Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 2 (1968)

Artikel: American experiences with thick pavements on orthotropic steel deck bridges

Autor: Fondriest, F.F.

DOI: https://doi.org/10.5169/seals-3972

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Mehr erfahren

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. En savoir plus

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. Find out more

Download PDF: 02.04.2026

ETH-Bibliothek Zürich, E-Periodica, https://www.e-periodica.ch

AMERICAN EXPERIENCES WITH THICK PAVEMENTS ON ORTHOTROPIC STEEL DECK BRIDGES

Expériences faites en Amérique avec les revêtements épais sur ponts à tablier orthotrope

Erfahrungen mit dicken Belägen auf orthotropen Brücken in Amerika

F.F. FONDRIEST

INTRODUCTION

The use of orthotropic steel deck bridges on the American Continent did not come until 10 or 15 years after developments in Europe. It was quite natural then that many of the construction methods and materials used would closely follow those used in Germany and elsewhere. The problems with the wearing surface were somewhat unusual, however, because of basic differences in asphalt concrete made in the United States and Canada as compared to the mastic asphalts used in Europe. Experience with paving materials other than asphalt was quite limited and not considered appropriate without a previous performance history. Despite anticipated problems, it was nonetheless the opinion of many American designers that a smooth and durable pavement could best be provided by an asphalt wearing surface with a thickness of 1-1/2 to 3 inches (3.75 to 7.5 cm). In some cases attempts were made to modify the properties of the asphalt with additives. In essentially all cases, special measures were taken to provide a good bond between the pavement and the steel deck.

This report will attempt to briefly describe (1) the paving materials and procedures used on bridges on the American Continent, (2) the performance of these pavements to date and (3) a discussion of limited laboratory studies which relate to the observed performance.

BRIDGES IN SERVICE

There are presently nine orthotropic bridges on the American Continent which are wholly or partially paved with thick wearing surfaces. Table 1 gives a summary of the paving details on these bridges.

Of particular importance to this discussion are the details of the bond coat used to anchor the pavement to the deck plate. In all cases where a bond coat was used, crushed stone chips were broadcast over the surface of the epoxy while still tacky. The purpose was to form a mechanical anchor between the protruding stone chips and the pavement. A variety of quantities and sizes of stone chips have been used for this purpose. Table 2 gives a summary of the bonding details used.

Service Performance

Of the nine bridges listed, three have been in service for less than one year with a fourth subjected to traffic only slightly longer than a year. All of these bridges have been inspected within the last three months and no damage or defects were observed. It is expected that at least another year will be required before any comments may be made about the performance of the pavements on these bridges. The remaining five bridges have been subjected to approximately 3 or more years of service and ample evidence is available to assess their suitability. The following is a brief description of the observed perfomance of each of these bridges.

Port Mann Bridge -- After more than 4 years under heavy traffic, the condition of the pavement must be considered excellent. The only noticeable defect observed was some slight unevenness.over a few of the splice plates after about 2 years in service. This condition is shown in Figure 1. A more recent inspection (after four years) indicated that transverse cracks may be forming at a few of these locations although there are none yet visible to the unaided eye. One such location is shown in Figure 2.

TABLE 1. DETAILS OF THICK PAVEMENTS ON ORTHOTROPIC BRIDGES ON THE AMERICAN CONTINENT

		Surfacing Details				
Bridge	Date In Service	Prime Coat	Bond Coat	Leveling Course	Wearing Course	Remarks
Port Mann	June, 1964	Red Lead Epoxy	Coal Tar Epoxy	3/4" SA(1)	1-1/4" AC(2)	
Humphreys Creek	July, 1964	None	Coal Tar Epoxy	1" AC	1" AC	E half
	July, 1964	None	Coal Tar Epoxy	1" AC-L(3)	1" AC-L	W half
Ulatis Creek	Sept.,1965	Inorganic Zinc	None	None	1-1/4" AC	1/5 section
	Sept.,1965	Inorganic Zinc	None	None	1-1/4" EAC(4)	1/5 section
Concordia	Aug., 1965	None	Coal Tar Epoxy	None	2" AC	
Dublin	Dec., 1965	Zinc Metallizing	Coal Tar Epoxy	None	2" AC	1/4 section
	Dec., 1965	None	Coal Tar Epoxy	None	2" AC	1/4 section
Battle Creek	May, 1967	None	Coal Tar Epoxy	None	1-3/4" AC	E half
San Mateo	Nov., 1967	Inorganic Zinc	None	3/4" EAC	3/4" EAC	
Poplar Street	Nov., 1967	Inorganic Zinc	Coal Tar Epoxy	1-1/4" AC-L	1-1/4" AC-L	
Longs Creek	Dec., 1967	Inorganic Zinc	Fiber Glass(5)	None	1-1/2" AC	

(1) SA = sand or sheet asphalt.

