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DISKUSSIONSBEITRAG
ZUM THEMA III (DÜNNE FAHRBAHNBELÄGE)

Contribution to the discussion
on Theme III (Thin Wearing Surfaces)

Contribution à la discussion
relative au Thème III (Revêtements minces)

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1. Allgemeines

In seiner abschließenden Bewertung der dünnen Fahrbahnbeläge faßt Mr. Elliott das Ergebnis seiner Erhebungen mit den Worten zusammen: "Der ideale Belag mit geringer Schichtstärke muß jedenfalls erst noch entdeckt werden".

Wenn ich aus deutscher Sicht nachfolgend noch einiges zu diesem Thema beitrage, so sei sogleich am Anfang klar ausgesprochen, daß auch wir leider zur Zeit keine bessere Zwischenbilanz aufzuweisen haben als der Herr Vorberichter. Trotzdem möchte ich über die bei uns in der Zwischenzeit noch angestellten Bemühungen berichten, die zur Findung eines brauchbaren, einigermaßen dauerhaften Belages von wenigen Millimetern Dicke führen sollen.

Die in Deutschland durchgeführten Beobachtungen gehen auf die Initiative des Bundesverkehrsministeriums zurück und nahmen bereits gegen Mitte des vergangenen Jahrzehnts ihren Anfang, als es sich darum handelte, die Klappbrücke über die Eider bei Friedrichstadt, im Zuge der Bundesstraße 5, mit einem geeigneten Fahrbahnbelag zu versehen.

Schon etwas früher hatte man sich bei der Stahlbaufirma Krupp in Rheinhausen bemüht, besonders auch durch umfassende Laborversuche Anhaltspunkte dafür zu finden, welche Materialien, insbesondere Kunststoffe, zur Belegung von Pionier- und Behelfsbrücken mit geringen Blechdicken infrage kommen könnten. Auf diese Versuche soll hier im einzelnen nicht eingegangen werden, weil darüber bereits an anderer Stelle ausführlich berichtet wurde. Ich darf es bei einem Hinweis auf die Veröffentlichungen von Sedlacek in der Zeitschrift "Der Bauingenieur", Heft 4, 1966 und Heft 6, 1968 bewenden lassen.

2. Kautschuk-Zementmörtel

Für die Verwendung auf beweglichen Brücken boten sich vor allem nichtbituminöse Beläge an, die sich besonders als Schiffsbeläge bereits seit mehreren Jahren bewährt hatten. Diese besitzen anstelle der in stärkerem Maße im Wettbewerb liegenden Kunstharz-Varianten eine Kautschuk-Zement-Grundlage und weisen eine Dicke von etwa 12 mm auf. Als bekannteste Beläge dieser Art sind S e m t e x der Firma Dunlopan in Hanau und T i v o p l a n der Tivoliwerke in Hamburg zu nennen. Beide bestehen aus einem hydraulischen Mörtel aus Zement und Sand (nicht mit Kunststoff) unter Verwendung einer Gummi-Komponente. Beim Semtex-Belag besteht diese aus Naturkautschuk in Form von Latexmilch, der natürlichen Gummiflüssigkeit. Dagegen wird bei Tivoplan flüssige Neoprene verwendet. In beiden Fällen wird als mineralischer Bestandteil Granit bevorzugt. Die erforderliche Minimaldicke dieser Beläge von 12 mm schließt ihre Verwendung bei dünneren Fahrbahnblechen, wie sie bei behelfsmäßigen Brükken üblich sind, aus Gewichtsgründen von vornherein aus.

Die bereits genannte Brücke bei Friedrichstadt war die erste von drei Klappbrücken über die Eider, die in den Jahren 1956 bis 1961 gebaut wurden und an denen die vorgenannten Beläge zur Erprobung kamen. Auf den beiden Klappen der ersten Brücke wurden die beiden vorgenannten Beläge aufgetragen und dadurch die Möglichkeit eines Vergleiches gegeben.

Eine Fahrbahn erhielt im Juni 1956 einen 12 mm dicken S e m t e x - B e l a g , der auf dem metallisch blank geschliffenen Fahrbahnblech der orthotropen Platte bei halbseitiger Sperrung des Straßenverkehrs aufgetragen wurde. Der Belag wies zunächst eine mehr oder weniger gute Haftung auf dem Blech auf, zeigte aber als Folge seines Aufbaues als hydraulischer Mörtel bald starke Rißbildung als Folge von Schrumpfung und begann stellenweise abzublättern. Es wurden seither mehrere Erneuerungen bzw. Instandsetzungen erforderlich, zuletzt im Jahre 1965. Jedoch bereits im Frühjahr 1966 löste sich der Belag unter großer Rißbildung erneut vom Fahrbahnblech und blätterte schichtenweise ab. Deshalb wurde von einer nochmaligen Erneuerung des Semtex-Belages abgesehen. Statt dessen wurde im September 1966 ein 12 mm dicker Tivoplan-Belag aufgebracht.

Auf der anderen östlichen Fahrbahn wurde im September 1956 ein 12 mm dicker T i v o p l a n - B e l a g verlegt. Auch hier wurde zuvor das Blech metallisch blank geschliffen. Der Straßenverkehr wurde ebenfalls halbseitig gesperrt. Die Haftung des Belages auf dem Fahrbahnblech war nicht überall gut. Rissebildung und stellenweises Abblättern erforderten Instandsetzungen bzw. Erneuerungen.

Im Jahre 1962 wurde diese Fahrbahn im Bereich der Nordklappe neu belegt, wobei die Rezeptur gegenüber dem Erstbelag vom Jahre 1956 verbessert wurde. Auch diesmal wurde wiederum nur halbseitig der Straßenverkehr gesperrt. Dieser Belagteil erhielt 4 Jahre später, im Herbst 1966, eine Latex-Schlämme zur Beseitigung von Verschleißerscheinungen. Die Verschleißschäden bestanden aus kleinen Löchern von etwa 1 mm Durchmesser in der Belagsoberfläche, die als Folge des Herauslösens oder einer Zerstörung kleiner Gesteinskörnchen zu deuten waren. Diese Latex-Schlämme hat sich jedoch nicht bewährt. Sie war in kurzer Zeit in den Radspuren bereits abgefahren, sodaß die vorerwähnten kleinen Löcher wieder sichtbar wurden, und blätterte dann zwischen diesen Radspuren nach und nach ab.

Auf der Südklappe war im Jahre 1960 ein zweiter Tivoplan-Belag aufgebracht worden, der 1966 wieder durch einen dritten ersetzt werden mußte. Bei einer im vorigen Jahr stattgefundenen Überprüfung ergab sich, daß die Haftung am Blech bei den letzten Beschichtungen verbessert werden konnte; dies scheint durch zweifache Voranstriche erreicht worden zu sein. Es bleibt abzuwarten, ob die Eignung von Tivoplan nunmehr besser beurteilt werden kann, als es nach den Erfahrungen der ersten Jahre möglich war. Der Semtex-Belag schied jedoch nach den Erfahrungen an dieser Brücke aus.

Als zweite Brücke über die Eider ist die einflüglige Klappbrücke Pahlhude zu nennen. Diese erhielt im September 1960 einen 15 mm dicken Tivoplan-Belag auf metallisch blank gesandstrahltem Fahrbahnblech. Daß das Sandstrahlen gegenüber dem Schleifen vorzuziehen ist, scheint am besseren Haften des sonst gleichen Belages auf dieser Brücke erkennbar zu sein. Im Bereich der beidseitigen Gehwege ist der Tivoplan-Belag nur 10 mm dick. Im Gegensatz zur Friedrichstädter Brücke wurde hier der Belag bereits 2 1/2 Monate vor Inbetriebnahme der Brücke aufgebracht; d.h. der Aushärtungsprozess konnte sich ohne Schädigung durch die Einwirkungen des Straßenverkehrs vollziehen. Die Klappe befand sich während dieser Zeit ebenfalls in Ruhestellung.

Bisher sind in diesem Belag keine Schäden aufgetreten, lediglich die bereits bei Friedrichstadt beobachteten kleinen Löcher an der Oberfläche zeigten sich auch hier und wiederum besonders stark im Bereich der Radspuren. Daß es sich hierbei tatsächlich um eine Verschleißerscheinung handelt, ist daraus zu erkennen, daß im Bereich der Gehwegbeläge diese kleinen Löcher nicht festzustellen sind. Es ist noch zu erwähnen, daß in einer eng begrenzten Fläche von einigen m^2 Größe eine stärkere Abnützung des Belages zu beobachten war und daß hier profilaktisch eine etwa 1 mm dicke Spachtelschicht aus dem gleichen Material aufgetragen wurde. Auch in diesem Bereich ist der Belag bisher rissefrei und ohne sonstige Schäden geblieben.

Eine dritte Klappbrücke über die Eider befindet sich bei L e x f ä h r e im Zuge der Bundesstraße 203. Dieses Bauwerk wurde im Oktober 1961 nach seinem Umbau mit einem 15 mm dicken T i v o p l a n - B e l a g versehen. Das Blech wurde metallisch blank gesandstrahlt. Die Arbeiten konnten bei voller Sperrung des Straßen- und Schiffsverkehrs durchgeführt werden. Bis heute besteht kein Anlaß zu irgendwelchen Beanstandungen.

Im Gegensatz zu den bisher genannten Brücken wird von einem 1961 aufgebrachten T i v o p l a n - B e l a g auf einer stark befahrenen Klappbrücke über den östlichen Bahnhofskanal in H a m b u r g - H a r b u r g , auf der auch zwei Straßenbahngleise liegen, ein recht ungünstiges Ergebnis berichtet. Der Belag haftet hier sehr schlecht und wird durch den Verkehr herausgerissen, wobei laufend neue Schlaglöcher entstehen, sodaß mit Zeitabständen von wenigen Monaten Flickarbeiten notwendig sind. Dabei ist der Verkehr als mäßig zu bezeichnen. Im Juli 1967 mußte der Tivoplan-Belag schließlich durch einen anderen Belag ersetzt werden, weil die Schlaglöcher so groß geworden waren, daß stellenweise auf dem glatten Stahlblech gefahren wurde. Besonders hatten sich, ausgehend von der Klappenspitze, infolge der Erschütterungen beim Aufsetzen der Klappe ganze Schollen vom übrigen Belag gelöst. Dieser Belag wurde inzwischen durch einen Epoxydharzbelag ersetzt. Bei einer nach 5-monatigem Verkehr durchgeführten Besichtigung konnten keinerlei Mängel festgestellt werden.

Es bleibt noch zu sagen, daß die Dicke des Fahrbahnbleches auf den vorerwähnten Brücken zwischen 12 und 15 mm betrug.

Aus den vorstehenden Einzelerfahrungen kann ein endgültiges Urteil über die Eignung des T i v o p l a n - B e l a g e s noch nicht abgegeben werden. Wir werden den genannten Belag auch weiterhin noch auf Klappbrücken verwenden, jedoch in Zukunft folgende Vorkehrungen treffen:

1. Der Belag sollte nach Möglichkeit in ganzer Breite, d.h. ohne mittlere Arbeitsfuge, hergestellt werden.

2. Vollsperrung des Straßenverkehrs zur Vermeidung von Verkehrserschütterungen ist erforderlich.
3. Der frisch aufgebrachte Belag ist während der Herstellung und einige Tage danach durch Zelte vor starker Sonnenbestrahlung und Wind zu schützen.
4. Der Belag darf bis etwa 10 Tage nach der Herstellung nicht befahren werden.
5. Im Hinblick auf den unvermeidlichen Verschleiß infolge des Straßenverkehrs ist in etwa 3-jährigem Abstand das Aufbringen einer etwa 1 mm dicken gespachtelten Schicht, die nach dem gleichen Rezept wie der Belag aufgebaut ist, zweckmäßig; Schlämmen ist jedoch nicht zu empfehlen.

3. Kunstharzbeläge

Von geringerer Dicke als die zuvor besprochenen gummihaltigen Beläge sind die vielen Arten von Kunstharzbelägen, die seit dem Jahre 1961 auf Pionier- und Behelfsbrücken, auf Schnellbaustraßen (Flyover-Brücken) oder den auf Autobahn-Baustellen verwendeten Stahlflachstraßen ausprobiert wurden. Alle diese Brükkenarten haben eines gemeinsam: ihre Fahrbahn besteht aus vorgefertigten Platten, die bei der Montage auf der Baustelle durch Schrauben miteinander verbunden werden. Der Gewichtsbeschränkung wegen sind die befahrenen Bleche von geringer Dicke, die schon bei 3 mm beginnt. Die Fahrbahnfläche ist daher mit Ausnahme der Plattenränder mehr oder minder großen elastischen Verformungen ausgesetzt. Daraus ergibt sich die an diese Beläge zu stellende grundlegende Forderung einer hohen elastischen Verformbarkeit. Im Bereich der Plattenränder werden weiterhin stets besonders hohe Beanspruchungen durch Stoßkräfte und zwar als Druck- und Schubkräfte auftreten. Der Verschleiß ist hier an den Plattenrändern daher besonders groß. Es ist offensichtlich, daß diese Beläge hohen Anforderungen im Hinblick auf ihre Haftung am Stahlblech genügen müssen.

Die Ebenheit der Fahrbahnfläche kann hier allerdings nicht die gleiche sein wie bei einer normalen orthotropen Brücken-platte. Daraus folgt eine geringere Sicherheit in der Fahrzeugführung. Die Oberflächenrauhigkeit sowie die Verschleißfestigkeit müssen daher besonders hoch sein. Eine rauhe Oberfläche wird durch Einstreuen von staubfreien, scharfen Sanden aus Quarz oder besser Siliziumkarbid und Korund erreicht.

Von geringem Erfolg waren die anfänglichen Versuche mit den sehr festen und harten Polyester-Harzen, die zuvor schon zur Verkleidung von Kohlen- und Erzrutschen verwendet worden waren. Ihre Verarbeitung macht die Anwendung von Lösungsmitteln erforderlich. Da diese Lösungsmittel nach Aufbringen des Belages verdampfen, entstehen Poren, durch die Feuchtigkeit bis an die Blechoberfläche gelangt. Es bilden sich dann Unterrostungen, die zu einer flächenweisen Ablösung des Belages führen. Außerdem besteht Neigung zum Schrumpfen. Hierdurch entstehen Risse, die den Wassereintritt ebenfalls herbeiführen. Um einen besseren Korrosionsschutz zu erzielen, behandelten wir die Blechoberfläche mit Wash-Primern. Das Gleiche erreichten wir durch metallischen Schutz in Form von Zink- oder Bleipulver, das mit Düsen unter Druck aufgeschossen oder der Kunstharzmasse beigegeben wurde. Diese Maßnahmen hatten jedoch eine Verminderung der Haftung des Belages am Blech zur Folge. Ein weiterer Nachteil ist die starke Alterungsempfindlichkeit dieser Beläge.

Auch bei Verwendung von Epoxydharzen ging man zunächst diesen Weg, bis man dann das entgegengesetzte Verfahren anzuwenden begann, indem man flüssige Epoxydharze mit Härtern ausprobierte, die den weiteren Vorteil boten, ohne besondere Haftanstriche anwendbar zu sein. Inzwischen sind solche Epoxydharz-Beläge in zahlreichen Variationen auf dem Markt erschienen, wobei auch die mit Teer verschnittenen Abwandlungen Bedeutung erlangt haben. Gegenüber den Polyester-Harzen hat das Epoxydharz insbesondere den Vorteil geringerer Schwind- und Alterungserscheinungen. Auf zahlreichen Behelfsbrücken und auch auf der Stahlflachstraße finden wir dies bestätigt.

