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III d 3

Roadway Surfacings on Steel and Aluminium Bridge Decks: Research and Progress in Great Britain

Revêtements routiers sur les tabliers de ponts, en aluminium ou en acier; recherches et progrès réalisés en Grande-Bretagne

Fahrbahnbeläge auf Brückentafeln aus Stahl und Aluminium: Forschung und Fortschritte in Großbritannien

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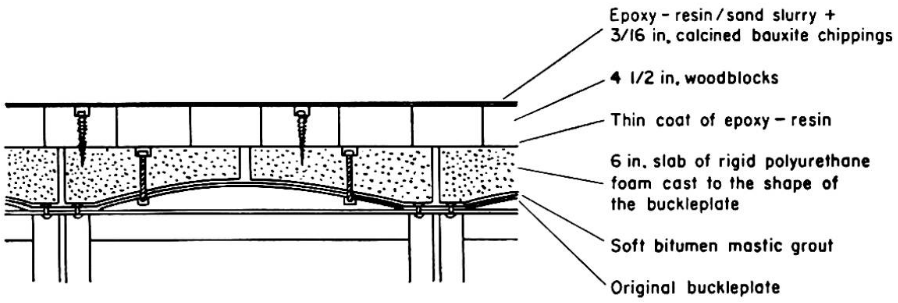
Introduction

Research on mastic-asphalt surfacings for steel orthotropic-plate decks was begun at the Road Research Laboratory in 1949; this work was summarized by Trott and Wilson in papers given to the 6th I.A.B.S.E. Conference at Stockholm in 1960 [1] and to the 4th Congress of the International Asphalt Association at London, in 1962 [2]. In the last 5 years research has been extended to surfacings on aluminium decks as well as steel and to materials other than mastic-asphalt. These recent materials, which are based on synthetic resins, are more expensive *per se* than asphalt, but because they are being applied more thinly the cost will be only slightly greater. On long-span bridges the saving in weight could lead to structural economies that would more than offset the surfacing costs which represent a small fraction of the total cost of a bridge. A further attraction of these recent surfacing materials is the way in which they have been applied to the bridge-deck sections at the factory before assembly. This avoids delays on the sites due to weather conditions.

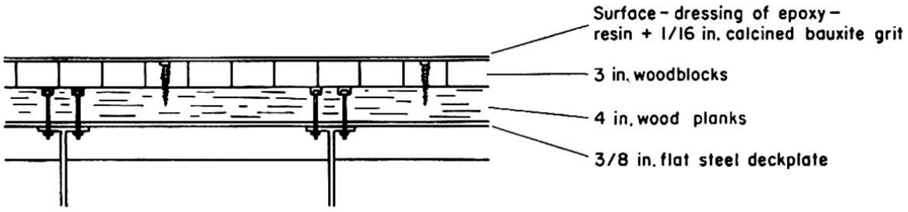
Details of some of the decks referred to are shown in Fig. 1.

Asphalt Surfacings

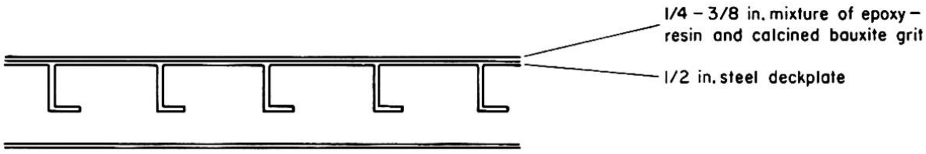
No pre-war work with asphalt on flat plate steel decks can be traced in this country. After the war, however, orthotropic plate decks were proposed for the Forth and Severn road bridges and work was started at the Road Research Laboratory in 1949 to investigate the problem. Full-scale deck-sections were set into a heavily-trafficked trunk roadway and covered with mastic asphalt surfacings of various types and thicknesses. This work has been reported in detail by Trott and Wilson [1, 2] who found from these



