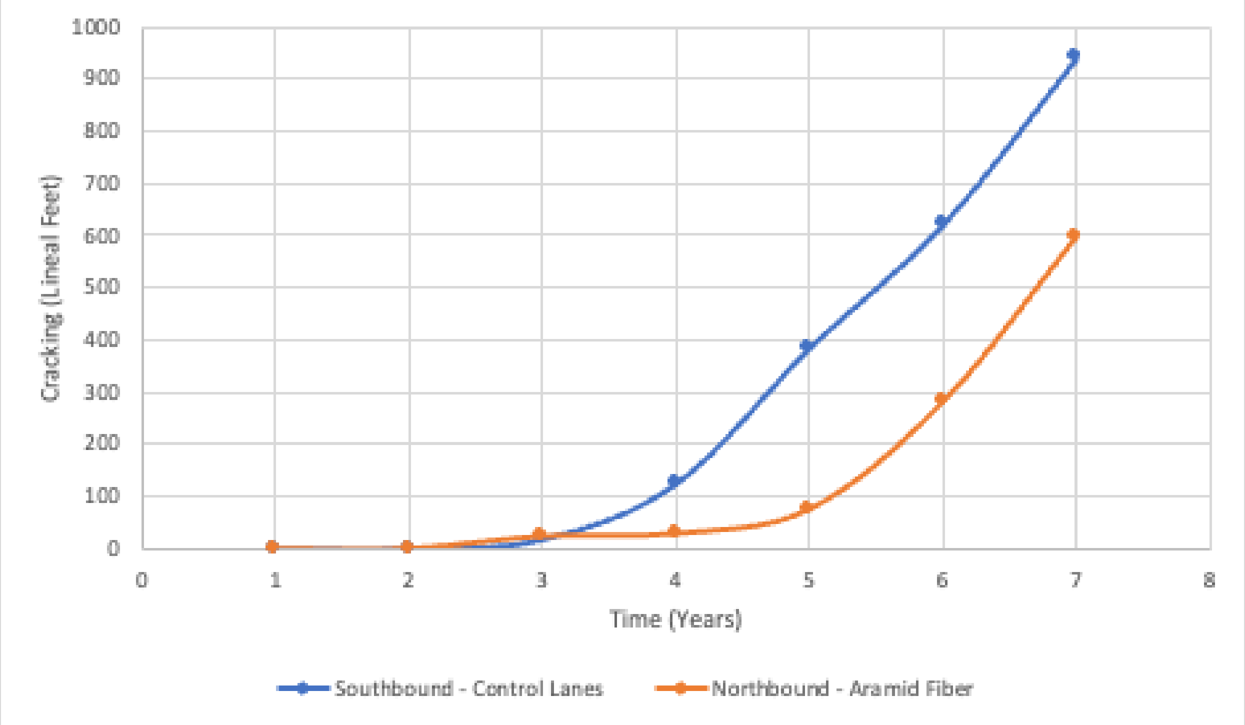


Table 5. Dixie Highway Field Performance

Road (Location with Year Constructed	Control – 2023 PCI	Fibre – 2023 PCI
Dixie Highway (West Louisville, Kentucky, 2015)	83	83.5

Stafford Road (Plainfield, Indiana)

The Stafford Road project was constructed in the fall of 2018 for the City of Plainfield, Indiana. The city wanted to evaluate technologies to control cracking on a 4-lane industrial road to access the Indianapolis International Airport (Indiana). The control section utilized a PG 76-22 polymer modified asphalt and the treatment section utilized a PG 76-22 polymer modified asphalt with aramid fibre at a dosage rate of 65.6 g per metric tonne of mixture. The rehabilitation technique used was a 50-mm mill and fill. Figure 7 shows a manual survey of lineal feet of cracking versus time. The data shows how the use of aramid fibre delays the onset of cracking compared to the control section (no fibre). On this pavement, the use of aramid fibre has greatly extended the pavement compared to the control. Table 6 shows the field performance for the aramid fibre section and the control section after five years of service. After five years, the aramid fibre section has outperformed the control section by approximately 5%. This technology met the expectations of the city in reducing cracking on their pavements.