Der von der Firma Robert A. Roehder angebotene R o a d - c o a t-B e l a g ist ein niedrigviskoses, flüssiges Zwei-Komponenten-Kunstharz, das in den USA schon unter dem Namen Philly-Guard 140 Paving Compound bekannt wurde und auch auf Beton-Fahrbahnen aufgebracht wird. Seine Anwendung auf der Stahlfahrbahn der S c h n e l l b r ü c k e L e v e r k u - s e n sei als Beispiel erwähnt. Der in diesem Falle nur 3 mm dicke Belag liegt auf einem Blech von nur 7,5 mm Dicke. Bei starkem Verkehr, von dem etwa 25 % auf LKW's fallen, bei 6 % Steigung und gekrümmter Fahrbahn ist der Zustand des Belages nach 3-jähriger Liegezeit noch immer als sehr gut zu bezeichnen. Seine elastische Eigenschaft erhält der Roadcoat-Belag durch 20-%igen Zusatz von Teerderivaten. Hervorzuheben ist auch seine geringere Temperatur- und Wasserempfindlichkeit, sodaß seine Aufbringung weniger vom Wetter abhängig ist als es bei anderen Kunstharzbelägen der Fall ist. Dieser Belag ist auch weitgehend mit anderen Belagsmassen verträglich, was ihn für Ausbesserungsarbeiten vielseitig verwendbar macht.

Als weitere Kunstharzgruppe seien noch die P o l y - u r e t h a n e genannt, die entweder mit einem Lösungsmittel oder zweikomponentig verwendet werden. Im ersten Falle ist der Nachteil in Kauf zu nehmen, daß dieser Belag sich nur in dünnen Schichten auftragen läßt. Auch das Einstreumittel muß hier besonders feinkörnig sein. Als Vorteil ist zu werten, daß eine geringere Empfindlichkeit gegen Feuchtigkeit vorhanden ist. Hingegen ist ein zweikomponentiger Polyurethanbelag bei der Verarbeitung sehr feuchtigkeitsempfindlich, da der Härter, ein Isocyanat, mit Wasser CO_2-Gas bildet, wobei Schaumkörper entstehen. Diese Gefahr, die eine Zerstörung der Belagsmasse bedeutet, besteht bereits, wenn beim Verarbeiten ein dünner Feuchtigkeitsfilm auf dem Fahrbahnblech vorhanden ist oder bei feuchter Luft gearbeitet wird.

Aus vorstehend beschriebenen Kunstharz-Gruppen sind unter den verschiedensten Bezeichnungen von der einschlägigen Industrie Belagstoffe angeboten worden. Beginnend mit dem Jahre 1961 haben wir in der Bundesrepublik viele solche Fabrikate im Großversuch geprüft. Die Ergebnisse sind nicht allzu sehr ermutigend. Zwar waren im Verhalten mehr oder minder große Unterschiede zu erkennen, jedoch kann von keinem Belag nach der bisherigen kurzen Liegedauer gesagt werden, daß er sich endgültig bewährt habe. Einige wenige Fabrikate haben immerhin die Aussicht, eine solche Beurteilung noch zu erreichen, sofern der Zustand der entsprechenden Versuchsbeläge in einigen Jahren noch als gut bezeichnet werden kann.

4. Gummiartige Beläge

Inzwischen sind Versuche unternommen worden, um die Verwendungsmöglichkeit von Neoprene in Beschichtungsmassen zu prüfen, die eine Gesamtdicke von nur 1 - 2 mm aufwiesen. Dieser Belag bestand aus 3 Schichten, und zwar einer Grundierung, einer mit Korund vermischten Zwischenschicht und einer Deckschicht. Obwohl sich hinsichtlich Gleitwiderstand, Abrieb und Haftung am Stahlblech sehr günstige Werte ergaben, erwies sich der Belag dennoch als ungeeignet, da die Bindung der mineralischen Einstreuung in der Zwischenschicht bei schwerem Verkehr den großen Schubkräften nicht gewachsen war.

Es wurden auch vorgefertigte Neoprenematten auf Fahrbahnhohlplatten mit einem Fahrbahnblech von 4,5 mm Dicke aufvulkanisiert, nachdem zuvor das Aufkleben von Gummimatten nicht gelungen war. Auf einer Behelfsbrücke über die Wupper bei Müngsten hat sich dieser Belag seit 4 Jahren sehr gut verhalten. Trotz starken Verkehrs, Längsgefälles und einer engen Straßenkurve an einem Brückenende, haben sich bisher keinerlei Ablösungserscheinungen gezeigt. Lediglich an den Kanten der Brückenplatten ist ein teilweiser Verschleiß festzustellen.

Die Kosten dieses Belages sind leider sehr hoch. Das Aufvulkanisieren erfordert hohe Drücke und Temperaturen und hierfür sind kostspielige Apparaturen notwendig.

5. Dünne bituminöse Beläge

Von großem Interesse dürfte es i.ü. sein, daß die Stadt Hannover kürzlich den Bau einer Schnellbrücke von 450 m Länge in Auftrag gegeben hat, bei der erstmalig ein 3 c m d i k -

k e r b i t u m i n ö s e r F a h r b a h n b e l a g zur Anwendung kommen soll. Das bedeutet, daß man aufgrund der bisherigen Erfahrungen vorerst diesem Belag eher die Fähigkeit zutraut, die hohe Beanspruchung des dichten Großstadtverkehrs, insbesondere durch Spikes auszuhalten, zumal auch in den beidseitigen Rampenstrecken Gefälle von 6 % vorhanden sein wird. Die Frage der Schalldämpfung dürfte hier bei der Wahl des Belages ebenfalls von großer Bedeutung gewesen sein.

ZUSAMMENFASSUNG

Es wird über Schiffsdeck-Beläge (Semtex und Tivoplan) berichtet, die seit dem Jahre 1956 auf einigen norddeutschen Klappbrücken ausgelegt wurden. Diese bestehen aus einem hydraulischen Zementmörtel mit Gummikomponente. Die Haltbarkeit ist unterschiedlich und nur von beschränkter Dauer.

Außerdem wird auf zahlreiche Arten von Kunstharzbelägen hingewiesen, die in Labor- und mehreren Großversuchen getestet worden sind. Ein abschließendes Urteil hierzu läßt sich noch nicht fällen, da die einzelnen Beläge noch nicht lange genug eingesetzt sind. Es wird mit Sicherheit noch einige Zeit dauern, bis eine befriedigende Lösung erreicht ist.

SUMMARY

The report concerns ship's deck wearing surfaces (Semtex and Tivoplan) which were laid out since 1956 on several bascule bridges in Northern Germany. These wearing surfaces are made of a hydraulic cement mortar with a rubber constituent. Their durability varies and is limited.

Furthermore, reference is made to several kinds of synthetic resin wearing surfaces which have been tested in laboratories and by some full-scale experiments. A conclusive opinion cannot yet be given as the individual wearing surfaces have not been used long enough. It may safely be said that some more time will pass before a satisfactory solution may be found.

RESUME

L'exposé porte sur les revêtements de ponts de navire (Semtex et Tivoplan), appliqués depuis 1956 à plusieurs ponts basculants d'Allemagne du nord. Ces revêtements consistent en un mortier de ciment hydraulique contenant du caoutchouc. Leur durée de vie est limitée.

En outre, de nombreux types de revêtements à résine artificielle sont mentionnés. Ceux-ci ont fait l'objet d'essais en laboratoire et sur place. Mais une appréciation définitive n'est pas possible à l'heure actuelle. Il faudra attendre que ces revêtements soient en place plus longtemps avant d'arriver à une solution satisfaisante.

LABORATORY AND FIELD EVALUATIONS OF THIN WEARING SURFACES FOR ORTHOTROPIC STEEL DECK BRIDGES

Essais de laboratoire et sur place de revêtements minces pour dalles orthotropes

Laboratoriums- und Feldversuche dünner Fahrbahnbeläge auf orthotropen Brücken

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INTRODUCTION

With few exceptions, all of the orthotropic steel deck bridges in Europe and elsewhere have been paved with asphaltic compositions applied in thicknesses of 1-1/2 inches (3.7 cm) or more. The use of these materials have been more or less dictated by general familiarity and proven performance histories. The application of thin wearing surfaces applied in thicknesses of 1 inch (2.5 cm) or less has generally been limited to moveable or demountable bridges where excess weight is highly undesirable. In long span continuous bridges, the dead load of thick wearing surfaces may also be undesirable because the pavement does not contribute to the overall stiffness of the bridge. In keeping with the design philosophy of light weight steel deck bridges, a thin light weight wearing surface also is highly desirable provided the known pavement requirements may be met.

The history of thick wearing surfaces has shown that considerable time and study is needed before the suitability of a paving system may be fully assessed. The process can be accelerated with the help of laboratory studies. With this in mind, an experimental program at the Columbus Laboratories of the Battelle Memorial Institute was devised by the author under the sponsorship of the American Iron and Steel Institute to investigate a variety of materials which showed some promise as thin light weight paving materials for steel deck bridges. The objective of this program was to develop a number of test methods and procedures for measuring specific material properties which have been shown by experience to be important to the performance of suitable wearing surfaces. It was reasoned that the experimental data could hopefully be correlated with field performance to establish realistic design criteria and to provide a means to quickly evaluate new and improved materials as they become available.

EXPERIMENTAL PROGRAM

In selecting the materials to be used in this study it was realized that numerous compositions might be suitable as worthy of consideration but as in any program of this kind, there is a practical limit to the number that can be handled. In order to confine the program to a manageable number of materials, the selection was limited to a few basic materials which were readily available on a commercial basis and with some performance history in reference to bridge deck reparis. With these considerations, the following thermosetting materials, in whole or in part, were selected for this investigation:

1. Coal tar epoxy
2. Oil extended epoxy
3. Polyester
4. Polyamide modified epoxy
5. Polyurethane
6. Epoxy asphalt.

Because of the relatively high cost of resinous binders, economics dictate that as high a filler content as practical be used. To investigate these practical limits, a portion of the program was devoted to determining the effects of different filler contents on the properties of the first four materials listed above. The remaining two were proportioned according to recommendations of the material suppliers.

Material Property Determinations

The specific properties of the experimental materials determined were as follows:

1. Flexural strength
2. Modulus of elasticity
3. Fatigue resistance
4. Shear and tension bond strength
5. Abrasion resistance.

Most of the evaluations were conducted at room temperature; where applicable, they were made also at temperatures of 0° and 140°F (-18° and 60°C). These values are representative of the temperature limits which might be encountered in service.

Flexural Strength and Modulus of Elasticity

The flexural strength of the resin mortar materials was determined from 1 x 1 x 10-inch (2.5 x 2.5 x 25 cm) specimens under three point loading over an 8-inch (20 cm) span. The elastic modulus of these materials was calculated from the deflections of the flexural specimens measured at the center of the span. The rate of loading was fixed at a loading head travel of 0.20 in/min. (5 mm/min).

The results of these measurements are given in Table 1. It is evident that the strength and the modulus of all the epoxy-resin materials decrease as the sand/resin ratio increases. Values of both also decrease with an increase in temperature with the exception of the polyamide/epoxy mortar. Heating these specimens to the test temperature of 140°F (60°C) apparently caused some slight additional curing of the binder, resulting in a higher strength.

The significance of these values is that many of these materials could increase the stiffness of a steel plate even at temperatures up to 140°F (60°C) and at sand/resin ratios as high as 8:1 under instantaneous loading. The magnitude of the increase would, of course, depend on the ratio of pavement thickness to plate thickness.

TABLE 1. FLEXURAL STRENGTH AND ELASTIC MODULUS OF EXPERIMENTAL PAVING MATERIALS UNDER VARIOUS CONDITIONS

Material	Binder Content, w/o	Flexural Strength, psi			Flexural Modulus, psi		
		0 F	77 F	140F	0 F	77 F	140F
Coal Tar Epoxy	18.7	3000	900	200	1,600,000	230,000	30,000
	12.1	2500	800	175	1,000,000	150,000	20,000
	8.2	1700	600	150	680,000	65,000	8,000
Oil Extended Epoxy	16.4	2350	1000	200	530,000	140,000	40,000
	10.6	2000	780	80	430,000	70,000	4,000
	7.0	1200	500	50	320,000	22,000	2,000
Polyamide/Epoxy	18.0	3650	3350	3500	1,050,000	900,000	700,000
	11.6	3300	2800	2950	950,000	850,000	650,000
	7.6	2800	1600	2850	800,000	740,000	600,000
Polyester	18.8	3100	1900	1000	900,000	320,000	35,000
	12.2	1700	850	300	800,000	220,000	32,000
	7.8	600	300	150	450,000	150,000	25,000
Polyurethane	20.0	3690	1800	1080	640,000	533,000	84,000
Epoxy Asphalt	7.25	3190	690	480	4,680,000	410,000	187,000

Shear and Tensile Bond Strength

The shear bond specimens consisted of a 1/2 x 4 x 8-inch (1.3 x 10 x 20 cm) long steel specimen which was coated with 1/2 inch (1.3 cm) of the various epoxy mortars over one half of the plate (end half). The plate was grit blasted to white metal and primed with a 1/32 inch (0.8 mm) thick layer of the pure binder prior to placing the mortar. After curing, a similar sized plate was cemented to the top of the paving mix so that the unpaved sections of the plate extended in opposite directions. The specimens were then placed in a loading jig. The bottom specimen plate was bolted to the jig and the top plate pulled in a parallel plane by means of a threaded rod tightened against an angle bar attached to the jig. A set of rollers was used to insure that the top plate remained parallel to the bottom plate while the load was being applied. The load was measured by means of a load cell. The shear jig with a specimen mounted is shown in Figure 1.

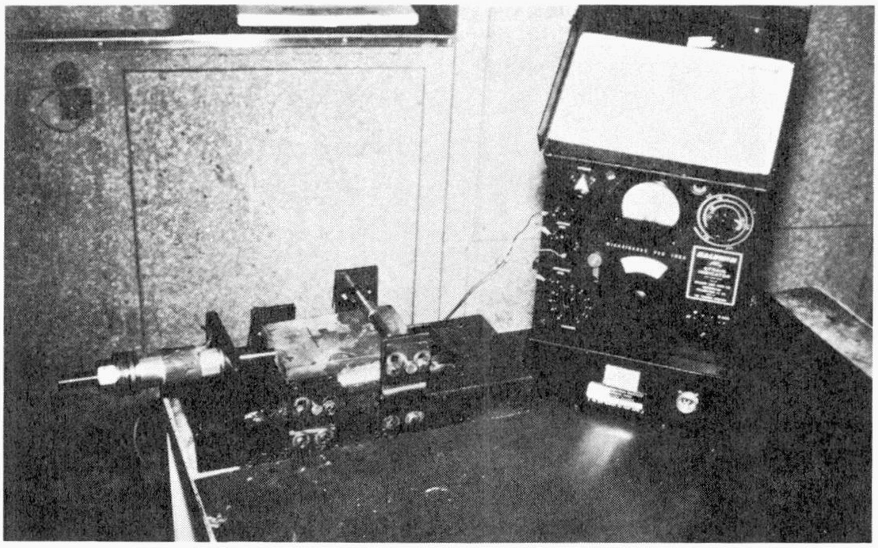

FIGURE 1. APPARATUS USED TO DETERMINE THE SHEAR BOND STRENGTH OF EXPERIMENTAL PAVING MATERIALS

The tension bond specimens were prepared by placing a 1 inch (2.5 cm) thick layer of epoxy mortar between two 2 inch (5 cm) diameter steel plates. The plates were grit blasted and primed with 1/32 inch (0.8 mm) of pure resin binder before placing the epoxy mortar. A load was then applied normal to the center of the plates through rods threaded into nuts welded to the back of the plates. A universal joint was fitted into each rod to compensate for any misalignment in the specimen. A tension bond specimen is shown in Figure 2.