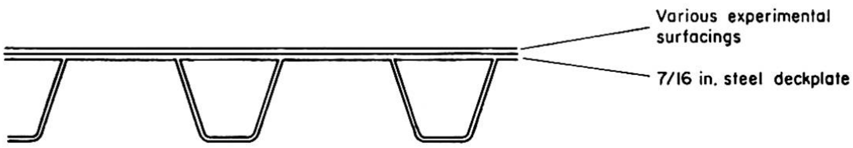
(a) Tower Bridge, London. Originally built 1894. Redecked 1962



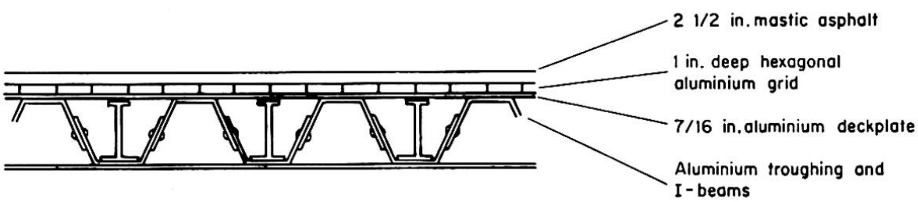
(b) Haven Bridge, Yarmouth. Originally built 1929. Surfaced 1961



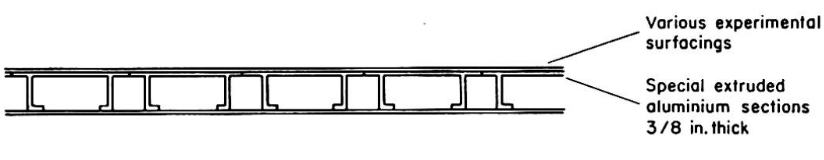
(c) Camp Hill Prefabricated Flyover, Birmingham. Built 1961



(d) Trial deckpanels for the Severn Bridge, now under construction.



(e) Drypool Bridge, Hull. Built 1961



(f) Lock Bridge, Gloucester. Built 1962

Fig. 1.

trials that at least $1^1/_2$-in. of mastic asphalt was necessary to withstand cracking on $^1/_2$-in. steel plate with stiffeners 15 in. apart. The surfacing on which these conclusions were based has been subsequently removed and it was found that fine cracks had in fact occurred in $1^1/_2$-in. asphalt (after 5 years) over some of the stiffeners. A little negligible deformation was noted. Thus 2 in. of mastic-asphalt to B.S. 1447 is a suitable surfacing for flat-plate decks of normal stiffness. If care can be exercized in laying the surfacing, the thickness can be reduced to $1^1/_2$ in. Because of the great spans of the Forth and Severn bridges, the Consultants have, in these cases, proposed this minimum thickness. To ensure that the best specification is chosen for the asphalt, and because engineers would like to use still lighter (i.e. more flexible) decks, further full-scale experiments are being carried out on asphalt surfacings.

A series of surfacings laid on a steel-decked swing bridge (Cross Keys Bridge in the village of Sutton Bridge, Lincolnshire) in 1960, include:

a) Single-course mastic asphalt, $1^1/_2$ in. thick.
b) Two-course mastic asphalt, $1^1/_2$ in. thick.
c) Single-course mastic asphalt, $1^1/_2$ in. thick containing a rubber additive.
d) Single-course mastic asphalt, $1^1/_2$ in. thick laid on a coat of epoxy resin in place of the normal bituminous primer. This resin was used in an attempt to improve adhesion between the asphalt and the steel as well as to provide a waterproof lower layer.

After 3 years there appears to be no significant difference between the various systems although trial patches have not yet been taken up to inspect the adhesion to the steel. No serious deformation has occurred and no major cracks have developed except over badly welded joints in the deck plates.