Figure 7. Manual Survey of Lineal Feet of Transverse Cracking vs Time for Stafford Road

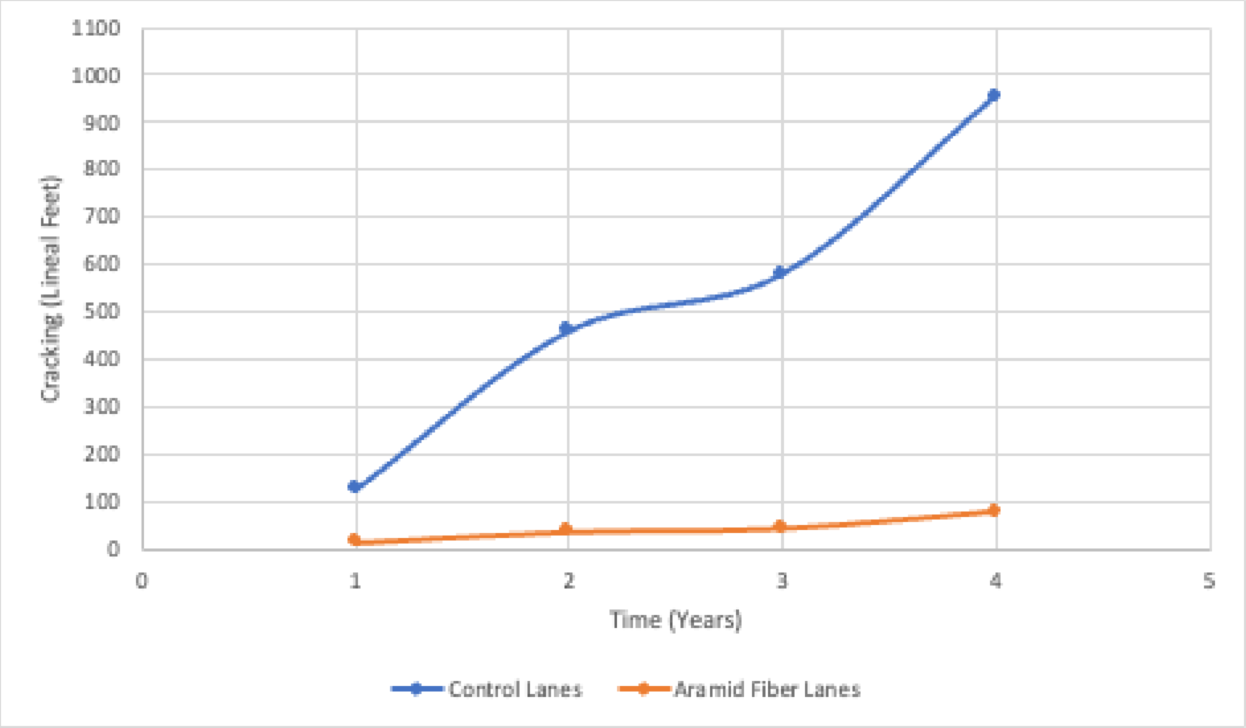


Table 6. Stafford Road Field Performance

Road (Location with Year Constructed	Control – 2023 PCI	Fibre – 2023 PCI
Stafford Lane (Plainfield, Indiana, 2018)	84.5	89

Mercer Road (Lexington, Kentucky)

The Mercer Road project was constructed in the fall of 2020 for the City of Lexington, Kentucky. The Lexington Fayette County Urban Government (LFCUG) wanted to evaluate technologies to allow more recycled asphalt pavement (RAP) without sacrificing pavement performance. The 2-lane road is an industrial access for the Lexington Bluegrass Kentucky airport. The control section utilized a PG 76-22 polymer modified asphalt with 20% RAP and the treatment section utilized a PG 64-22 asphalt with 45% RAP plus a bio-based recycling agent with a double dose of aramid fibre at a dosage rate of 131.2 g per metric tonne of mixture. This dosage was double (2x) as compared to the previously mentioned projects. The "green" based mixture allowed for a CO_2 reduction of approximately 30% as calculated using the publicly available National Asphalt Pavement Association (NAPA) spreadsheet for hot mix producers. The rehabilitation technique used was a 50-mm mill and fill. Table 9 shows the field performance for the aramid fibre section and the control section after three years of service. After three years, the aramid fibre section has outperformed the control section by approximately 8%. This technology met the expectations of the city in reducing cracking on their pavements.