In all cases the specimens were maintained at the desired test temperature for at least four hours prior to loading. In all but a few cases failure occurred by complete separation of the wearing surface at the steel plate interface. Occasionally a small portion of the wearing surface broke free and remained attached to the steel plate. In no case did the portion of the wearing surface which remained attached to the plate exceed 5 percent of the bond area. The results of the bond strength measurements are given in Table 2.

TABLE 2. SHEAR AND TENSILE BOND STRENGTH OF THE CANDIDATE PAVING MATERIALS TO A STEEL PLATE

Material	Binder Content, w/o	Shear Bond Strength, psi			Tensile Bond Strength, psi		
		0 F	77 F	140 F	0 F	77 F	140 F
Coal Tar Epoxy	18.7	900	640	75	--	--	--
	12.1	680	380	55	700	475	155
	8.2	420	255	45	365	195	95
Oil Extended Epoxy	16.4	475	330	50	--	--	--
	10.6	450	300	50	525	445	35
	7.0	385	250	20	460	175	30
Polyamide/Epoxy	11.6	900	830	950	2000+	1150	1300
	7.8	840	630	700	535	415	830
Polyester	18.8	715	450	180	--	--	--
	12.2	470	425	100	730	575	80
	7.8	245	300	80	120	90	65
Polyurethane	2.0	830	645	275	1620	1420	340
Epoxy Asphalt	7.25	665	185	50	1650	220	110

Fatigue Tests

The fatigue tests consisted of subjecting the experimental paving materials mounted on steel plates to continuous flexing at specified deflections to determine their tensile cracking susceptibility.

The materials were placed on 3/8 and 1/2 inch (1 and 1.3 cm) steel plates, 4 inches (10 cm) wide and 17 inches (42.5 cm) long. The paving materials were cast over the middle 14 inches (35 cm) of the plates in various thicknesses. The epoxy resin mortars were applied by hand painting a 1/32 inch (0.8 mm) primer of the resin binder on the grit blasted steel plate and casting the mortar directly on the prime coat. There were slight variations in the above procedure depending on the specific recommendations of the materials supplier.

The specimens were mounted in a specially-designed machine which tested two specimens simultaneously at different deflections and with separate controls. The specimens were enclosed in an insulated box and the required temperature was automatically maintained. Each specimen was deflected about its center point to simulate three point loading by applying a cyclic load at one of the end supports by means of an eccentric cam. The load was transmitted to the specimen through a heavy spring so that the load would remain constant during small variations in the deflection. The load applied was that required to deflect the bare steel plate to the desired span/deflection ratio. A slight preload was applied to the specimen to prevent it from bouncing on the supports. The paving materials were stressed in tension only.

After the specimen reached the desired test temperature, the machin started automatically and applied the load at a frequency of 1750 cycles/min. A stripe of electrically conductive material was painted on the paving material the full length of the specimen and wired into a circuit breaking mechanism. When a surface crack occurred the circuit was broken and the machine was automatically shut down.

The specimens were run at various span/deflection ratios down to 300 as representing the maximum value used in design. It was intended to determine the maximum deflection (lowest span/deflection ratio) the paving material could withstand over a period of 5 million cycles. The results of these experiments are given in Table 3. No attempt was made to determine the minimum allowable span/deflection ratio when it was less than 300 and in the table of results the value is merely given as something less than 300. No values are given for tests performed at 140°F (60°C) as in no case did failures occur at this temperature for span/deflection ratios of 300.

TABLE 3. SPAN/DEFLECTION RATIOS SUSTAINED WITHOUT FAILURE FOR FIVE MILLION CYCLES

Binder Material	Binder Content w/o	Pavement Thickness inch	3/8-inch Steel Plate		1/2-inch Steel Plate	
			0 F	77 F	0 F	77 F
Coal Tar Epoxy	12.1	5/8	< 300	< 300	< 300	< 300
	8.2	5/8	"	"	"	"
Oil Extended Epoxy	10.6	5/8	"	"	"	"
	7.0	5/8	"	"	"	"
Polyamide/Epoxy	7.6	5/8	"	"	"	"
	7.6	1	"	"	"	"
Polyester	18.8	1	400	--	350*	--
	11.6	5/8	< 300	< 300	< 300	< 300
	7.8	1/2	600	400	530	--
	7.8	3/4	530	--	670	560
Polyurethane	20.0	3/4	< 300	< 300	< 300	< 300
Epoxy Asphalt	6.5	3/4	"	"	"	"

* Estimated.

Abrasion Resistance

This evaluation was intended to determine the relative resistance to wear of the various paving materials examined. Since there is no standard laboratory method for evaluating wear rates, a scheme was devised whereby the wear rate of epoxy mortars could be compared with asphalt concrete. In this experiment, the various epoxy mortars were applied to 4 inch (10 cm) square steel plates in 1/2 inch (1.3 cm) thicknesses. The specimens then were placed in a drill press and the surface ground with a cone shaped grinding wheel rotated to 800 rpm with a force of 15 pounds (6.8 kg). The grinding operation was continued for 1 to 3 minutes and the wear rate calculated from the weight loss per unit of time. The specimens were immersed in water during the grinding operation to prevent heat buildup. The setup used is shown in Figure 3. The results of these experiments are given in Table 4.

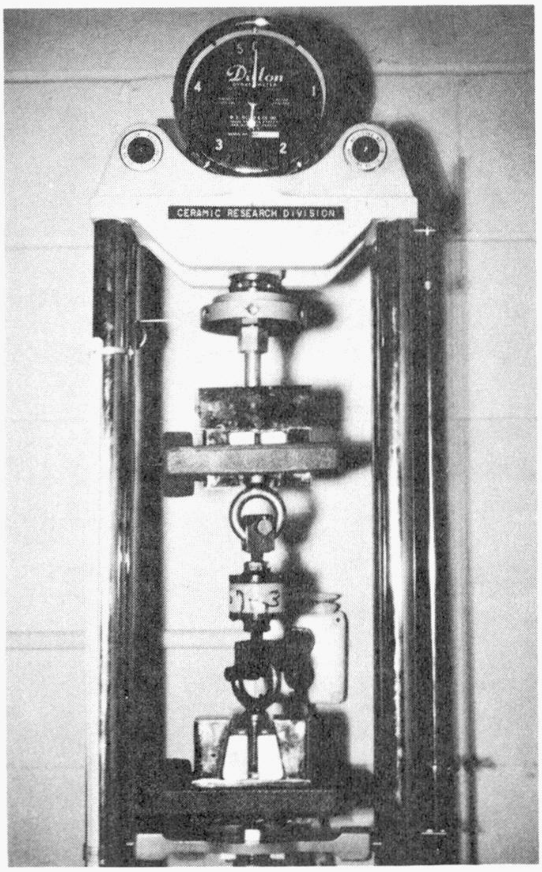

FIGURE 2. APPARATUS AND PROCEDURE FOR DETERMINING TENSION BOND STRENGTH OF EXPERIMENTAL PAVING MATERIALS

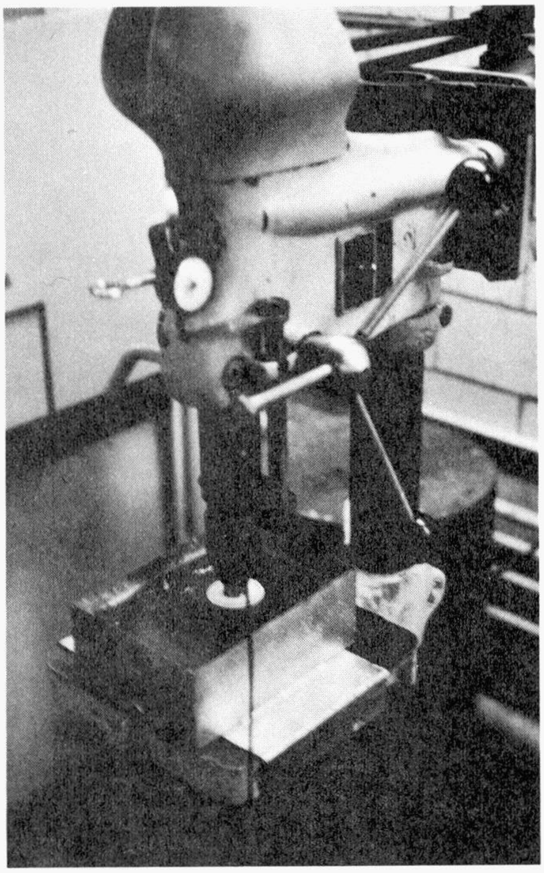

FIGURE 3. EXPERIMENTAL SETUP FOR DETERMINING RELATIVE WEAR RESISTANCE OF THIN PAVING MATERIALS

TABLE 4. RELATIVE WEAR RESISTANCE OF EXPERIMENTAL PAVING MATERIALS

Material	Binder Content, w/o	Wear Rate Weight Loss, gms/min
Coal Tar Epoxy	18.7	0.33
	12.1	2.50
	8.2	4.33
Oil Extended Epoxy	16.4	4.17
	10.6	7.0
	7.0	22.6
Polyamide/Epoxy	18.0	0.33
	11.6	0.83
	7.6	3.83
Polyester	18.8	0.67
	12.2	2.33
	7.8	14.63
Polyurethane	20.0	0.25
Epoxy Asphalt	7.25	1.33
Asphalt Concrete	6.5	1.97

FIELD EXPERIENCE

Laboratory data have little meaning unless they can be related to field performance. Unfortunately, there is a limited amount of field data on these wearing surfaces available at the present time. There are, however, four American bridges wholly or partially paved with thin epoxy based surfacing materials. The following is a brief description of the paving materials used on these bridges and their field performance.

Ulatis Creek Bridge*

In September of 1965, one lane of this bridge was paved with five different paving materials. Three sections were paved with epoxy mortar containing 11.25 weight percent of oil extended epoxy (three different suppliers) 1-1/4 inches (3.2 cm) in thickness. Another section was paved with epoxy asphalt. A tack coat of the pure resin binder was used for each material. The steel deck was first primed with three mils of inorganic zinc.

After approximately three years in service, all of the above mentioned materials are performing quite well. The only problem has been near the joints between the different pavements where a small angle was tack welded to the deck plate to serve as a divider. Several of these angles have broken loose and the pumping action has chipped away the pavements within

* For a complete description of the paving procedures, see Bulletin No. 6, Paving Practices for Wearing Surfaces On Orthotropic Steel Bridge Decks, January, 1968, American Iron & Steel Institute.

a few inches of the joint. With these exceptions, no cracking, rutting, excessive wear or other defects are noticeable. Test cores in the epoxy asphalt and one of the epoxy mortar sections yielded tension bond strengths of approximately 210 and 425 psi (15 and 30 kg/cm^2), respectively.

New Jersey Turnpike Bridge*

This bridge was paved in November, 1965, using the "Realgirt" and "Cybond" paving system, each over half the bridge. The "Realgrit" system involves tack welding an expanded mesh to the deck plate and then pouring an epoxy-grit slurry over the mesh to a depth of 1/4 to 3/8 inch (6 to 8 mm). This system is shop applied with a similar treatment given to the joints in the field. The Cybond system involves pouring polyester resin over the resin primed deck plate to a depth of approximately 1/8 inch (3 mm) and then scattering sand over the resin resulting in a finished thickness of 1/4 to 3/8 inch (6 to 8 mm). This system was applied in the field.

After 2-1/2 years in service, the epoxy grit of the "Realgrit" system has been worn away over the high points of the expanded mesh in the wheel paths. As yet there are no signs that moisture has penetrated at these points but the condition may be expected to get progressively worse.

The Cybond system has developed a fine crack over each of two longitudinal bolted joints in the deck. These cracks extend the full length of the joint and were apparently caused by relative movement of the adjoining plates at the joint. There was some evidence of water seepage through the crack and the joint. Except for these cracks, no other defects were noted.

Dublin Bridge*

Two spans of this four-span bridge were paved in December of 1965 with a coal tar epoxy-grit slurry. Prior to paving, the steel deck had been prepared by three methods: (1) sandblast only, (2) sandblast followed by 1 mil (.028 mm) of hot zinc metallizing, and (3) sandblast followed by 5 mils (0.14 mm) of hot zinc metallizing. After the deck preparation, the epoxy was sprayed over the deck at a rate of 6.6 lbs/yd^2 (3.6 kg/m^2) after which alumina grit was broadcast over the surface at a rate of approximately 27 lbs/yd^2 (15 kg/m^2). The finished thickness varied from 1/4 to 3/8 inch (6 to 8 mm).

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* Ibid.

After one year of service the surfacing had failed over a large area leaving the steel deck exposed. There was evidence that the amine curing agent for the epoxy had reacted with the zinc metallizing to form hydrogen gas which in turn destroyed the bond. The pavement breakup was the most severe over the area which had been metallized. Much of the pavement placed on the bare sandblasted deck was still intact although there were some signs of wear.

During the summer of 1967, the failed sections were removed and the pavement replaced. The deck was sandblasted and primed with an inorganic zinc preparation. The new pavement was essentially the same as the old one. A subsequent inspection (November, 1967) indicated that the alumina grit had not been uniformly distributed as a few spots were found with little or no grit over the epoxy. A further inspection only a few months ago indicated than in these thin spots, the pavement had been worn down to the steel plate. Except for this wear, no other defects such as cracking were observed. The bond of the new pavement to the steel deck appears to be quite good.

Battle Creek Bridge*

One lane of this small three-span bridge was paved in May, 1967, with two types of epoxy mortar placed in a thickness of approximately 5/8 inch (1.6 cm). Half of this lane was paved using an oil-extended epoxy binder. The aggregate was a No. 7 Joplin grit having a binder content of approximately 9 percent by weight. The other half used a coal tar epoxy binder with a content of approximately 14 percent by weight. The same aggregate was used in this latter mix.

Within three months the wheel paths on the oil-extended epxoy mortar pavement was worn down to the steel plate almost over its full length. The coal tar epoxy mortar was still intact but from one half to two thirds of the pavement thickness had been worn away. In September, 1967, both pavements were repaired using the oil-extended epoxy mortar and No. 7 grit as before. In this case, however, the binder content was increased to approximately 20 percent and a hand roller was used to compact the mix in place. In making the repairs, the old material was not removed but merely brought up to grade.

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* Ibid.

To date, the repair material has performed quite well with no further signs of wear or any other defects.

CORRELATION BETWEEN LABORATORY AND FIELD DATA

On the basis of the field performance data, few if any problems may be expected with fatigue cracking for any of the epoxy materials when pavement thicknesses are one inch or less. Polyester resin is the only material investigated which has been found to be fatigue sensitive primarily owing to the fact that this material is more brittle than the others evaluated. For high resin content, however, i.e. in excess of 15 percent as is commonly used in field applications, fatigue is generally not a problem. The cracks observed on the New Jersey Turnpike Bridge are attributed to relative movement of the deck plates and not associated with the fatigue characteristics of the polyester resin.