Two of the most interesting non-experimental works carried out in recent years, are the aluminium-decked bascule bridges at Hull, both of which have the same type of deck (shown in Fig. 1e) and a 100×40-ft. roadway. The first of these (North Bridge) was surfaced in 1958 with mastic-asphalt $2^1/_2$ in. thick laid over large-meshed expanded metal welded to supporting studs. Within

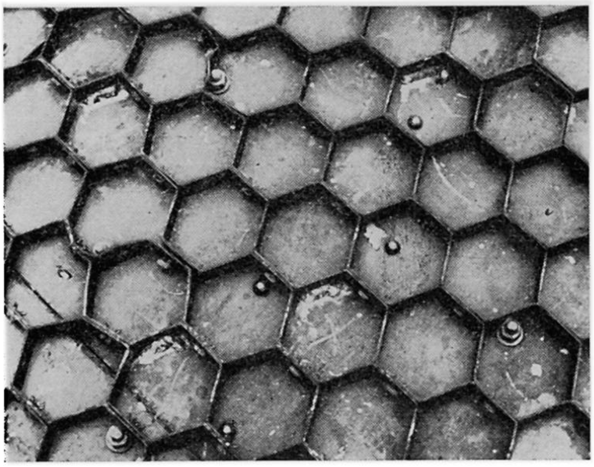


Fig. 2. Aluminium grid on aluminium deck plate before laying mastic-asphalt surfacing Drypool Bridge, Hull, 1961.

the first year bad crazing had occurred in the asphalt. For the second bridge (Drypool Bridge), therefore, the expanded metal was omitted and a hexagonal aluminium grid 1 in. deep was welded directly to the deck plate (Figs. 1e and 2). The surfacing of $2^1/_2$-in. mastic-asphalt was completed in July 1961 [3]: after 2 years it is in very good condition.

Rubberized Bitumen Surface-dressings

An asphalt surfacing 2 in. thick weighs as much as the $^1/_2$-in. steel plate of the deck on which it lies, yet it contributes nothing to its strength at summer temperatures [1]. Alternative, lighter surfacings are therefore being sought. A surface dressing of rubberized bitumen has given good results under light traffic. The rubber-bitumen is spread at a rate of about 6 yd^2/gal. and is covered with small chippings (about $^1/_8$ in.) at the rate of 180 yd^2/ton. One such surfacing, laid in 1960, is still in very good condition and it is therefore proposed to lay rubber-bitumen surface-dressings on the footpaths and cycle tracks of the new Forth suspension bridge.

On heavily-trafficked sites surface-dressings have been found to be insufficiently durable, and for major bridges the use of lightweight non-bituminous surfacings is being investigated.

Rubber-latex / Cement Mixtures

The first non-bituminous surfacing to be tested on steel by the Road Research Laboratory was a proprietary material consisting of a mixture of natural rubber latex, cement, sand or crushed granite, and asbestos, laid about $^3/_8$ in. thick [4]. In 1950 several such mixtures were tested on the Laboratory's road-machine and the best of these were laid on a steel plate carrying heavy road traffic. Durability proved satisfactory but after 5 years when the surfacing was removed, it was found to have admitted water to the steel plate in places: the material had also become noticeably softer than it was when laid. Despite these faults, the surfacing was regarded as worthy of further development if it could be made completely impermeable. But work has been concentrated on other materials and no further road tests have been carried out in Great Britain. A similar material was laid commercially, however, on the footpaths of a steel-decked bascule bridge in London, in 1960 and so far it is satisfactory.

Epoxy-resin-based Mixtures

Bituminous mixtures are thermoplastic, i. e. they tend to soften and deform in the summer and become brittle and crack in the winter, especially when laid on a smooth and flexible, metal bridge-deck. A material with adequate physical properties which remain substantially the same at both summer and winter temperatures would be advantageous. Concrete for instance is non-thermoplastic but it is too inflexible to be laid as a thin surfacing. One method of obtaining a relatively flexible, non-thermoplastic composition, i. e. by using a mixture of rubber latex and Portland cement as the binding medium, has been described. Another is to make the surfacing with a suitable chemically-hardened resin of the so-called "thermosetting" type: this class of resins includes the polyesters and epoxies.

The Road Research Laboratory began investigating the use of polyester and epoxy resins for road-marking materials in 1956 and, in 1958, started a more comprehensive programme of research which includes their use in bridge-surfacings. At present little work is being done on polyester resins as they were found to exhibit high setting-shrinkage and brittleness; consequently most of the current work is with epoxies.

