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SURFACINGS ON AN EXPERIMENTAL DECK PANEL IN A HIGHWAY

Essais de revêtements sur un modèle de tablier de pont routier

Beläge auf einer Prüfdecke einer Straßenbrücke

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1. INTRODUCTION

For several years the Road Research Laboratory has been conducting experiments in the United Kingdom to determine the most suitable material for thin surfacings on steel bridge decks, in order that adequate protection for corrosion and good resistance to skidding shall be provided for many years with minimum maintenance and at low initial cost.

The experiments have sometimes been carried out on actual bridge decks, when suitable opportunities arose, and also on panels laid over pits in the highway. The techniques and previous results have been reported in papers to the 6th and 7th Congresses of I.A.B.S.E. (1) (2) A greater latitude in the range of the experiments is possible when the trials are carried out on panels; failures can be corrected quickly, with no risk to a major structure, and experimental sites with a wider range of traffic conditions can be considered. Moreover, better access can be obtained to the panels for the purposes of making measurements, than is usually the case on bridge decks. These were the main factors which influenced the form of the trial which is described in this paper, and which was carried out primarily to make a final selection of the most suitable surfacing material for the Severn Bridge.

2. THE EXPERIMENTAL SITE

An experimental site was chosen on a busy dual carriageway road (A40) on the western outskirts of London. Two deck panels, each 52 ft (15.8 m) long x 13 ft.(4.0 m) wide, were set, end to end, in the slow lane of the eastbound carriageway over a concrete structure (Fig.1). This has the dual function of supporting the deck plate in a manner similar to that in a bridge and of allowing access underneath it for measurements of deflections and strains. A weighbridge and vehicle detector are located in the road on the approach to the panels to record the loads and frequency of vehicle axles in the normal traffic stream over them.

In the $4\frac{1}{2}$ years that have elapsed since the panels were installed, 20×10^6 axles have passed over them. This is approximately equivalent to 9×10^6 vehicles. 13 per cent of the axle loads have been in excess of 4 tonf. (40 kN).

3. THE DECK PANELS

The two panels are of the design shown in Fig. 2. The deck plate is 7/16 in. (11mm) thick and has trough shaped stiffners in the longitudinal direction with welded connections at (12 in.) 300 mm. pitch transversely. The aim was to use a test panel of such a size that local stresses and deformations under wheel loading would be comparable with those in the larger panels forming the deck of a bridge. It was estimated that the tracks of vehicle wheels nearest the kerb would be concentrated in a strip 4 ft (1.2 m) wide and that a margin of at least 4 ft.(1.2 m) should be allowed on either side of this strip to reduce edge effects. A further reduction is obtained from the edge stiffening provided by the channel. In the longitudinal direction, the spacing between transverse diaphragms is shorter at the end of each panel than in the centre, to compensate for the loss of continuity at the ends.

4. THE ROAD SURFACINGS

The road surfacing on each panel has been divided into four sections. Three of the sections are 15 ft (4.6 m) long; they are so located that a transverse stiffener occurs under each one. The fourth section is 7 ft. (2.1 m) long, without a transverse stiffener.

One panel is surfaced with two sections of rolled asphalt and two sections of mastic asphalt, all of them $1\frac{1}{2}$ in.(38 mm) thick. The other panel is surfaced with resin-based materials, $\frac{3}{8}$ in. (9.5 mm) thick; three made with epoxy resins and one with a polyester resin. These are described in a paper under Theme III and they are only referred to briefly here since the comparison of their performance with the asphalts, under the same conditions of traffic, weather and support is of interest. The materials and composition of the surfacings were selected from those which had given the more favourable results in previous trials. The layout of the sections is given in Fig. 3.

The sequence of laying the asphalt sections on Panel 2, after it had been installed in the roadway, were as follows:-

(i). The plate, which was delivered with a zinc sprayed surface and coated with etch-primer, was brushed to remove any dirt present.

(ii). Tack coats and/or waterproofing layers were applied. On Section 2A, a fluid slurry consisting of equal parts of epoxy resin and fine sand was spread at 3 lb/yd^2 (1.6 kg/m^2): before it hardened this was sprinkled with $\frac{1}{4}$ in. (6.4 mm) dry chipping to enable the asphalt to key mechanically to it. On Sections 2B and 2C a thin priming coat of "Bostik 1255" was applied at about 25 to 40 sq. yd/gal (5 to 8 m^2/litre) and allowed to dry: over this a layer of filled rubber bitumen was applied with squeegees to a thickness of about 0.1 in (2.5 mm). This layer is sometimes referred to as the "insulating" layer or "cushion" layer. It consists of approximately 3 parts of limestone filler to 1 part of bitumen, with approximately $1\frac{1}{2}$% of Pulvatex unvulcanised rubber powder added. The exact compositions are adjusted to give a final softening point (ring and ball) of 90 to 95°C. On Section 2D (the short section) a bitumen paint priming coat was applied thinly.