As with any material, good bond to the deck plate is an absolute necessity. Once the bond is destroyed, as on the Dublin Bridge, any pavement will soon be destroyed. The improved bond of the new pavement on the Dublin Bridge has shown that better performance may be expected. The high bond values found for all the materials in the laboratory experiments indicate that no problems may be expected from this standpoint. The cores pulled from the paving materials on the Ulatis Creek Bridge indicate that equally high bond strengths may be obtained in the field if care is taken during installation. If not, some debonding and subsequent failure may be expected.

Wear has been found to be the most critical problem with thin epoxy based materials. The abrasion experiments carried out in the laboratory have shown that wear may become a problem when the binder content is below 10 percent by weight. In these experiments, a well graded aggregate was used so as to produce a dense pavement. The wear problem on the Battle Creek Bridge has borne out the need for a well graded aggregate. On this bridge, a single sized aggregate was used which produced a coarse, open textured material. It was apparent upon observation that much of the epoxy binder migrated to the bottom of the mix leaving a weak skeletal structure near the surface. This type of structure was easily broken down and worn away by traffic. A gap graded aggregate will have a high void ratio with large pores which cannot retain the binder especially when the binder content is not sufficient to fill all the voids in the aggregate. When the Battle Creek Bridge pavement was repaired, the binder content was doubled and gave the appearance of filling all the aggregate voids. No wear of this epoxy mortar was observed after several months in service.

The Ulatis Creek pavements contained a well graded aggregate with a binder content of 11.25 percent. These materials have shown essentially no signs of wear after three years of heavy service. All of these paving materials were premixed insuring that the aggregate will be fully wetted. In the case of epoxy-grit mixtures, where the aggregate is broadcast over the surface of the epoxy, equal wetting is not assured and the pavement may experience more rapid wear. This was found to be the case on the Dublin Bridge, particularly where the aggregate coverage is insufficient to completely impregnate the epoxy binder.

CONCLUDING REMARKS

Taking into consideration both laboratory and field data, it appears that a suitable thin wearing surface of epoxy mortars may be designed to give a useful life. The use of 3/8 inch (8 mm) or less epoxy-grit mixtures appear questionable not only from the standpoint of excessive wear but also because no leveling of the deck plate may be accomplished. An epoxy mortar on the order of 1 inch (2.5 cm) thick, using a well graded aggregate and having a binder content of 10 to 12 percent should perform quite well if properly installed. As with asphaltic compositions, however, the quality of the field application can be critical in providing a durable pavement. At this time epoxy mortar pavements are hand placed in the field. Before an increase in use may be expected, a mechanized operation must be developed.

SUMMARY

An extensive laboratory investigation was carried out on six different types of epoxy mortar to determine their suitability as lightweight pavements. The results of the laboratory study were compared with the observed field performance of four bridges paved with similar materials. The comparison shows that several epoxy mortars would be suitable for steel deck pavements if certain precautions are taken.

RESUME

Des recherches de laboratoire importantes ont été faites sur six types de mortier d'époxy pour déterminer leur aptitude comme revêtement léger. Les résultats de cette étude de laboratoire ont été comparés avec les performances sur place observées sur quatre ponts traités de revêtements semblables. Il en résulte que plusieurs mortiers d'époxy conviennent au revêtement de tabliers en acier, à condition de prendre certaines précautions.

ZUSAMMENFASSUNG

Weitgehende Laboratoriumsuntersuchungen sind an sechs verschiedenen Epoxydmörteln mit dem Zweck durchgeführt worden, um festzustellen, ob sie sich als Leichtbeläge eignen. Die Ergebnisse dieser Untersuchungen wurden mit den Beobachtungen an vier mit ähnlichen Belagsstoffen überdeckten Brücken verglichen. Der Vergleich zeigt, daß mehrere Epoxydmörtel als Fahrbahnbelag von Stahldecken in Frage kommen, sofern bestimmte Maßnahmen getroffen werden.

THE THIN LAYER PAVEMENT ON THE BRIDGE DECKS

Revêtements minces sur tabliers de ponts

Dünnschichtbeläge auf Brücken

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It is now planned to construct huge bridges with a span of as long as 1,500m in Japan.
For these huge bridges, a thin layer pavement of 1 - 2cm is studied in order to lighten the dead load. However, as it is not yet decided which type of deck to adopt, among the steel deck, I-beam lok slab, and precast concrete slab, laboratory tests and trial pavements were performed to develop a thin layer pavement that could be applied to any of these types of decks.
This report is description of results of various trial pavements.

(1) TRIAL PAVEMENT AT KITAKOGANE ON NATIONAL HIGHWAY NO. 6

This trial pavement was performed to see the possibility of thin layer pavement. The pavement is located in one of the typical national highway in the suburbs of Tokyo, and the traffic volume of the test section is about 30,000 vehicles/day (all lanes), in which 30% of heavy vehicles are included. The width of the highway is 14m.
In the construction of trial pavement, the existing concrete slab were taken as the bridge decks, upon which 15 types of test mix-

No.	Kind of Binder or Mixture	Materials and Its Percentage (by wt.)						
		Binder	Coarse Emery	Fine Emery	Mineral Filler	Silica Sand No.3	Silica Sand No.6	Cement
1	Rubberized Asphalt No.1	7.0%	37.5%	46.5%	9.0%			
2	Rubberized Asphalt No.2	7.0	37.5	46.5	9.0			
3	Rubberized Asphalt No.3-1	7.0	37.5	46.5	9.0			
4	Rubberized Asphalt No.3-2	8.5			8.5	55.0%	28.0%	
5	Rubberized Asphalt Emulsion No.4	15.9	64.3	19.8				
6	Gussasphalt	9.0	25.0	36.0	36.0			
7	Cement-Clay Asphalt Emulsion	12.5		77.5				10%
8	Cement-Clay Asphalt Emulsion	12.5	59.5	26.0				10
9	Polyester Resin	18.9		81.1				
10	Tar Epoxy No.1	16.0	28.0	56.0				

Table-1 COMPOSITION OF MIXTURE (by wt.) continued

No.	Kind of Binder	Materials and Its Percentage (by wt.)						
		Binder	Coarse Emery	Fine Emery	Miniral Filler	Silica Sand No.3	Silica Sand No.6	Cement
11	Tar Epoxy No.2	16.0%	28.0%	56.0%				
12	Tar Epoxy No.3	16.0	28.0	56.0				
13	Colored Binder	12.4	29.2	43.8	7.3%		7.3%	
14	Cement-Rubber Latex No.1	41.5	58.5 (Granite)					
15	Cement-Rubber Latex No.2	36.4		63.6				

NOTE

Coarse Emery	2.5mm pass	35%
	1.2mm pass	1
Fine Emery	2.5mm pass	100
	1.2mm pass	50
Silica Sand No.3	1.2mm pass	73
	0.6mm pass	17
Silica Sand No.6	0.3mm pass	67
	0.15mm pass	30
Crushed Granite	2.5mm pass	60
	1.2mm pass	8

Table-1 COMPOSITION OF MIXTURE (by wt.)

tures were layed in 10mm thick, 3m wide, and 1m long for each mixture.
The composition of these 15 types of mixtures are shown in Table-1. Emery was used for aggregates with a few exception, and 4 types of rubberized asphalt, 1 type of straight asphalt (gussasphalt), 1 type of cement-clay asphalt emulsion, 1 type of polyester resin, 3 types of tar-epoxy, 1 type of colored binder, 1 type of cement-rubber latex were used for binder in which 2 types were applied by neat method and the rest were all mixtures.
The construction was performed in March 1964, and since then, the pavement were kept observing up to date.
The results of the observation are as follows:

i) Those showed least wear, in the survey 2 years after the construction, were tar-epoxy, polyester-resin, gussasphalt. Rubberized asphalt emulsion and colored binder which are performed by neat method showed little wear as well.
Those showed comparatively much wear were rubberized asphalt mixture, cement-rubber latex and cement-clay asphalt emulsion.

ii) Those showed high skid resistance coefficient in the measurement by the portable skid resistance tester were rubberized asphalt mixture with silica sand for aggregate and cement rubber latex. Other types showed approximately similar results.

iii) Those with less flexibility and caused scaling were 1 kind of tar-epoxy, 1 kind of cement rubber latex and polyester resin. Others are still in good condition serving under heavy traffic for 4 years.

iv) Judging from the above all results, it is remarkable in particular, that resinous materials had faults in inflexibility and rubberized asphalt mixture was economical and more durable.

(2) TRIAL PAVEMENT ON THE HANAWA OVERBRIDGE IN KEIYO TOLL ROAD

Rubberized asphalt mixture was placed in 1.5cm thick in average on the precast concrete slab upon the above said overbridge in

September 1964.
The composition of the mixture is shown in Table-2.

Materials	% by wt.
Asphalt Cement	6.5
Coarse Emery	37.7
Fine Emery	46.8
Mineral Filler	9.0

Table-2 Composition of Mixture

This overbridge which is located in Hanawa Interchange has traffic volume of about 10,000 vehicles/day (all lanes) including 30% of heavy vehicles.
No cracking and wearing has been found in the results of observation and the surface keeps good texture except only a little reflection crack at joint of slab.

(3) BUNKA BRIDGE IN OSAKA CITY

In March of 1957, upon the Bunka Bridge with steel deck, asphalt emulsion mixed with rubberized latex was sprayed, over which chipping of crushed stone (5 - 10mm) were uniformly spread. This bridge is located in the residential quarter and has about 600 vehicles/day (all lanes).
By the observation executed in 1963, the pavement was partially scaled off causing the deck exposed.
In April of 1965, replacing this pavement, tar epoxy mixture was placed in 10mm. By the observation executed in 1968, many cracks were found on the surface.

(4) MISOGI BRIDGE

This is a suspension bridge of which concrete slab was replaced to steel deck in 1965. The pavement was performed placing the tar epoxy mixture in about 5mm by hand. By the observation executed after 3 years, in 1968, the surface kept a very good con-

dition.
The traffic volume is about 600 vehicles/day (all lanes) with few heavy vehicles.

(5) NUMAKAWA SLUICE GATE BRIDGE

This is a steel deck bridge constructed in March of 1967. The pavement was performed by placing tar epoxy mixture in about 20mm by hand. At present after 1 year, the surface keeps a very good condition. The traffic volume on this bridge is 3,300 vehicles/day (all lanes) including 50% of heavy vehicles.

The above are the various types of trial pavement performed in Japan, but the definitive mixture for the huge bridges is not yet developed.
Therefore, Construction Ministry plans to execute another trial pavement for steel deck in a large scale on the road with a very heavy traffic in 1969. In this project, rubberized asphalt mixture and tar epoxy mixture, etc. will be adopted.

SUMMARY

This report describes several thin layer pavements trially constructed for surfacing steel bridge decks or cement concrete slabs. Various materials were used for these trial pavements and some of them are still kept in good condition after the lapse of several years under considerable volume of traffic. By the result of survey, it is observed that rubberized asphalt mixture and the tar epoxy mixture are most suitable for this purpose. However, for applying as the pavement on important bridges which support heavy traffic, further study is necessary.

RESUME

Ce rapport décrit plusieurs revêtements minces réalisés pour des essais sur tabliers de ponts en acier ou en béton. Des matériaux divers ont été employés pour ces tests, et plusieurs d'entre eux sont toujours en bonne condition après plusieurs années de trafic lourd. On est arrivé à la conclusion qu'un mélange d'asphalte caoutchouté ainsi qu'un mélange goudron-époxy sont les plus indiqués. Cependant, les revêtements destinés à des ponts importants à trafic lourd, exigent des études plus poussées.

ZUSAMMENFASSUNG

Dieser Beitrag beschreibt mehrere Versuche an Dünnschichtbelägen für Stahl- oder Betonbrücken. Verschiedene Stoffe sind verwendet worden, von denen einige nach Verlauf vieler Jahre unter schwerem Verkehr ihren guten Zustand bewahren konnten. Nach den Versuchsergebnissen zu schließen, sind Gummi-Asphalt-Mischungen und Teer-Epoxyd-Mischungen am geeignetsten für diesen Zweck. Es zeigt sich, daß für wichtige Brücken mit schwerem Verkehr weitere Studien notwendig sind.

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SOME THIN PAVEMENTS IN GREAT BRITAIN

Quelques revêtements minces en Grande-Bretagne

Einige dünne Beläge in Großbritannien

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1. INTRODUCTION

Conventional surfacings for orthotropic plate decks consist of bituminous mixtures laid from $1\frac{1}{2}$ to $2\frac{1}{2}$ in (38 to 63 mm) thick. Such thicknesses impose a weight penalty on this form of deck which partly nullifies its economic and structural advantages. The first investigation carried out by the Road Research Laboratory, almost 20 years ago, was aimed at finding the thinnest mastic surfacing which could be used satisfactorily. It was found that surfacings less than $1\frac{1}{2}$ in (38 mm) thick will crack on the more flexible decks unless the traffic is light.

On a road, the surfacing material must be cheap and the simple solution is to increase the thickness. On a bridge, however, the cost of the material is relatively less important; for long span and moveable bridges the primary requirement is that it must be lightweight, i.e. capable of being laid thinly. For this reason resinous binders costing £500 ($1,200) or more per ton, compared with bitumen at £20 ($48) per ton, can be considered feasible.

2. THIN BITUMINOUS SURFACINGS

Before discussing resinous binders, however, it is worth considering possible ways in which bituminous materials might be utilized more thinly. One can make surfacings more flexible by increasing the bitumen content and by using softer bitumen. It is possible that by using a very soft asphalt, restrained from deforming by a metal grid of rectangular or hexagonal shape fastened to the deck-plate, one could reduce the surfacing depth to perhaps $\frac{3}{4}$ in (19 mm) or even less. This has not been put to the test, however, because the weight of steel in the mesh (Specific Gravity about 8.0) would largely counteract the weight of asphalt saved (Specific Gravity about 2.3). Such grids have of course been used with thicker surfacings in several European countries (Fig. 1).

Another form of thin bituminous surfacing is a single or double surface dressing with bitumen (preferably rubberised bitumen) and $\frac{1}{4}$ or $\frac{3}{8}$ in (6 or 9 mm) chippings. This type of surfacing is only suitable for medium or light traffic but has given good results on several less important road bridges, and was used on the footpaths and cycle tracks of the Forth and Severn Bridges thereby saving a considerable weight.

3. RUBBER-LATEX/PORTLAND CEMENT MIXTURES

For heavily-trafficked bridges, however, it seems probable that one must abandon bituminous materials, if very thin surfacings are required. One of the first non-bituminous mixtures to be tried in the United Kingdom was a mixture of aggregate and asbestos fibre with rubber latex and portland cement. Following road-machine trials, several mixtures of this type were laid on test plates set in a heavily-trafficked road in 1950. After 5 years, the surfacings were still in good condition but it was found that water had penetrated to the steel at the edges and through localised clusters of asbestos fibres. No further experimental work was, therefore, carried out on this type of material although it has subsequently been used on the footpaths of several bridges.