Three different surfacing techniques have been used with epoxy resins:

1. *Surface-dressing method.* A layer of resin is applied at the rate of about 2 lb./yd^2 (i. e. about 0.05 in. thick) and then sprinkled with grit, usually $^1/_8$ to $^1/_{16}$ in. in size.

2. *Slurry method.* A 1 : 1 or 2 : 1 mixture of sand and resin is spread at the rate of 3 to 6 lb./yd^2 (i. e. about 0.1 in. thick) and then sprinkled with grit, usually $^3/_{16}$ to $^1/_8$ in. in size.

3. *Trowelling method.* A mixture of grit and resin in 6 : 1 proportions is laid over a priming coat of unfilled resin by trowel to a thickness of about $^3/_8$ in.

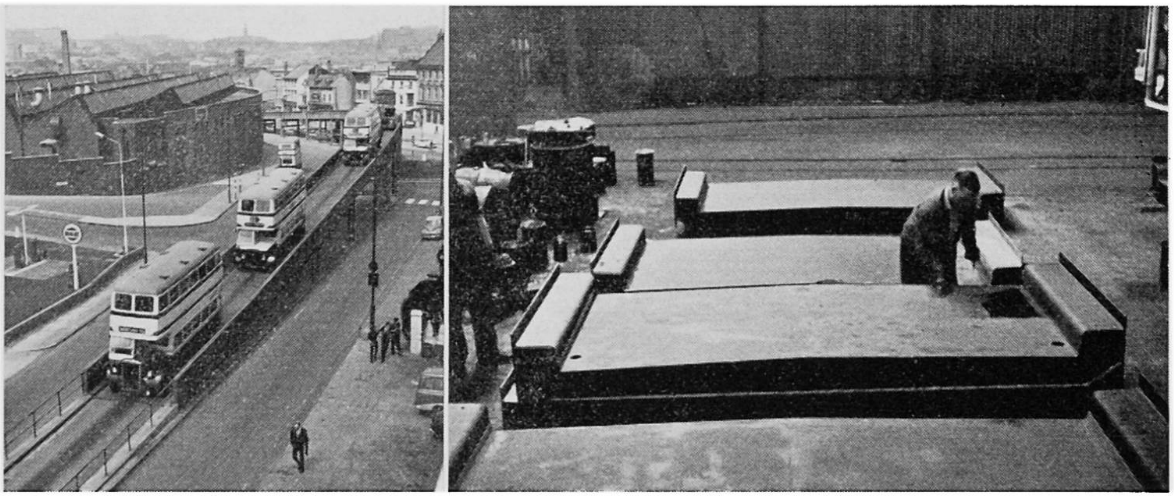
The amount of traffic-wear expected, the weight of surfacing which can be permitted on the bridge and the irregularity of the deck determine the type of surfacing used. A wide variation in the mechanical properties of the surfacings can be obtained by varying the resin formulation and incorporating various flexibilizers and diluents.

A discussion of the compositions of epoxy-based mixtures and the techniques of laying them together with a review of British experiments has been given elsewhere [7].

A brief description of some of the major road trials is given below:

The first British trial of epoxy resins on a steel deck was on orthotropic panels 7 ft. wide, of the type described by Trott and Wilson [1], set into a heavily-trafficked road in 1960. Epoxy-resin surface-dressings and trowelling mixtures were laid: the latter are still in good condition but the surface-dressings have been replaced. In 1960, a 100-ft. length of trowelled surfacing $^3/_8$ in. thick was laid on the Cross Keys swing bridge, referred to earlier. This is still in good condition. In 1961 two experiments were begun to compare various resin formulations. In the more important of the two, various resin-sand slurries were applied to 6-ft. × 4-ft. × $^1/_4$-in. steel plates screwed to the timber deck of a small swing bridge in the City of Lincoln: good results are being obtained. Recently an aluminium bascule bridge in Gloucester was surfaced with various materials including epoxy-resin-based trowelled mixtures $^{3}/_{8}$ in. and $^{1}/_{4}$ in. thick and an epoxy-resin/sand slurry (Fig. 1f). Further trials are being made in 1963 on 60-ft. long steel deck panels of the type now being constructed for the Severn Bridge (Fig. 1d).