Table 7. Mercer Road Field Performance

Road (Location with Year Constructed	Control – 2023 PCI	Fibre – 2023 PCI
Mercer Road (Lexington, Kentucky, 2020)	89	96

Man O' War Boulevard (Lexington, Kentucky)

As with any pavement design project, certain design considerations should be investigated for durable and sustainable pavements such as traffic loading, environmental conditions, subgrade properties, and existing pavement condition. ATS Construction was awarded a project to provide asphalt mixture on Man O' War Boulevard. in Lexington, Kentucky in the summer of 2020 (Figure 8).

Figure 8. Project Location

The project consisted of two components:

- The first area of the project was to replace the 254-mm thick Portland cement concrete (PCC) intersections with 254-mm of asphalt concrete. Table 8 shows the thickness of each layer that was utilized at the intersection. Aramid fibre at a dosage rate of 65.6 g per metric tonne of mixture was used in the base asphalt layer, intermediate asphalt layer, and surface asphalt layer.

Table 8. Intersection Layer Thickness

Layer	Thickness (mm)
3/8” NMAS[1] PG76-22 with 20% RAP[2]	50.8
1” NMAS PG 76-22 with 20% RAP	88.9 to 101.6
1” NMAS PG 58-28 with 30% RAP	101.6 to 114.3
Dense Graded Aggregate Base	152.4
Geo-Grid	N/A
Subgrade	Semi-infinite.

[1] Nominal Maximum Aggregate Size
[2] Recycled Asphalt Pavement

- The second area of the project consisted of milling 50.8-mm of the surface of the pavement (mainline), adding a 6.35-mm to 19.1-mm leveling mix and using a 9.5-mm NMAS PG 76-22 plus 20% RAP with and without aramid fibres.

Various paving sections were constructed on this project as shown in
Falling Weight Deflectometer (FWD) testing was performed on November 21, 2021 (approximately 1 year after construction), in the northbound and southbound lanes of Man O’War Boulevard. Each direction has two lanes with additional partial lanes for left and right turns. The pavement was also cored to verify the thickness of the intersection and mainline pavement. FWD tests were conducted only in the left lane (inside lane) in each direction. Tests were conducted at approximately every 25.4-cm in the full depth asphalt sections (i.e., the intersections) and approximately every 15.2-m in the mill and overlay sections. S&ME utilized a Dynatest Fast FWD (Model 8012, Serial Number 8012-014) calibrated by Dynatest in November 2021. The testing procedure included two seating drops followed by two loading drops targeting 3,900 MPa contact pressure under the FWD plate, or approximately 40 kN impact load in the center of the plate. Two FWD geophones located at 0, 20, 31, 46, 61, 91, 122, 152, and 183-cm from the center of the FWD plate were utilized to measure the deflection. The FWD deflection data was used to back calculate the asphalt pavement, Dense Graded Aggregate (DGA), and reinforced subgrade moduli at a test temperature of 6ºC (as measured on the surface). Back calculation was performed following North Carolina’s Department of Transportation’s (NCDOT) design guide method for moduli and overlay calculations that are based on the AASHTO 1993 method for pavement design.
Additional data and details on the analysis can be found in Blankenship et al. 2025. The full depth aramid fibre sections have an effective structural number (SN_{eff}) of 6.4 compared to the mill and overlay cross sections which have a SN of 5.3. The impact of the improved modulus on the SN_{eff} of the pavement cross section is approximately a 20 percent improvement (i.e., larger structural number based on AASHTO ’93). This project demonstrates the improved modulus and structural capacity (structural number) if aramid fibre is used in all asphalt pavement layers.
Figure 9. A total of three pavement sections were constructed on this project. The first section is PG 76-22 with aramid fibre (65.6 g per metric tonne of mixture) in the 9.5-mm NMAS surface mixture. The second section is the PG76-22 with no aramid fibre (i.e. control section). The third section (i.e. the

intersections) would be the full depth aramid fibre mixtures dosed at 65.6 g per metric tonne of mixture in each layer.