4. SURFACINGS BASED ON THERMOSETTING RESINS

Bituminous surfacings are thermoplastic: if they are made relatively soft and flexible to avoid cracking, then they tend to deform in hot weather. In the late 1950's, therefore, attention was turned to thermosetting resins as alternative binders to bitumen. There has been no difficulty thereby in eliminating the risk of deformation, but it has proved extremely difficult to find a resin which is sufficiently flexible to resist cracking while still retaining other properties such as weather resistance and adhesion to steel.

Several trials of surfacings made with epoxy and polyester resins on small bridges and experimental panels have been made from 1959 onward and progress has been reviewed from time to time(1-4). An important trial was that made in 1963 in connection with the surfacings proposed for the Severn Bridge, for which two large deck panels were set in Trunk Road A.40 at Denham (6). The panels have been described in detail in a paper under Theme I. Three epoxy-resin-based surfacings and one based on a polyester resin laid $\frac{3}{8}$ in (9 mm) thick were compared with two types of asphalt laid $1\frac{1}{2}$ in (38 mm) thick. The epoxy resin/hardener systems chosen were those found to be most promising from previous trials. The resins were the considered choices of three major manufacturers of epoxy resin and they provided a range of flexibility and strength. In each case, they were mixed with six times their weight of fine calcined bauxite aggregate (passing $\frac{1}{8}$ in B.S. sieve), to form a surfacing material trowelled by hand on to the deck panel to a depth of $\frac{3}{8}$ in (9.5 mm). Before laying the mixtures, a coating of unfilled resin was brushed on to the panel at about $\frac{1}{2}$ lb/sq. yd. (0.25 kg/m^2). The panel was delivered with a zinc-sprayed surface, coated with etch-primer. All the surfacing work was done under cover before the panels were taken to the experimental site. The layout of the sections is shown in Fig. 2.

For the fourth section (1D), which is only 7 ft (2.1 m) long and does not contain a transverse stiffener, a proprietary polyester resin/Portland cement binder was used in place of the epoxy resin. This material, known as "Estercrete", is cheaper than epoxy resins. Its mixing and laying is described in a later paragraph.

The panels were opened to traffic in November 1963. The first cracks appeared over the stiffeners in the wheel tracks on Sections 1A and 1D, early in 1964. Subsequently, there was a rapid deterioration of the condition of Section 1A, probably due to a defective constituent in the resin, and it was replaced in October 1964. The replacement was made with a fresh batch of the material to the same specification. It was more durable than the previous batch, but it deteriorated in a similar manner and was removed in April 1968. Cracks have developed in the "Estercrete" on Section 1D over all the stiffeners, but they have not widened appreciably and the material still firmly adheres to the steel.

On Sections 1B and 1C the surfacing was in good condition until the beginning of 1965. Then one crack appeared over the stiffener in the nearside wheel track. Since then additional cracks have developed in both the wheel tracks, but the materials still adhere firmly to the deck between cracks. The condition of the four resin surfacings in November 1967 is shown in Figs. 3-6. As reported in a previous paper the mastic asphalt laid at the same time is still uncracked and has vindicated its selection for the deck of the Severn Bridge in 1966.

The resin on Sections 1B, 1C and 1D would still be regarded as providing a good running surface with a good skidding resistance. However, they are not adequately protecting the steel in a region where a small amount of corrosion could have a serious effect on both the ultimate and fatigue strength of the bridge deck.

Apart from flexibility, however, it is clear that numerous thermosetting resins are available with all the other qualities desirable in surfacings i.e. durability, abrasion resistance, adhesion to steel etc. It may be confidently expected that more flexible resins will be developed in the future.

Two sizeable commercial uses of epoxy-resin-based surfacings on orthotropic plate bridges may be commented on. The 800 ft long prefabricated flyover at Camp Hill, Birmingham was bult in 1961.[5] It has a steel deck plate, ½ in (12.5 mm) thick, with angle type longitudinal stiffeners at 12in (300 mm) centres and transverse diaphragms 5ft (1.5 m) apart. For at least 6 years the epoxy-resin surfacing remained uncracked and in very good condition although a recent inspection has shown that a few hair cracks have now appeared in the surfacing in the wheel tracks. It is otherwise still good and another prefabricated flyover with a somewhat similar surfacing was erected in Bristol in 1967. In 1966 the historic suspension bridge over the Thames at Marlow was renovated and given an orthotropic plate deck with epoxy resin surfacing which is still in good condition.[6] This bridge has a deck plate ½ in (12.5 mm) thick with plate stiffeners at 12 in (300 mm) centres. Vehicles using the bridge deck are restricted to 5 tonf (50 kN) total load.

The epoxy resin surfacing material selected for the bridge was subjected to a dynamic plate bending test, simulating the strain cycle in transverse bending over the stiffener. The material withstood, without cracking, approximately 10^5 applications of a constant amplitude strain cycle oscillating between 5 tonf/sq. in. (77 N/mm^2) tensile and 1.5 tonf/sq. in. (23 N/mm^2) compressive on the upper surface of the deck plate. The temperature varied between 9°C and 15°C during the test. Because of the weight restriction it is estimated that a stress of 5 tonf/sq. in. (77 N/mm2) will only occur 4,000 times per annum.

At present, a difficulty discouraging the use of epoxy-resin-based surfacings is the problem of mixing and laying them on a large scale. The dense, tough, solvent-free mixtures which give the best ultimate results tend to be very viscous and tacky to handle, and the exothermic reaction of epoxies limits the size of batch which can be used. One suggestion for overcoming these difficulties is to build up the required ¼ to ⅜ in layer by the application of several successive spray-and-chip processes. The spraying of epoxy resins via metering pumps, mixing head, and spray bar has been successfully carried out for a number of years.

Another interesting solution to the handling problem may be found along the lines adopted in the proprietary material "Estercrete" (7-9). This material is supplied as a slurry of polyester resin and Portland cement with a latent catalytic hardener already in it. When this slurry is added to suitable aggregate with an appropriate volume of water a multiple reaction occurs. Hydration of the cement begins, the catalyst starts to function and the mixture cures in a few hours to a hard mass. Both the stickiness of the resin and exothermic heat are dissipated by the water and the size of batch is unlimited. At least one large road paving job has been carried out using conventional mixing and paving machinery handling ½ ton (500 Kg) batches[11]. A small area (hand-laid) was laid on one of the Road Research Laboratory's Severn Bridge test panels in 1963. It has suffered very little wear and is still bonded well to the deck plate. Although, as with the epoxy-resin-based surfacings, cracks have appeared over the stiffeners, the material would appear to have considerable potential especially if greater flexibility can be incorporated into the basic resin.

In his introductory paper, Elliott[10] raises the questions of surface irregularity and wear. Recent experience in Britain would indicate that with welded construction of the deck, as typified in the Forth and Severn Bridges, a good profile can be obtained on the steel, which would, without surfacing, be acceptable for high speed motorways. The mastic surfacings, laid by hand, did not improve the riding quality. The wear on epoxy-resin surfacings has not proved to be a serious problem in Britain. Even with thin surface dressings, provided sufficient resin is used and the grit is well chosen, several years life has been obtained. Calcined bauxite has proved to be superior to more expensive abrasives such as silicon carbide and corundum. With trowelled mixes, the wear is not detectable after five years of heavy traffic, in terms of either thickness or texture. It should be mentioned in this connection that tyres with steel studs are not common in Britain at present.

Zinc metal spray has been widely used in Britain as the initial coat for a steel deck, with the object of providing temporary protection from corrosion during the construction period and a second corrosion barrier should there be failure of the surfacing system. It is found, however, that its presence impairs adhesion. In "pull-off" tests on actual surfacings comparative figures for the adhesion to steel were: zinc spray - 300 lbf/sq. in. (2 N/mm^2); asphalt - 500 lbf/sq. in. (3.3 N/mm^2); epoxy resin - greater than 750 lbf/sq. in. (5.1 N/mm^2). Moresoever, when cracking of the surfacing has occurred and water has penetrated the surfacing, the zinc is sacrificed fairly rapidly, leaving a white corrosion product with low adhesive strength.

5. STRAINS IN DECK UNDER TRAFFIC

It is evident from the results of all the trials carried out hitherto that the failure of thin resin-based surfacings takes the form of cracking over the longitudinal stiffeners. This is a result of the large strains or strain gradients in the deck plate near the stiffeners due to transverse bending under local wheel loads. Measurements of these strains have been attempted under stationary and moving traffic and the main features of the results may be summarised as follows:-

(i) Because strain gauges are $\frac{1}{4}$ in (6 mm) or more in length, they cannot record the peaks of a strain in a stress field with high gradients, e.g. at the toe of a weld. It is, therefore, an average strain which is usually being measured.

(ii) Fig. 7 shows the distribution of transverse strain in the top of the deck plate, at the position of the wheel, due to various wheel loads and configurations. The gauges are located mid-way between transverse diaphragms that were 14 ft (4.3 m) apart. It is apparent that the distribution is sensitive to wheel position and that the strain gradients are high. The highest tensile strains are measured at the position of the connection between stiffener and deck and the highest compressive strains occur over a wider strip mid-way between stiffeners.

(iii) If the transverse strain at the position of the deck/stiffener connection, mid-way between transverse diaphragms, is plotted as an influence line against the longitudinal position of the wheel, the change in strain for three different tracks of the same twin-tyred wheel is shown in Fig. 8. In this case, the strain is measured under the deck plate so that compared with Fig. 7, strains for corresponding wheel positions will be reversed. It is found that for transverse bending, the neutral axis lies horizontally, near the mid depth of the plate. As the wheel crosses the transverse diaphragm in the direction of the gauge point, it causes a tensile stress followed by a short peak of compressive stress, when the wheel is at the gauge point, and a return to tensile stress. This pattern reflects the superposition of the longitudinal bending effects of the deck on the local transverse bending of the plate. The ratio of peak tension to peak compression varies markedly with the transverse position of the vehicle wheel tracks with respect to the strain gauge and also with the effective loaded area of the wheel. A dynamic test of a surfacing on a deck plate which does not take account of the change from tension to compression does not simulate conditions prevailing under traffic.

(iv) The effect of resin surfacings, $\frac{3}{8}$ in (9.5 mm) thick and less, on the spreading of the load to the deck plate is negligible. Also their contribution to the strength of the deck in transverse bending is very small.

6. ACKNOWLEDGEMENTS

The author wishes to epxress his gratitude to Mr. D. E. Nunn and Mr. J. G. James for their assistance in the preparation of this paper.

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FIG. 1 HEXAGONAL GRID 1 in (25 mm) DEEP, ON AN ALUMINIUM DECK OF A BASCULE BRIDGE IN HULL.

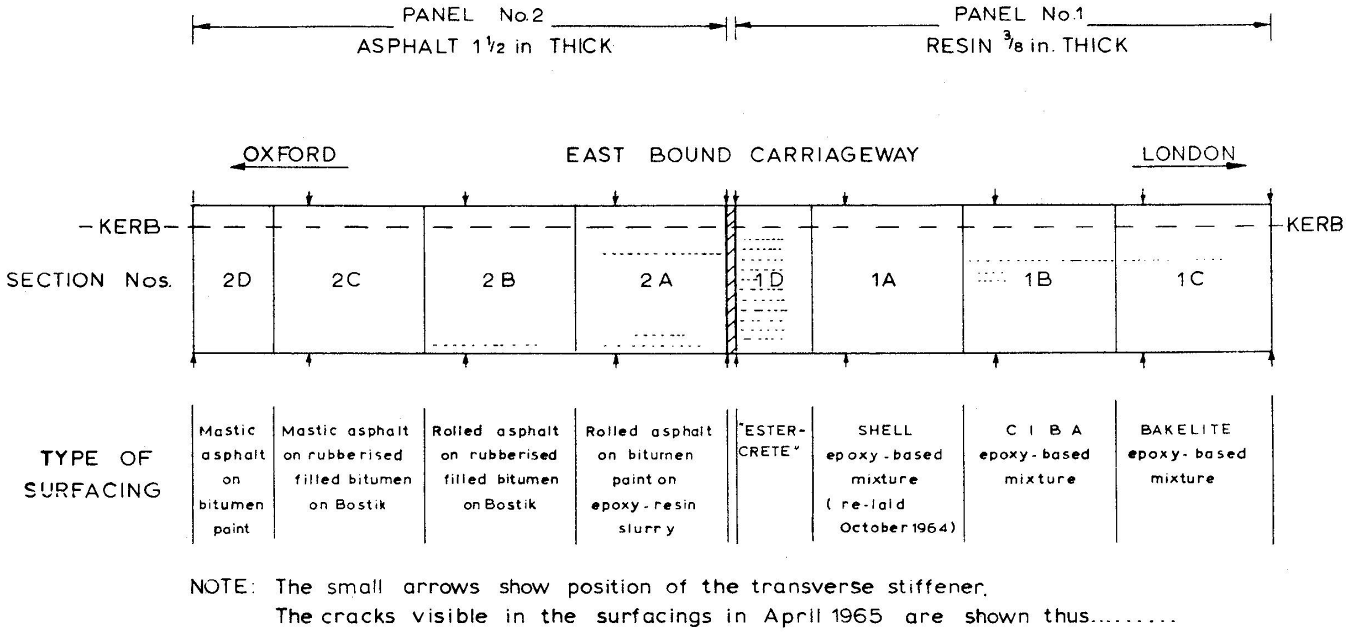

Fig. 2 LAY-OUT DIAGRAM. SEVERN BRIDGE TEST PANELS ON TRUNK ROAD A40 (WESTERN AVENUE), DENHAM, BUCKS., NOVEMBER 1963.