(2) AC = asphalt concrete.

(3) AC-L = rubber latex modified asphalt concrete.

(4) EAC = epoxy asphalt concrete.

(5) Fiber glass impregnated with asphalt emulsion and sealed with mastic asphalt.

TABLE 2. SUMMARY OF SYSTEMS USED TO ANCHOR BITUMINOUS PAVEMENTS TO STEEL DECK BRIDGES

Bridge	Primer lbs/yd^2	Chips lbs/yd^2	Gradation - percent passing										Leveling Course
			3/4"	1/2"	3/8"	1/4"	#4	#6	#10	#16	#20	#30	
Troy(1)	1.0	15-18										100	AC & SA
Port Mann	2.8	7.5					100			0			SA
Humphreys Creek	1.85	4						100			10	0	AC & AC-L
Ulatis Creek	None	None											AC
Concordia	2.5	2.5					100	50					AC
Dublin	6.6(2)	7.5(3)	100	0									AC
Battle Creek	2.5(3)	10(3)				100			0				AC
Poplar Street	1.0	5-8			100		90		10	5			AC-L

(1) *Small test bridge used to evaluate pavements for the Poplar Street Bridge.*

(2) Applied in two equal coats before and after chips were applied.

(3) Estimated.

FIGURE 1. SLIGHT UNEVENESS IN THE SURFACE COURSE OVER THE SPLICE PLATES ON THE PORT MANN BRIDGE AFTER 2-1/2 YEARS IN SERVICE

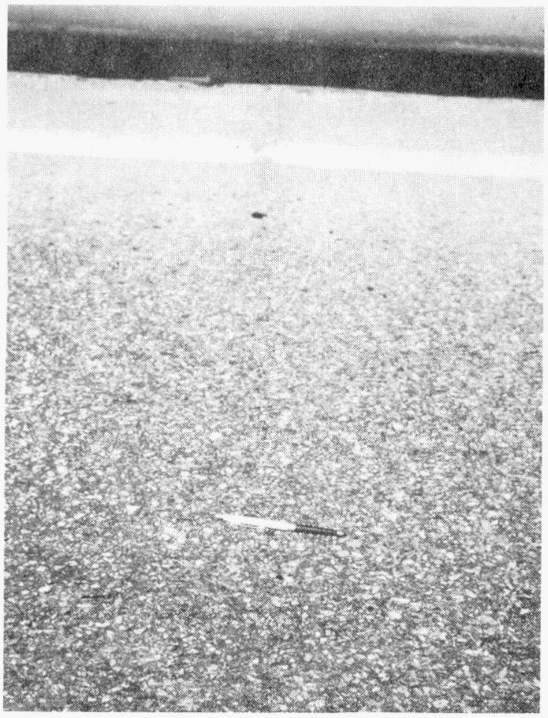

FIGURE 2. EVIDENCE OF A TRANSVERSE CRACK FORMING OVER THE SPLICE PLATES ON THE PORT MANN BRIDGE AFTER FOUR YEARS OF SERVICE

With the exception of these few isolated spots, no other defects such as longitudinal cracking or shoving and rutting were noted. It is expected that any cracks which may form over the splice plates will be noticeable within an additional year.

Humphreys Creek Bridge - Soon after this bridge was opened to traffic, several sections of the pavement were removed to correct minor structural deficiencies in the bridge. These sections could be removed only with great difficulty indicating excellent bond between the seal coat and the leveling course. The appearance of the underside of the pavement sections removed showed that the leveling course conformed well to the protruding stone chips of the bond coat.

The major portion of the pavement which has not been disturbed reamins in excellent condition with no cracking or other defects visible.

Ulatis Creek Bridge - Approximately three years ago, one lane of this bridge was paved with 1-1/4 inch (3 cm) of five experimental surfacing materials. Three of these materials were epoxy mortars (discussed in a separate report) while the two of interest here were asphalt concrete and epoxy asphalt concrete. In the case of the AC, only an emulsion tack coat was used to bond the pavement to the deck plate. For the epoxy asphalt, a tack coat of the epoxy binder was used.

Within a few weeks after being opened to traffic, random cracks appeared in the AC surfacing. Shortly thereafter the pavement began debonding and within three months was literally shoved off the bridge. The mode of failure can be seen in Figure 3. The AC was replaced again using only an emulsion tack coat to bond the pavement to the deck plate. Within nine months the new AC pavement had again failed in the same manner as before. The pavement was replaced a second time in the same manner. This third pavement has remained in place and is performing reasonably well after almost two more years of service.