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Figure 9. Mixture Types Used on the Project

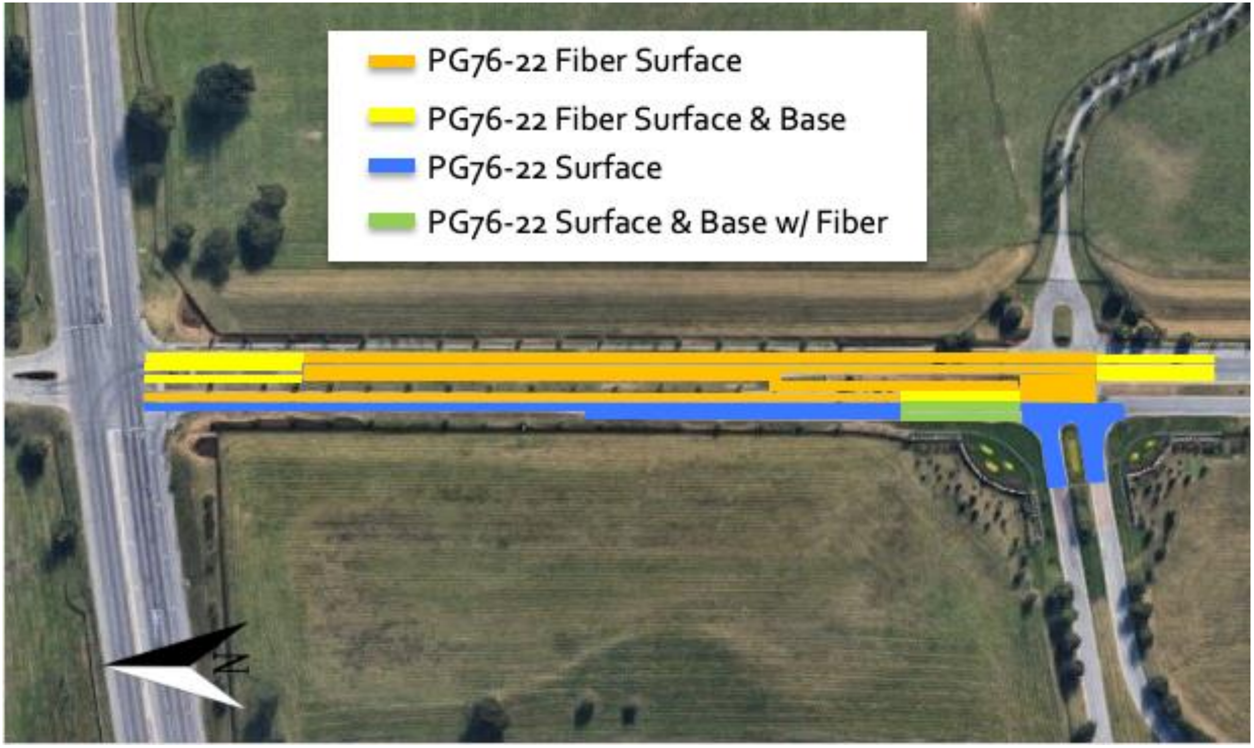


Table 9 shows the field performance for the aramid fibre section and the control section after four years of service. After four years, the aramid fibre and control section have equal performance. Even though performance is similar, the aramid fibre section does show improved structural capacity based on the FWD testing.

Table 9. Man O' War Boulevard Field Performance

Road (Location with Year Constructed	**Control – 2023 PCI**	**Fibre – 2023 PCI**
Man O' War Boulevard (Lexington, Kentucky, 2020)	92	92

National Center for Asphalt Technology (NCAT) Test Track (Opelika, Alabama)