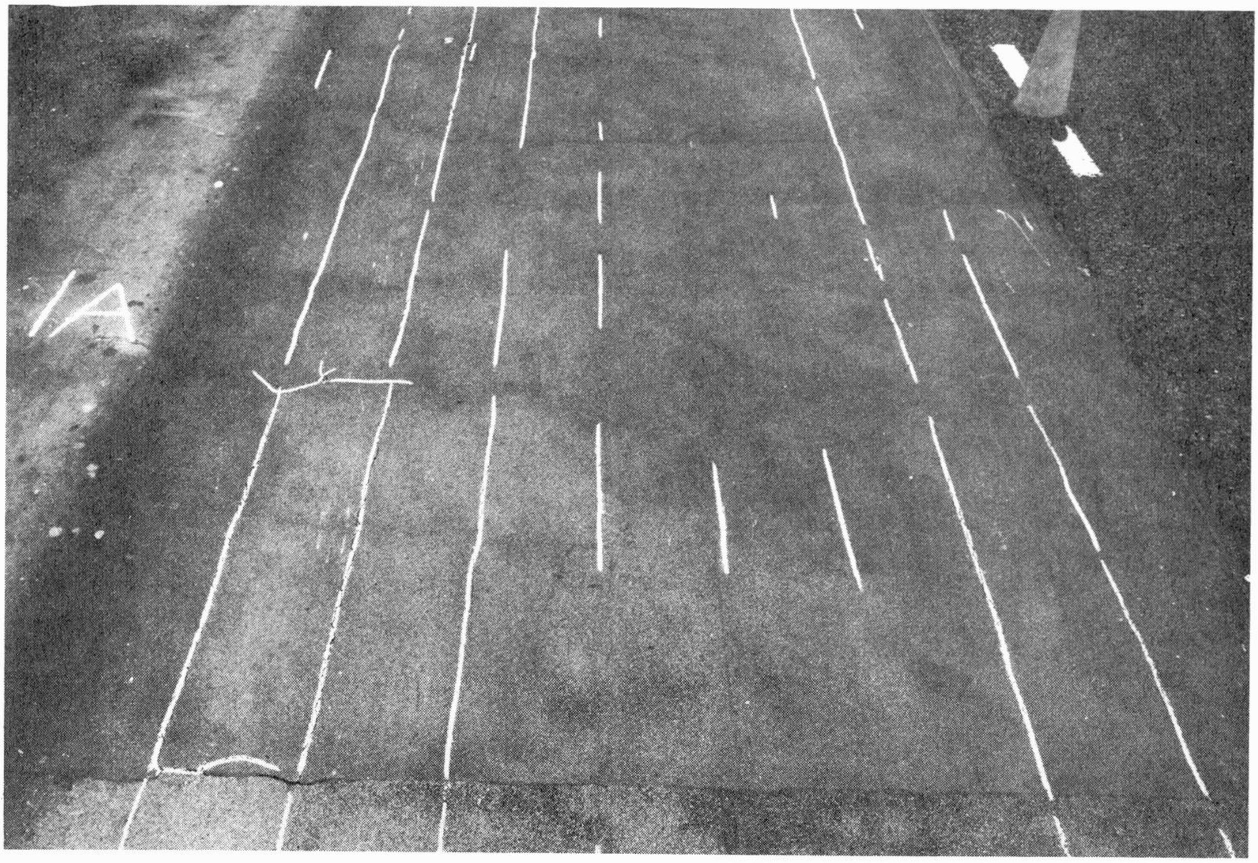

FIG. 3 CRACKING IN EPOXY RESIN SURFACING ON SECTION 1A, NOVEMBER, 1967

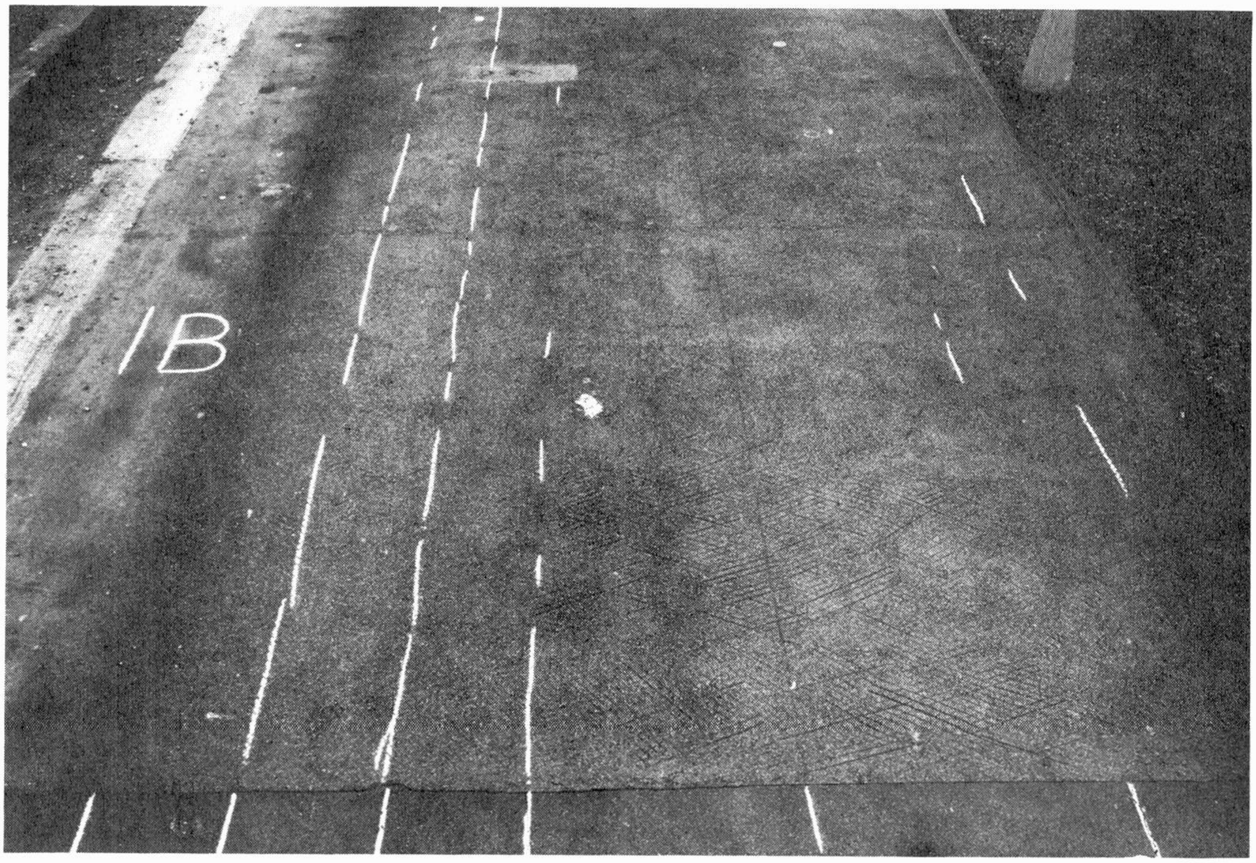

FIG. 4. CRACKING IN EPOXY RESIN SURFACING ON SECTION 1B, NOVEMBER, 1967

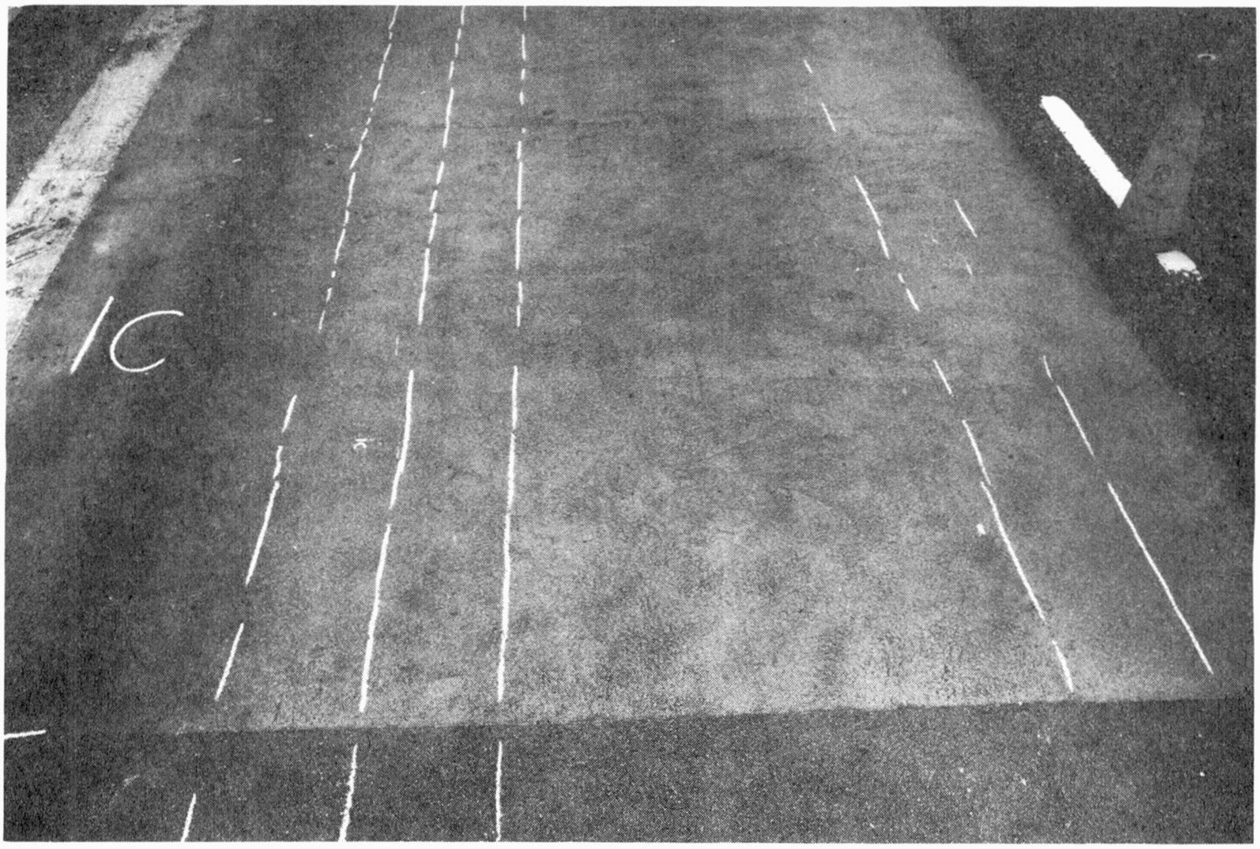

FIG. 5 CRACKING IN EPOXY RESIN SURFACING ON SECTION 1C, NOVEMBER, 1967

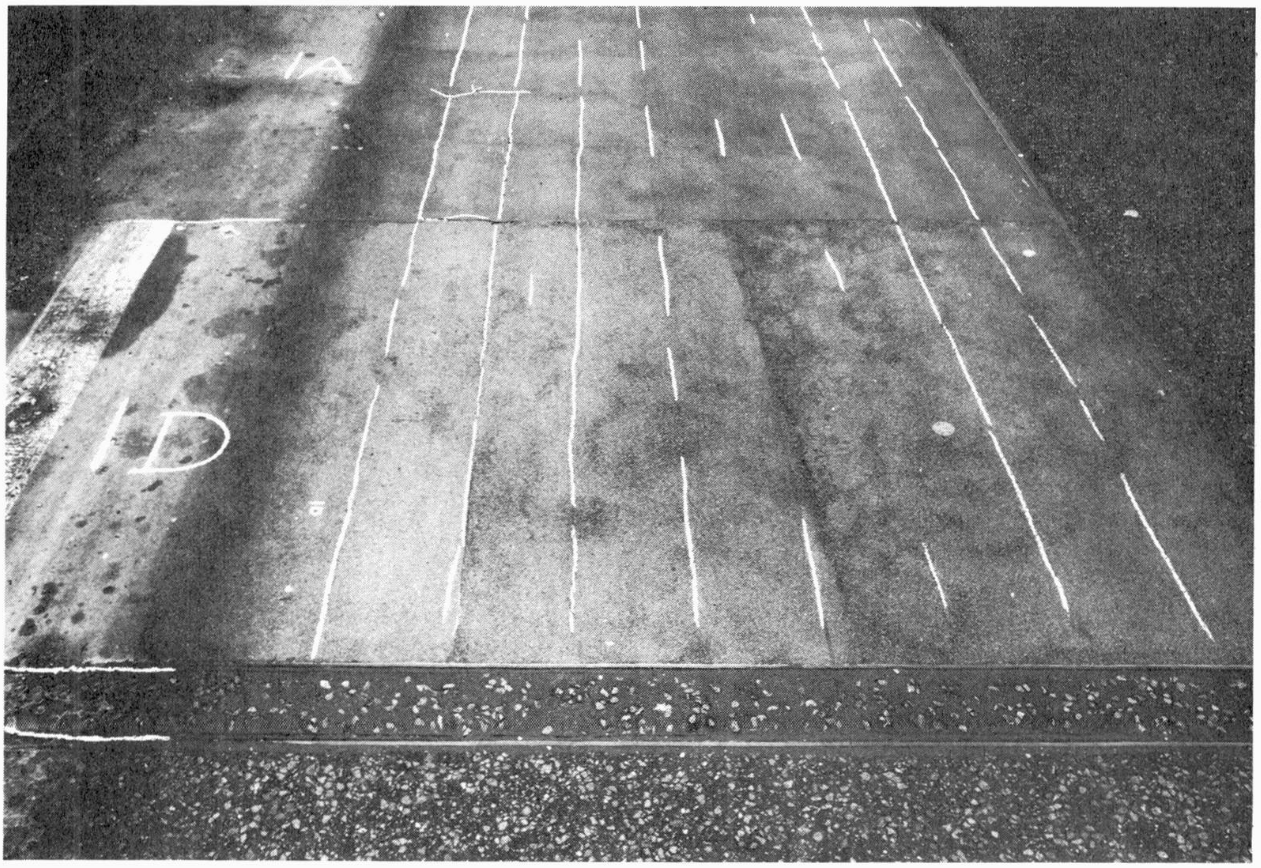

FIG. 6 CRACKING IN "ESTERCRETE" SURFACING ON SECTION 1D, NOVEMBER, 1967

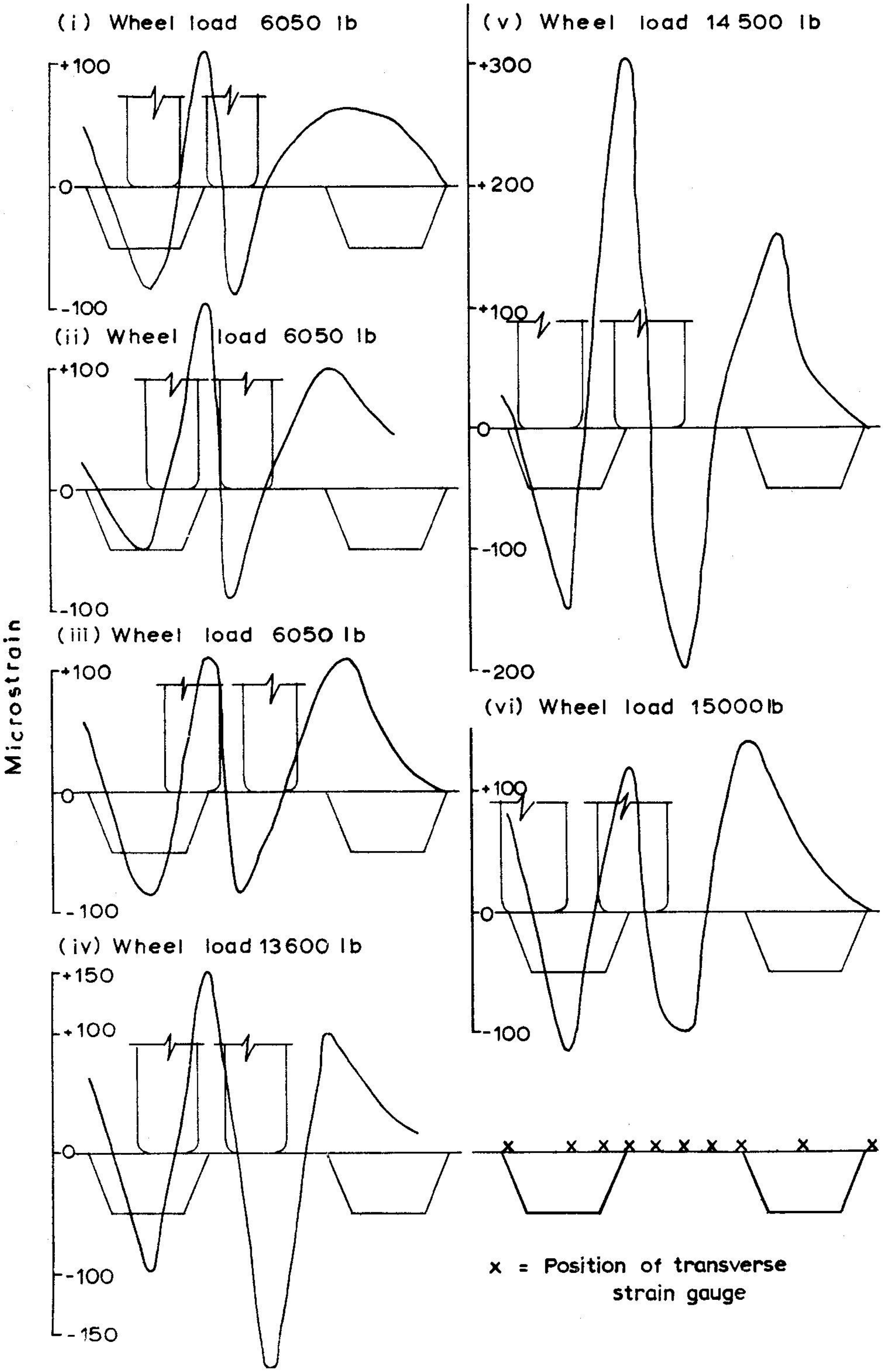

Fig. 7 DISTRIBUTION OF TRANSVERSE STRAINS IN THE DECK PLATE UNDER WHEEL LOADING SHOWING THE POSITION OF THE WHEELS RELATIVE TO THE DECK STIFFENERS