In addition to these direct experiments the Road Research Laboratory has been associated with several commercial jobs and the performance of the materials used is being closely followed. The most important of these jobs is a steel flyover in Birmingham [5] which is 790 ft. long and was prefabricated in sections surfaced with a trowelled mixture of epoxy-resin and grit before assembly (Figs. 1c and 3). In 1961, a surfacing of epoxy-resin slurries was applied to the old wood-block deck of a large two-leaf bascule bridge in Great Yarmouth (Fig. 1b). Before surfacing, vehicle collisions on the slippery wood were frequent due to the slope of the deck and poor approaches to the bridge:



a) General view. b) The deck sections being surfaced before assembly.

Fig. 3. Prefabricated steel flyover, Camp Hill, Birmingham, 1961.

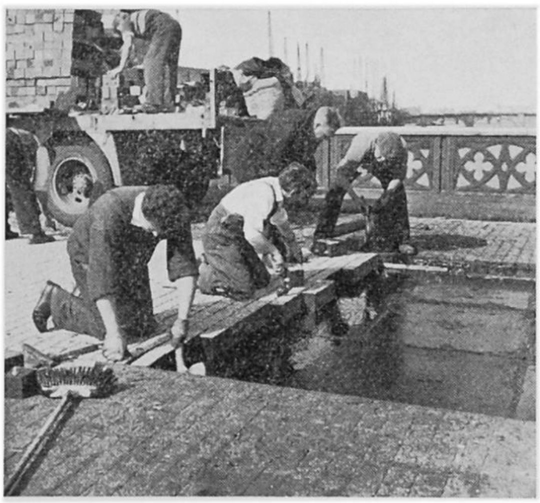


Fig. 4. Laying wood blocks which have been previously coated with an epoxy-resin-based surfacing; Tower Bridge, London, 1962.

since the surfacings were applied, however, accidents have been eliminated. When the re-decking of Tower-Bridge, London, was carried out in 1962 a similar surfacing was used on the wood-blocks [6]. In this case the coating was applied to the blocks under controlled conditions in the factory thus saving working-time on the bridge and avoiding adverse weather conditions. Rigid polyurethane foam was used between the wood-blocks and the buckle-plate base in place of the former timber (Figs. 1a and 4). The foam weighed only 20 lb./ft.^{3} and had a compressive strength of 1000 lb./in^2.

Summarizing the present situation of research on epoxy-resin-based surfacings for bridge decks, some of them appear promising, especially where weight must be kept to a minimum. However, not all of the trials have been successful and several years must elapse before conclusions can be drawn and recommendations made.

Prefabricated surfacings

The use of prefabricated sheeting stuck to the deck is a possible solution to the light-weight surfacing problem. Theoretically such sheeting could have the following advantages:

a) A wider range of materials could be used in its manufacture than is possible by normal road-making methods, e.g. plastics which require heat-curing or pressure-forming.
b) Under factory conditions uniformity of properties could be maintained during its manufacture.
c) In localized areas, such as in wheeltracks, the sheeting could be easily taken up and replaced.
d) Bad weather difficulties would be minimized especially if the sheeting was stuck to the deck-sections in the factory before assembly.

In practice the two main difficulties are likely to be:

a) The slipperiness of most plastic sheetings.
b) The adhesion of the sheeting to the deck.

The American "asphalt plank", a primitive form of surfacing of this type, consists of bitumen/sand/asbestos mixtures compressed into slabs 1 to $1^1/_2$ in. thick. These have not been used in Great Britain. The Road Research Laboratory, however, has investigated many forms of rubber and plastic sheeting over the last ten years for road-markings and more recently has been examining the use of the most promising of these as a bridge-deck surfacing. This material, shown in Fig. 5 being stuck to a timber deck, is a proprietary material about 0.1 in. thick based on P.V.C. (polyvinyl chloride). When introduced some years ago it was in a very smooth and slippery form but it now contains 70 per cent of a gritty filler and is embossed with a pyramidal pattern. Since these modi-