After three years in service, the epoxy asphalt pavement is in excellent condition with no signs of cracking or other defects. Test cores taken from the pavement indicated a bond strength of over 200 psi (14 kg/cm^2).

Concordia Bridge - This bridge is located within the Exposition grounds in Montreal. Half of the bridge width is used for rail traffic while the other half has little traffic at this time. The bridge was however used for all construction traffic prior to the opening of Expo '67. An inspection of this bridge was made approximately two years after completion. Numerous longitudinal cracks were formed essentially over the entire length of the bridge as shown in Figure 4. The most severe crack (shown in the center of Figure 4) is located over the web of the supporting box girder while the finer cracks are located over the stiffening ribs where they are attached to the deck plate.

About the same time a small breakout occurred in the wearing course over a splice plate as shown in Figure 5. Although the damage is still relatively confined, the pavement adjacent to the breakout could be easily lifted up indicating essentially no bond to the deck plate. It is merely a matter of time before this defect increases in size.

Dublin Bridge - After about one year of service, an inspection of this bridge revealed transverse cracks over a pier and several longitudinal cracks in the pavement. The transverse cracks widened to about 1 in. (2.5 cm) in width after about a year when they were filled with a mastic. The longitudinal cracks were generally very slight with the most pronounced being located over a main support girder. Approximately a year after these cracks were first observed, the major cracks were still visible although most of the fine cracks, located over the ribs, closed up and were no longer visible. No other defects or indications of loss of bond were visible.

Analysis of Performance

Although there is as yet limited field performance, observations have pointed out two problem areas associated with thick asphalt pavements or steel deck bridges. These will be discussed separately below.

Bonding Mechanisms

The structural interaction between the deck plate and the wearing surface necessitates a strong bond. The reliance on a mechanical bond requires a careful match between the size and distribution of the stone chips and the coarseness of the leveling course as it is generally assumed that the bond is achieved by the interaction of the finer of the sand asphalt or AC which penetrates the interstices of the stone chips. If the leveling course mate-

FIGURE 3. MODE OF FAILURE DUE TO DEBONDING OF THE AC PAVEMENT ON THE ULATIS CREEK BRIDGE AFTER ONLY A FEW MONTHS IN SERVICE

FIGURE 4. LONGITUDINAL CRACKS IN THE ACPAVEMENT ON THE CONCORDIA BRIDGE AFTER TWO YEARS IN SERVICE

FIGRE 5. BREAKOUT OF WEARING COURSE OVER SPLICE PLATE ON CONCORDIA BRIDGE AFTER TWO YEARS OF SERVICE

rial lacks sufficient fines and/or the stone chips are too small, there will be no significant interlocking. If the stone chip gradation contains a high percentage of fines and the application rate is heavy, the interstices which would ordinarily be formed by the larger particles will be filled by the excess number of finer particles making any interaction difficult. Such a surface would provide horizontal shear resistance but would undoubtedly be low in tension bond.

As was shown in Table 2 there is a wide variation in the amount and gradation of aggregate chips used. The importance of an effective bond can be determined from the experience of the AC surfacing placed on a portion of the Ulatis Creek Bridge. In this installation, only an emulsion tack coat was used to provide bond between the deck and the pavement. This lack of bond resulted in a complete failure of the pavement. Another instance of a lack of good bond was noted on the Troy Test Bridge where a heavy loading of fine stone chips was used in conjunction with an AC leveling course. After about 2 years in service, moderate cracking had occurred in the surfacing and upon removal of the pavement, little or no bond was found between the seal coat and the asphalt pavement. There was, however, sufficient shear resistance to prevent the pavement from shoving. The only other instance where the bond between the bond coat and the pavement was qualitativly checked was on the Humphreys Creek Bridge. In this instance the bond was found to be excellent.

The relationship of bond strength and shear strength to the performance of the pavement is not known quantitatively, but undoubtedly both are important. No definite limits as to the gradation and rate of application of aggregate chips can be determined on the basis of present information but it appears that a number of systems will provide sufficient bond. The important factor appears to be the need to provide a careful match between the size and quantity of chips used and the consistency of the asphalt used in the leveling course. This intuitively implies that the coarser the asphalt material, the larger the stone chips need to be. The converse would undoubtedly hold true.

It should be pointed out that the epoxy asphalt material requires no stone chips to provide a mechanical bond to the deck plate as a tack coat of the binder provides an excellent bond strength by itself.

Cracking

Cracks have been observed in the wearing course of the Concordia and Dublin Bridges. On both of these bridges the most severe longitudinal cracks occurred over the main girder webs where high negative bending movements are produced. Transverse cracks occurred over a pier on the Dublin Bridge--also an area of high negative movements. Comparable points of high negative movements are not present on the Port Mann and Humphreys Creek Bridges where no surface cracks have been observed.