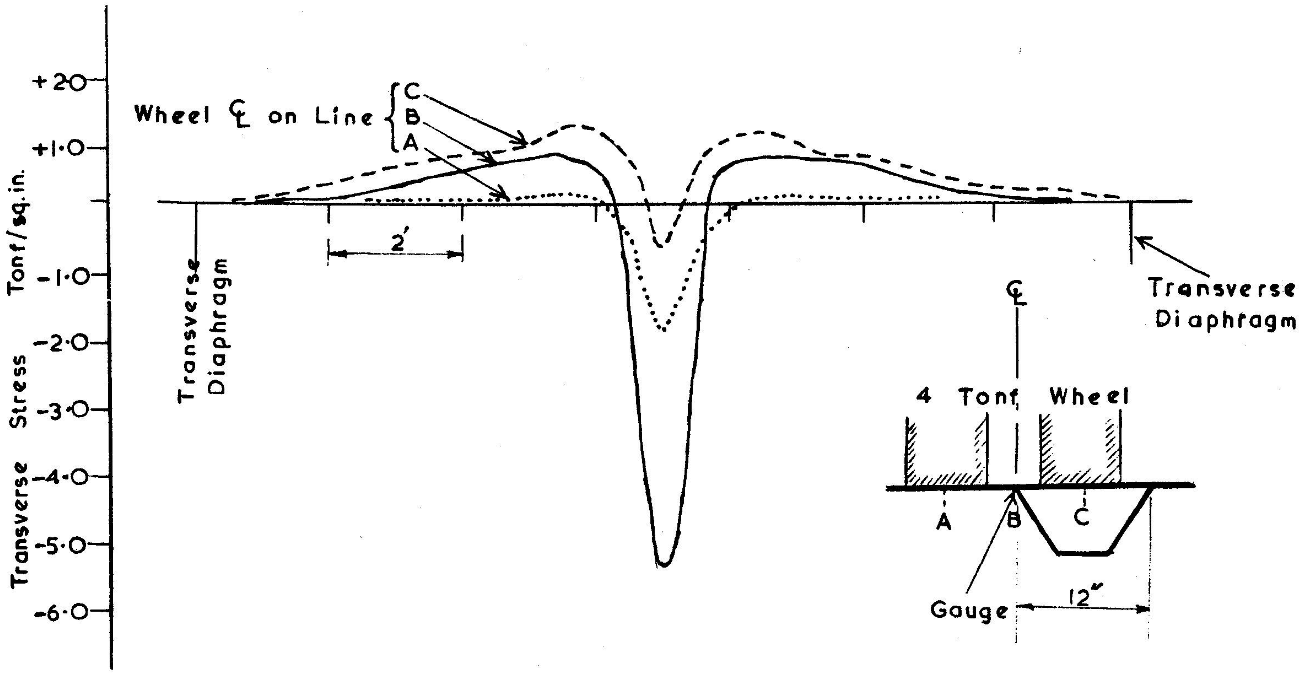

FIG. 8 TRANSVERSE STRESSES IN A DECK PANEL AT THE STIFFENER CONNECTION

SUMMARY

The experience in Great Britain with the performance of thin surfacings on bridge decks and on experimental panels is described in general terms. Thin bituminous surfacings are found to be suitable only on lightly trafficked bridges and on footpaths and cycle tracks. Neoprene or Rubber-latex/portland cement mixtures have tended to be lacking in waterproofing quality and have hitherto been less satisfactory than surfacings based on thermosetting resins. Epoxy resin surfacings have been used with moderate success on the stiffer decks and there are examples of such materials performing satisfactorily on temporary flyovers. On the more flexible decks, resin-based surfacings tend to crack over the deck stiffeners, and are likely to be less durable than mastic asphalt, 1 1/2 in (38 mm) thick.

RESUME

L'article décrit en grandes lignes les expériences faites en Grande Bretagne sur le comportement de revêtements minces sur des tabliers de ponts et sur des panneaux modèles. Les revêtements légers en goudron ne sont acceptables que sur des ponts à faible trafic ainsi que sur des voies de piétons ou de cyclistes. Des mélanges de ciment de Portland avec du néoprène ou du caoutchouc-latex ont tendance à laisser passer l'eau et ont donné jusqu'ici moins de satisfaction que les revêtements à base de résines thermoplastiques. Les résines d'époxy ont été utilisées avec un succès modéré sur les tabliers rigides, et il existe des cas où de tels revêtements donnent satisfaction sur des viaducs temporaires. Sur les tabliers plus flexibles, les revêtements à base d'époxy ont tendance de fissurer au-dessus des raidisseurs, et sont probablement moins durables que l'asphalte coulé, d'une épaisseur de 38 mm.

ZUSAMMENFASSUNG

In allgemeinen Zügen wird die Erfahrung über das Verhalten dünner Beläge in Großbritannien auf Brückendecken oder experimentellen Platten beschrieben. Geeignete dünne, bituminöse Beläge sind für leicht befahrene Brücken, Gehwege und Radstreifen gefunden worden. Neopren oder Gummi-Latex/Portland-Zement-Mischungen neigten zu einem Mangel an Wasserdichtigkeit und sind bisher weniger zufriedenstellend denn thermoplastischer Harz. Epoxyd-Harz-Beläge sind mit unterschiedlichem Erfolg auf steifen Decken gebraucht worden und Beispiele solcher Stoffe erfüllten auf provisorischen Überführungen befriedigend ihren Zweck. Auf biegsameren Decken neigen Beläge auf Harzgrundlage zu Rissen über den Plattenaussteifungen und sind weniger dauerhaft denn 38 mm dicker Gußasphalt.

DISCUSSION ON EXPERIENCE IN APPLICATION AND BEHAVIOUR OF RESIN-BASED WEARING SURFACES ON STEEL BRIDGE DECKS IN HOLLAND

Expériences dans l'application et le comportement de revêtements à base de résine sur des ponts à travée d'acier aux Pays-Bas

Erfahrungen in der Anwendung und im Verhalten von Belägen auf Harzgrundlage auf Stahlbrückendecken in Holland

K. VAN NESTE
Holland

1 Introduction

Trials on the application of thin wearing courses on orthotropic steel decks started in Rotterdam in 1955 with latex-cement binders and in 1956 with synthetic resins as binder. The first practical application based on polyester resin was in 1959 on a bascule bridge.

Since then the new bridges were designed as orthotropic plate construction. The movable spans, about 10 with a total area of 6000 m^2, mainly were equipped with a thin wearing course based on epoxy-tar, while for the fixed spans mainly a 50 mm. asphalt has been chosen, the exceptions for special reason.

For maintenance purposes on old bridges with wooden decks thin wearing surfaces,(surface dressings), directly applied on the deck, have been tried, but not with much succes. The last years prefabricated wearing courses have been applied. Rolled up mats, about 10x1 m. in size and consisting of the wearing course fixed on cloth like emery-cloth, are glued on the wooden deck with hot asphalt. The surface is practicable immediately after cooling.

2 Description of constructions used

2.1 12 mm. thick mortars

This wearing surface is specially used for the movable bridges to meet the disadvantages of the asphalt surfaces for this type of bridges, viz., the relative heavy weight of the 50 mm. asphalt and the risk of sliding down in the vertical position when the bridge is opened for a considerable time during sunshine.

The layer is applied on orthotropic steel deckplates of 12 mm. thickness, stiffened at about 300 mm. distance as a maximum with either flat bulb steels or with box-sections.

The wearing surface is applied as a mortar of a graded quartz-sand of about 2 mm. max. size and a binder. As a binder resins of the polyester-, polyurethane- and epoxy-type are available now as very flexible(rúbbery) to very hard materials. The elastic behaviour is more or less influenced by the plastic (liquid) behaviour and is determined by the stiffness-modulus S, being a function of time and temperature. An apparatus measuring the deflection of a short beam at constant load, applied by air pressure to make the measurement at short loadingtime possible without mass effects, gave very useful results.

For the first applications a polyester binder was used. Test panels generally showed good behaviour, but in practical applications polyester proved to be very critical. To meet this problem softer polyesters were used with the disadvantage of being more sensitive for water.

Epoxy-tar proved to be so much better in general behaviour that now only this binder is used.

Tests and experiance on executed bridges showed that the formation of haircracks formes the main problem.

If we make a calculation of the stresses due to traffic, we see that 12 mm. thickness is unfavourable in this respect. Fig. 1 gives the calculated bending stresses σ_w in the wearing course as a function of the stiffnessmodulus S of the mortar and the thickness δ_w of the wearing course. The figures are based on a 12 mm. steelplate, stiffened at 300 mm. distance and a regularly occurring moment due to local bending of 250kgf.cm per cm. For the wearing surface the short time stiffnessmodulus is important with a loading time of less than 0.1 sec. At low temperature, -20°C, the stiffness may rise up to 250000 kgf/cm^2. and more. By applying 15% by weight of binder it is possible to keep the stiffness below 200000. Though the breaking strength in bending of the mortar at this condition of temperature and loadingtime is well beyond 250 kg/cm^2, due to fatigue the reserve in strength is small.

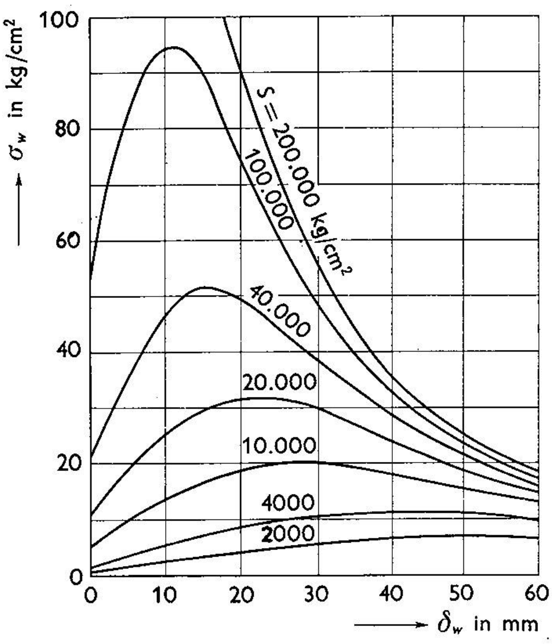

Fig. 1 Bending stresses in the wearing surface.

Plastic flow caracteristics appeared to be important too. Stresses due to temperature changes and due to shrinking of the binder are both present. Measurements with a special frame with built-in straingauges showed that, when cooling the mortar at a rate of 40°C. in 4 hours, above the glass transitiontemperature stresses do not build up, while under this temperature there is but little stress relaxation.

Application of the layer needs careful sandblasting of the steelplate. After blasting a primer based on epoxy-resin is applied. Short before the mortar is troweled a heavy coat of the pure binder is applied in which the mortar is troweled before this coat is cured. The coat gives an extra corrosion protection and an excellent adhesion.

Experience on a bridgedeck where haircracks occurred learned that a good adhesion prevents the cracks to penetrate to the steelplate. The primer and tackcoat should have at least the same or greater strength than the binder of the mortar. Zinc-rich primers do not seem to have good properties in this respect.

A practical testmethod is just chipping testpieces of the cured layer from the steelplate. If it is not possible to cleave the layer from the steel as a whole, but if the layer is cleaved in little pieces, breaking through the mortar itself, then adhesion is good.

A detailed description about application and behaviour of testpanels and executed bridges can be found in ref.[1])

Briefly it can be stated about the experience gained that the polyester wearing surface of the first bridge, finished in 1959 is still present with a few damaged spots. The traffic is moderately heavy. Though there are still no visible haircracks or detachements beside the damaged spots mentioned, the surface shows signs of penetration of water when the surface dries after being wet and tiny spots of rust can be seen. Replacing is planned within the near future, so that the service life of this surface is about 10 years.

A second bridge with polyester is still in good condition. During the execution difficulties were encountered by cracking due to shrinkage. The waterresistance seems to be better than the first.

In 1963 a bridge with epoxy-tar mortar (1500 m^2) was completed. The traffic on this bridge is very heavy. A few month afterwards, at the end of the winter, the whole surface was full of haircracks, above the stiffeners as well as between. The pattern between the stiffeners shows that beside bending of the steelplate, stresses due to shrinkage have played an important role. In the further 4 years till now the situation did not change. Beside a single spot no rust developed under the cracks and measurements of the electric resistance at places of haircracks showed that the cracks do not penetrate to the steel. Testpieces chipped out of the surface affirmed this.

Further bridges have been executed with epoxy-tar mortar, but instead of the polyamine hardener a polyamide is used now. Some disadvantage being a slower rate of curing. This hardener shows more plastic flow in bending tests.

The surfaces of these bridges are still in good condition after 3 years, though still some haircracks have been found above the stiffeners.

A comparison with the experience gained from the testpanels laid in 1962 on a bridge with very heavy traffic and from experience from executed bridges, giving the possibility to compare the behaviour of the formulation of the first bridges mentioned with the construction used now, justifies the expectation that the servicelife of these wearingcourses will be much beyond 10 years.

1) A.J.van Neste,"Kunstharsen op stalen brugdekken"(Synthetic resins on steel bridgedecks),Mededeling 18, febr. '68. Stichting Studie Centrum Wegenbouw, ARNHEM-HOLLAND.

A steelplate of 10 mm. thickness is believed to be too thin and a 12 mm. plate at least necessary to limit the formation of haircracks and their influence on servicelife of the wearing course.

The wear resistance is good provided the binder is not too flexible. At the testplates wear was measured by inserting white coloured flat cones in the wearing course. Increase of the diameter of the visible white circle being a measure for the amount of wear. The epoxy-tar mortar used at the moment shows a wear of about 1 mm. in 5 yars, 2 million vehicles passing the testplates a yar, among which relative much heavy traffic.

These mortars show good skid resistance at moderate speeds. Measurements with a skid testing vehicle (slip 86%, measuring speed 50 km/h.) yielded breaking coefficients from 0.50-0.70.

2.2 Surface dressings

This very thin type has been used for special circumstances on small removable bridges and in 1966 for a series of panels on the railway track of an existing bridge of 500 m. length, to add an extra bridge lane for peak hours of traffic.

The steelplate is 8 mm. thick and stiffened at 250 mm. intervals. After blasting with aluminum oxyde and priming with an epoxy-primer, a slurry of epoxy-tar, sand and a natural aluminum oxyde has been spead at a rate of 5 kg/m^2.,directly covered with the same aluminum oxyde at a rate of 6 kg/m^2.