Fig. 5. Laying thin sheeting based on polyvinyl chloride.

fications it has been used increasingly for marking pedestrian-crossings although its skid-resistance is probably still unacceptable at high speeds. Despite this fault, which it may be possible to overcome by the incorporation of a more suitable abrasive, its durability under heavy traffic and its light weight make it a potentially useful material for surfacing bridge-decks. Following a small trial on a steel panel set in the road which is still in good condition after 2 years, larger areas were laid in 1962 on the timber deck of a swing bridge and on the aluminium deck of a bascule bridge. On steel or aluminium, using the normal adhesive (of a rubber-bitumen type) no trouble has so far been experienced with movement or lifting, but there are signs that an improved adhesive may be needed on timber or other porous bases.

Acknowledgement

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Summary

Research begun in 1949 into the use of mastic-asphalt surfacings laid on orthotropic steel plate decks, as proposed for the new Forth and Severn Bridges, was described by TROTT and WILSON in 1960 in a paper to the International Association for Bridge and Structural Engineering in Stockholm.

More recently work has been carried out on the associated problem of surfacing aluminium — in addition to steel-decked bridges. Surfacings which investigated include normal and rubberized mastic asphalt from 1 to 2 inches thick (weight 100 to 200 lb./yd.^{2}), cement/rubber-latex mixtures $^1/_2$ inch thick (weight 40 to 50 lb./yd.^{2}), cold-laid, epoxy-resin/grit mixtures $^1/_8$ to $^3/_8$ inch thick (weight 15 to 45 lb./yd.^{2}) and thin plastic sheeting 0.1 in. thick stuck to the deck (weight 10 lb./yd.^{2}).

Résumé

On a commencé en 1949 des recherches sur l'utilisation des revêtements asphaltiques sur les platelages métalliques, du genre utilisé pour les nouveaux ponts sur le Severn et le Forth. Ces recherches ont été décrites par TROTT et WILSON dans un rapport présenté devant l'AIPC à Stockholm (1960).

Plus récemment, tout en continuant les recherches sur les ponts à platelages métalliques, des travaux ont été effectués sur le problème connexe des revêtements pour tabliers en aluminium. Les revêtements étudiés comprenaient le mastic d'asphalte, normal et caoutchouté, d'une épaisseur comprise entre 2,5 et 5 cm (54 à 108 kg/m^2), des mélanges latex/ciment d'une épaisseur de 1,25 cm (22 à 27 kg/m^2), des mélanges mignonnette/résine époxyde, posés à froid, d'une épaisseur comprise entre 3 et 9 mm (8 à 25 kg/m^2) et des feuilles minces en matière plastique, d'une épaisseur de 2,5 mm, collées au tablier (5,4 kg/m^2).

Zusammenfassung

Die Forschungen über die Anwendung von Fahrbahnbelägen aus Asphaltmastix auf orthotropen Platten aus Stahl, wie sie auch für die neue Forthbrücke und die Severnbrücke vorgeschlagen wurden, sind im Jahre 1960 in einer Veröffentlichung von TROTT und WILSON am IVBH-Kongreß in Stockholm beschrieben worden.

Zur Lösung der mit der Oberflächenbehandlung von Aluminium- und Stahlbrückenfahrbahnen zusammenhängenden Probleme wurden neuere Untersuchungen durchgeführt. Die untersuchten Fahrbahnbeläge umfassen normalen Asphaltmastix und solchen mit Gummibeigabe von 1 bis 2 Zoll Dicke (Gewicht 100 bis 200 lb./yd.^{2}); Mischungen von Zement, Gummi und Latex $^1/_2$ Zoll dick (Gewicht 40 bis 50 lb./yd.^{2}), kalt aufgebrachte Epoxydharz-Kiessandmischung $^1/_8$ bis $^3/_8$ Zoll dick (Gewicht 15 bis 45 lb./yd.^{2}) und dünne, fest am Blech haftende Plastikbahnen 0,1 Zoll dick (Gewicht 10 lb./yd.^{2}).