While the above explanation may account for the cracks over the griders it does not fully explain the cause of cracking over the stiffening ribs. It is known that AC is subject to fatigue cracking under continuous flexing but it is not known to what extent low bond strength may contribute to the cracking.

LABORATORY STUDIES

In conjunction with an extensive laboratory study on this wearing surfaces, occassional experiments were conducted on thick-wearing surfaces of asphalt concrete and epoxy asphalt. The experiments of greatest interest were bond strength and fatigue resistance.

Bond Strength

No real attempt was made to quantitatively determine the bond strength of AC to a steel plate because of the variations possible with differing amounts and size of stone chips. However a 1/2 x 4 x 16-inch (1.3 x 10 x 40 cm) steel plate was paved with a duplicate of the pavement used on the Troy Test Bridge (see Item 1 in Table 2). This plate, with a 1-1/4 inch (3.0 cm) AC surfacing was cooled to 0 F (-18 C), simply supported at the ends and loaded at midspan with the pavement on the tension side. The pavement sheared free of the steel plate at a length/deflection ratio of approximately 900. At 0 F (-18 C) the modulus of elasticity of AC may reach 1×10^6 psi (70,000 kg/cm^2) or more. With this stiffness, high shear stresses will be set up between the pavement and the deck plate. If loading produces deflections sufficient to destroy the bond, failure of the pavement will follow.

Similar experiments were carried out in which the bond was provided by a coal-tar fraction modified synthetic resin. In this case no shear failure occurred at a load/deflection ratio of 300 at temperatures of 0, 77, and 140 F (-18, 25, and 60 C). No failures were encountered in similar specimens using a 1-1/4-inch (3 cm) epoxy asphalt pavement bonded to the steel plate with a tack coat of pure asphalt epoxy binder.

Fatigue Resistance

A series of fatigue specimens were run to determine the maximum deflection a steel plate paved with 1-1/4 inches (3 cm) of AC or epoxy asphalt could withstand for 5×10^6 cycles without cracking. These experiments were conducted using 3/8 and 1/2 inch (10 and 14 mm) steel plates and conducting the experiments at 0 and 77 F (-18 and 25 C). The results of these experiments are given in Table 3.

Table 3. Span/Deflection Ratios Sustained Without Failure for Five Million Cycles

	Pavement Thickness	3/8 inch Steel Plate		1/2 inch Steel Plate	
Material	inches	0 F	77 F	0 F	77 F
AC	1-1/4	1340	1240	1400	1150
Epoxy Asphalt	1-1/4	<300	700	<300	770

Concluding Remarks

When considering even this limited laboratory data it becomes apparent that some of the failures observed in the field could have been anticipated. For relatively thin deck plates or where high deflections are expected, it is questionable whether AC as presently applied can ever be expected to withstand failure. The fatigue resistance at low temperatures is quite low and reliance upon mechanical methods of bonding to the steel deck appears to be unrealistic. Undoubtedly the flexibility or fatigue resistance of AC may be improved by changes in the mix design or by using additives but the greatest improvement will likely result by using more efficient bonding agents.

Both laboratory and field studies to date indicate that epoxy asphalt may be an excellent paving material for steel deck bridges having many of the combined advantages of asphalt concrete and epoxy mortars.

SUMMARY

There are nine orthotropic bridges on the American continent paved with thick wearing surfaces. The performance of these pavements after three or more years in service has been mixed. The primary problems encountered are fatigue cracking of asphalt concrete and low bond strength between the pavement and the steel deck. These problems could have been anticipated by a brief laboratory investigation.

RESUME

Actuellement, il y a sur le continent américain neufs ponts à tablier orthotrope couvert d'un revêtement épais. Dans les trois années de service ou plus, ils n'ont pas toujours donné satisfaction. Les défaillances principales étaient la formation de fissures de fatigue dans le béton asphaltique et l'adhésion insuffisante du revêtement. Quelques essais de laboratoire vite faits auraient pu prévoir ces difficultés.

ZUSAMMENFASSUNG

Zur Zeit gibt es auf diesem Kontinent neun orthotrope Brücken mit dicken Fahrbahnbelägen. Nach einer Beanspruchungszeit von drei oder mehr Jahren haben sich diese Decken nur teilweise bewährt. Die Hauptschwierigkeiten lagen in der Bildung von Ermüdungsrissen im Asphaltbeton sowie in der mangelnden Haftfestigkeit zwischen Belag und Stahldecke. Diesen Problemen hätte man durch kurze Laborversuche begegnen können.