The epoxy-tar binder is a very hard, polyamine cured type, giving excellent adhesion to the grains.

The surface is still in a perfect condition.

Experience with these dressings on steelplate showed that the binder should be very hard to prevent the grains to be worn out, flexible binders are not believed to give sufficient fixation of the graines, so that the steelplate should not be too thin with a view of the restricted bending ability of the surface.

2.3 30 mm. thick mortar.

An experimental execution of 700 m^2. is carried out on a part of a new bridge. This wearing surface is thought as an alternative for the 50 mm. asphalt surfaces used normal on the fixed spans.

From fig. 1 it is clear that the bending stresses decrease rapidly when the thickness is over 15 mm. This gives the possibility to decrease the amount of epoxy-tar binder inthe mortar to 8%. Measurements of the stiffness modulus gave values up to 270000 kgf/cm^2., but bending stresses remain at about half the level which has to be calculated for with a 12 mm. thick surface.

Compared with the asphalt surfaces the reduction in weight is about 40% or 50 kg/m^2.

Due to the low content of the most expensive material, the epoxy resin, which is less than 2 kg/m^2. and the fact that this wearing surface is laid in one layer, the difference in cost compared with the three- layer asphalt surface seems to be favourable.

3 Technical and economical prospects.

The use of thin wearing surfaces is believed to be justified for these applications, where a 5 cm. asphalt surface has disadvantages like on movable bridges. It is not likely that they will replace the use of asphalt on fixed spans, both for technical as for economical reasons.

Specially for the bigger bascule bridges a substantial saving may be gained, the reduction of weight having a very favourable influence on the cost of all parts of the construction.

The mortar type seems to be preferable, though surface dressings on steelplate seem to have good prospects too, provided they are based on a very hard binder and mineral.

SUMMARY

A 12 mm thick mortar seems to be an acceptable solution for movable bridges. Epoxytar with a polyamide hardener showed to be preferable. A service life of much more than 10 years may be expected. For fixed bridges the thin wearing surfaces are not believed to replace the 50 mm asphalt, but an alternative may be a 30 mm one-layer epoxy tar surface with a binder content of 8 percent.

RESUME

Un mortier de 12 mm d'épaisseur s'est montré utile pour les ponts mobiles. Cependant le goudron avec époxy, additionné d'un durcisseur du type polyamide est préférable. On pourrait s'attendre à une durée de vie de bien plus de 10 années. Il n'est guère probable que les revêtements minces remplacent l'asphalte épais de 50 mm, mais une alternative serait un revêtement à une couche de 30 mm de goudron avec époxy, contenant 8 % de liant.

ZUSAMMENFASSUNG

Ein 12 mm dicker Mörtel hat sich für bewegliche Brücken als annehmbare Lösung gezeigt. Teerepoxydharz mit einem Polyamid-Härter erwies sich überlegen; so kann eine Lebensdauer von über zehn Jahren erwartet werden. Für feste Brücken werden die dünnen Verschleißschichten nicht als Ersatz für die Asphaltbeläge betrachtet, aber eine mögliche Alternative kann ein 30 mm dicker, einschichtiger Teerepoxydbelag mit 8 % Bindergehalt sein.

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REHABILITATION OF A MOVEABLE HIGHWAY BRIDGE USING ORTHOTROPIC PLATE WITH THIN WEARING SURFACE

Réparation d'un pont-routier mobile au moyen de plaques orthotropiques avec revêtement mince

Ausbesserung einer beweglichen Straßenbrücke durch orthotrope Platten mit dünner Deckschicht

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The Hull River Bridge, near Beverley, Yorkshire, constructed in 1912, consists of two side spans (each of 17 ft.) and a central rolling retractable span of 33 ft. The central span tilts and rolls onto the West span and West abutment to allow passage of river craft.

The central span consisted of Hobson trough units formed by arch plates riveted to inverted tees at the bottom and spanning transversely between half through main girders spaced 25'9" apart. As constructed the troughs were filled with coke breeze concrete and a one inch asphalt layer provided the carriageway wearing carpet as shown in Fig. 1. There are two 9'6" lanes of roadway.

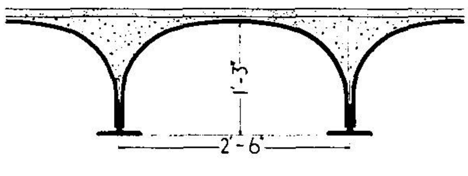

Fig.1.

In 1930 when repairs were required to the floor of the central span the concrete filling was removed from the crowns and from the valleys to a depth $3\frac{1}{2}$" below the crowns to accommodate longitudinal oak timbers of $6\frac{1}{2}$" maximum depth, shaped to the contour of the trough and valley concrete surfaces. The new wearing surface consisted of transverse elm boarding $1\frac{1}{2}$" thick nailed to the oak timbers as in Fig.2. This wearing surface was subsequently replaced by a 1" asphalt layer.

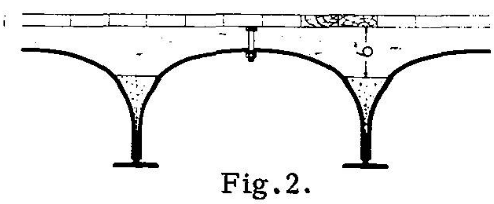
Fig.2.

Inspection of the bridge in 1961 disclosed marked vibration and racking under road traffic which had increased in weight and volume over the years. The bridge had become difficult to open and close on account of the added dead load due to water-logging of the floor timbers. Spot checks where timbers were temporarily lifted for inspection disclosed serious sporadic corrosion, aggravated by the timber and steel being in contact. An analysis of the strength of the bridge indicated overstress of the trough units both under a single 16 ton vehicle and two 10 ton vehicles, one per lane, allowing 25% for impact.

The analysis assumed that the troughs behaved independently under wheel loads but in fact considerable distribution by the timber infilling was revealed in tests.

It was decided to provide a new fixed bridge and approaches about 100 yards upstream of the drawbridge but before this can be done the drawbridge has to remain in continuous service and strengthening was essential.

In view of the extensive corrosion and other suspected hidden defects in the deck it was decided to provide an orthotropic steel deck after removing the timber filling. Fig. 3 shows a cross section of the deck after strengthening. The orthotropic deck consisted of a 7/16 in. thick mild steel plate stiffened below by 3" x 3" x $\frac{1}{4}$" longitudinal closed ribs cut from 6" x 3" hot finished seamless rectangular hollow sections. The use of hot finished sections reduced locked-in stresses induced by welding. Fig. 4.

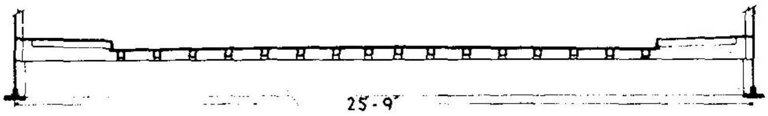

Fig. 3.

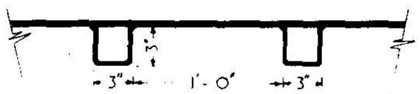

Fig. 4.

The deck was fixed with high strength bolts at the crowns of the troughs which still formed the floor beams. Valley stiffeners were welded to the troughs to maintain their stability. The bolts were inserted through holes in the top plate which were sealed by plugs welded in after the bolts had been tightened as shown in Figs. 4a and 4b.

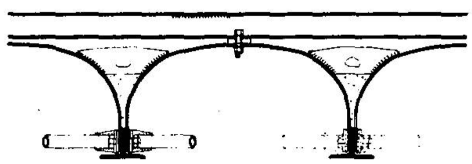

Fig.4a.

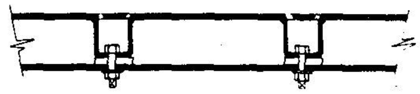

Fig.4b.

To increase the torsional resistance of the trough system and improve the capacity of the deck to distribute wheel loads, a tubular lacing system was applied in the horizontal plane of the tees as in Fig. 4a. Corroded portions of the troughs were made good by reinforcing plates welded to them.

A 3/8" thick epoxy wearing surface was applied directly to the steel deck at site under controlled temperature and humidity. A resin binder base coat was first laid at the rate of 1 lb. per square yard on the cleaned surface to the following composition:

Epikote 828	40% by weight
Orgol Coal tar	43% " "
Yarmol Pine Oil	8% " "
Phenol	2% " "
Dimethylene triamine	7% " "

The surfacing mixture consisting of 1 part resin binder to 4 parts of dry aggregate by weight was trowelled immediately over the base coat to a thickness of 3/8".

The composition of this binder was as follows:

Araldite F	44% by weight
Soft tar	22% " "
Versamid 125	21% " "
Thiskol LP3	2% " "
Hardner 956	2% " "
Hardner 960	2% " "
Butyl glycidyl ether	7% " "

The aggregate used consisted of:

Calcined bauxite	3/16" to No. 6 B.S.	sieve	30% by weight
" "	No.6 to No.10	" "	35% by weight
" "	No.10 to No.30	" "	15% " "
Silica sand	No.25 to No.100	" "	20% " "

The surface was lightly dusted with fine calcined bauxite No.10 to No.30 B.S. sieve at a rate not exceeding 400 sq.yd. per ton.

Work proceeded on one traffic lane at a time in order to avoid complete closure of the bridge.

Stresses were measured in the floor beams and main girders induced by test loads at critical stages of the work and at completion.

Two Matador lorries loaded with Atkinson gritter boxes were used as test loads. These were placed side by side three feet apart with their rear axles first over the crown of the trough at mid span and then at each adjacent valley.

An initial approximate study of stresses due to the test loads gave the maximum compressive and tensile live load bending stresses in the trough units as 4.27 ton/sq.in. and 8.06 ton/sq.in. respectively, and in the main girders as 1.68 ton/sq.in. A more recent study using the finite element technique has considered the deck as an orthotropic plate elastically supported on torsionally stiff transverse beams which frame into the main girders. This study has given live load stresses which are considerably below the original estimate. The maximum compressive and tensile bending stresses in the trough units are respectively 1.75 ton/sq.in. and 4.06 ton/sq.in. and the maximum main girder stresses are 1.22 ton/sq.in. in tension and compression.

Measured trough unit stresses are 84.5% in compression and 63% in tension of the calculated stresses. Main girder stresses are 100% in compression and 77% in tension of the calculated stresses. In analysing such a complex structure it is impossible to take account of all strength increasing factors. It is a tribute to modern techniques of analysis that observed and calculated stresses are as close as indicated above. Based on the results of the analysis alone the repaired bridge is shown to have a wide margin of safety under live load. A separate check has shown that there is also a wide margin of safety against stress fluctuation and reversal which occurs when the bridge is withdrawn for purposes of navigation.

The epoxy wearing surface remains in good condition after two years under heavy and almost continuous traffic.

I should express my thanks to Mr. L. F. Crossley, the East Riding of Yorkshire County Surveyor for his permission to make this contribution.

This repair and strengthening job was undertaken in close association with the Bridges Department of the British Ministry of Transport.

This department had already gathered experience in providing thin wearing surfaces to steel decks. Their recommendations were very largely followed in preparing the epoxy specification detailed above.

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SUMMARY

The floor of a two lane half through steel retractable highway bridge constructed in 1912 was formed of transverse troughs built of arch plates riveted to inverted tees at the bottom. Signs of overstress in the floor became apparent with increase of live load and strain gauge measurements indicated the extent of overstress. Traffic had to be maintained during rehabilitation but single lane working was allowed. After removal of shaped timber and concrete infilling from trough valleys an orthotropic steel deck system with thin epoxy wearing surface was superimposed one lane at a time, attached to the troughs by high strength bolts at the arch crowns and a tubular lacing system was applied in the horizontal plane of the tees to improve torsional resistance of the troughs, so improving longitudinal distribution of wheel loads. The wearing surface was applied at site under controlled temperature and humidity. Live load strain measurements were made in floor and main girders under test loads at critical stages of the work and after completion.

The bridge now has a substantial margin of strength and fatigue resistance and with little increase in dead weight. The epoxy wearing surface remains in good condition after two years heavy and almost continuous traffic.

RESUME

Le plancher d'un pont-routier escamotable en acier à deux voies et à tablier inférieur construit en 1912, était constitué d'auges transversales formées de plaques courbées rivées à leur extrémités inférieures à des Tés renversés. Des signes de surcharge se sont manifestées par suite de l'augmentation des charges appliquées. Le degré de la surcharge a été mesuré au moyen de jauges de déformation. Il fallait maintenir la circulation pendant la réparation, toutefois il fut possible de travailler sur une voie. Après avoir enlevé le plancher en bois taillé et le béton contenu dans le creux des auges, on plaça un plancher orthotropique en acier et une surface frottante mince en époxy. Le placement s'effectua voie par voie. Le plancher orthotropique fut fixé aux sommets des auges au moyen de boulons de haute résistance. Une structure tubulaire fut placée dans le plan horizontal des Tés, et ceci afin d'augmenter la résistance des auges à la torsion. En même temps, la distribution longitudinale des charges des essieux fut améliorée. La surface frottante fut appliquée sur le chantier même. Pendant l'application on contrôla la température et le degré d'humidité. Des tests par poids roulant ont été effectués à certaines étapes critiques du travail ainsi qu'à son achèvement, ceci pour mesurer la déformation du plancher et des poutres maîtresses.

Malgré une légère augmentation du poids mort du pont, il y a maintenant une marge substantielle de résistance et une résistance plus effective à la fatigue. La surface frottante d'époxy se maintient en bon état et ceci après deux années de circulation intense et pratiquement continuelle.

ZUSAMMENFASSUNG

Die untenliegende Fahrbahn einer 1912 erbauten zweispurigen und zurückziehbaren Stahlträgerstraßenbrücke bestand aus querlaufenden Trögen, die aus halbrunden Blechen zusammengesetzt waren, welche auf ihren unteren Kanten an umgekehrte T-Profile genietet waren.

Mit zunehmender Verkehrslast zeigte sich eine Überbeanspruchung der Fahrbahn und Messungen mit Spannung-Dehnung-Messern zeigten die Größe dieser Überbeanspruchung. Während der Ausbesserungsarbeiten mußte der Verkehr aufrecht erhalten bleiben, jedoch war es gestattet, jeweils nur an einer Fahrbahn zu arbeiten. Nach der Entfernung des Holzes und der Betonausfüllung der Trogtäler wurde ein orthotropes Stahlfahrbahnsystem mit dünner Epoxyddeckschicht jeweils über einer Fahrbahn aufmontiert. Dieses System wurde an den Trögen durch hochfeste Bolzen an den Bogenscheiteln befestigt und eine Rohrvergitterung wurde in der Horizontalebene der T-Profile angebracht, um den Drillwiderstand der Tröge zu erhöhen und dadurch die Längsverteilung der Radlasten zu verbessern. Der Belag wurde auf der Baustelle bei kontrollierter Temperatur und Feuchtigkeit aufgebracht. Während kritischer Arbeitstufen und nach Abschluß der Arbeit wurden Messungen der Nutzlastspannung in den Fahrbahn- und Hauptträgern unter Probelasten gemacht.

Die Brücke hat jetzt wesentliche Festigkeits- und Ermüdungsfestigkeitsreserven ohne große Zunahme des Eigengewichts. Die Epoxydfahrbahndecke bleibt nach zwei Jahren starken und fast ständigen Verkehrs in gutem Zustand.

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