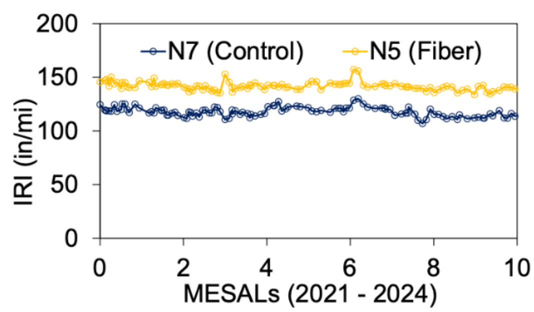
The additive group (AG) experiment was part of the Phase VIII (2021-2024) NCAT test track. This experiment evaluated a limited set of asphalt mixture additives that were selected by highway agency sponsors through laboratory testing, pavement modeling, environmental assessments and accelerated field performance testing[20]. The additives that were evaluated in this experiment were ground tire rubber (GTR), recycled plastics, and aramid fibre. Each additive was added to the same dense-graded asphalt mixture without changing the asphalt binder content or the gradation of the asphalt mixture. The control mixture was simply the same mixture without any additive. The recommended dosage rate for this aramid fibre is 65.6 g per metric tonne of mixture. West et al[20] details the balanced mix design test results and advanced mixture characterization tests that were used for the structural analysis to predict pavement performance. Because the focus of this paper is on field performance, refer to West et al[20] for additional data on the mixture characterization and structural analysis. The control mixture was test section N7 and used 3% SBS in a virgin base asphalt (PG 67-22) which graded out to a PG 76-22. N5 was the aramid fibre test section and that used the same 3% SBS in a virgin base asphalt which graded as a PG 76-22, but this section used a single fibre dosage rate (65.6 g/mix tonne). Test sections were paved in September 2021 at similar temperatures (165°C). Table 10 shows the as-built cross section for N7 and N5. Both test sections are similar in total pavement thickness and meet the target that selected for this study.

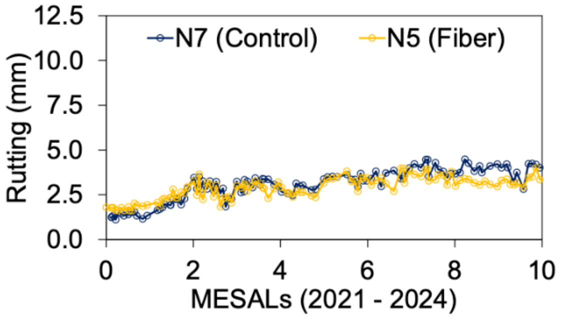
Table 10. NCAT N5 Pavement Cross-Section – As-Built

	N7 Control Mixture	N5 Aramid Fibre	Target
Surface (mm)	144.3	142.2	139.7
Aggregate Base (inches)	152.1	151.9	152.4
Avg. in-place density (%)	95.9	94.2	>93.0

After 3 years of traffic (10,000,000 equivalent single axle loads (ESAL's)) and environmental loading, both test sections are performing the same. As shown in Figure 10, IRI is approximately constant over the three years of traffic loading. No increase in IRI was shown. Both the control and fibre test section show a slight increase in rutting over three years, but rutting was well below the 12.5 mm threshold. No cracking was observed in either test section after 10,000,000. This section will remain in place and be trafficked for another 3 years.

Figure 10. NCAT N5 vs N7 Field Performance[18]





No Cracking

Conclusions

This paper provides a brief introduction of synthetic fibre inclusion in and past field studies that quantify positive field performance. Next, more modern, synthetic fibre, aramid, is discussed and evaluated. Aramid fibre represents a class of fibre that is stronger and more heat resistant than the early synthetic fibre making it ideal for use in hot mix asphalt applications to provide tensile reinforcement.

This paper shows cases several field studies that compare the performance of aramid fibre pavement sections versus a control pavement section. Two methods were used to characterize the field performance:

1. Manual survey that measures lineal feet (meters) of cracking and,
2. Automated distress survey utilizing the ASTM PCI method to quantify pavement condition

As measured by manual and automated distress surveys, aramid fibre sections are outperforming the control sections with the most significant deviation in the early life of the project and on older projects up to eight years old. The improvement in pavement performance should lead to pavement life extension where the control sections will need to be treated years before the aramid fibre sections. The field studies are in agreement with previous research(10-14) that have shown that the use of aramid fibres delays the onset of cracking and extends the pavement life.

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