(iii). The asphalt wearing courses were laid. The rolled asphalt (hot process) complied with B.S. 594: 1961, Table 7, Schedule 1, with 30% of coarse aggregate; the asphaltic cement complied with Table 1, Column 3. This mixture is normally laid on the road by machine, but because of the limited size of the panels this was not possible, so that it was spread on Sections 2A and 2B by hand rakes. It was compacted in the usual manner with an 8 ton diesel roller. The mastic asphalt was spread on Sections 2C and 2D by hand with wooden floats and rolled with a hand roller. Its composition complied with B.S. 1447: 1962 and it contained 40% of coarse aggregate; the asphaltic cement conformed with Table 1, column 3.

(iv). Coated chippings of $\frac{3}{4}$ in (19 mm) size were rolled into all the asphalt sections on Panel 2 at about 100 sq. yd/ton (80 m^2/Mg).

The asphalt surfacings were laid in October, 1963 and opened to traffic in November, 1963.

5. PERFORMANCE OF SURFACINGS

The surfacings were inspected periodically for signs of cracking, deformation and wear. The observations may be summarised as follows:-

Section 2A.

A very fine crack, a few inches long, appeared during the Spring of 1964 in the nearside wheel track. It remained largely unchanged until the Winter of 1964/5 when the crack lengthened to extend almost over the length of the section by the Spring of 1965. By that time two intermittent cracks had developed in the outer wheel tracks, near the edge of the panel. During 1966, parallel cracks developed in the near side wheel track over the webs of the underlying stiffener, that is 6 in. (15 mm) on either side of the existing crack. By November, 1967, when the photograph in Fig. 4 was taken, a crazed pattern of cracks was established over a 12 in (300 mm) wide strip, with short crack appearing over the line of the next stiffener towards the centre of the panel. When last observed in July, 1968 (Fig. 5) a depression about ¼ in (6 mm) deep had formed in the centre of the strip. Cracks along the off-side wheel tracks had become more continuous, but these are not such good indicators of performance, because of the proximity of the edge of the panel. It is significant that cracks have not run over the transverse disphragm of the deck panel, but have terminated some 9 in (225 mm) from it.

Section 2B.

In February, 1965, short intermittent cracks were noticed in the off-side wheel tracks near the edge of the panel. These cracks occur mid-way between lines of stiffeners. They have continued to develop, until in November, 1967 there were two fairly definite lines of cracks about 12 in. (300 mm) apart with some interconnecting cracks (Fig. 6). Again the cracks disappear within about 9 in (225 mm) of the position of the transverse stiffener.

Section 2C.

No cracking has so far occurred in this section. In the Spring of 1964, however, a blister about 9 in. to 12 in (225 to 300 mm) dia. appeared near the centre of the section, When it was cut out and repaired in September, 1964, it was observed that separation had occurred between the layer of filled rubber bitumen and the mastic asphalt wearing course (Fig. 7).

Section 2D.

No cracking or other defects have so far occurred in this section.

Panel 1.

All the sections with epoxy and polyester-resin-based surfacings have cracked to a considerable degree during the same $4\frac{1}{2}$ year period.

6. DISCUSSION OF RESULTS.

In terms of freedom from cracking and deformation, this trial confirms that mastic asphalt gives a better performance than rolled asphalt or resin-based systems. The cracking in Section 2B (rolled asphalt on an insulating layer of filled rubber bitumen) could be attributed to proximity to the edge of the panel and so is not to be taken as typical of such a surfacing on orthotropic decks in general. However, the mastic asphalt was subjected to similar conditions of stress and deformation and it has withstood them successfully hitherto.

The value of the insulating layer cannot be determined from a comparison of Sections 2C and 2D. Firstly the panel behaviour on the two sections is not identical, stresses in the deck plate tend to be lower on 2D. Secondly, both surfacings are still in good condition. Nevertheless, the filled rubber bitumen layer will usually be used because it provides additional waterproofing and better adhesion. It is known, however, from experience elsewhere that the risk of sliding of the surfacing is increased when insulating layers are too thick or too soft. It would now be the tendency to reduce the thickness of the insulating layer to .04 in(1 mm) to reduce this risk. No sliding was observed on the panel, but its slope was only that of the road camber (1 in 48) and there was no significant amount of stopping or accelerating traffic over it.

One alternative to the filled rubber bitumen, as a means of providing the necessary adhesion between asphalt and steel, is the use of an epoxy resin instead of a bituminous primer. The asphalt is laid over the epoxy before it has hardened. Such a system was laid in 1960 on Cross Keys Bridge, Lincolnshire[2]. as part of a trial to compare the performance of various types of mastic asphalt, $1\frac{1}{2}$ in. (380 mm) thick . It has given the best performance in terms of resistance to cracking on a very flexible deck. There was difficulty in laying the asphalt by hand on the wet epoxy-resin, because the latter tended to flow under the asphalt. This could now be overcome by the use of resins which harden sufficiently to permit working traffic, but are only fully cured when they receive the hot asphalt. Another conclusion drawn from the Cross Keys Bridge trial was that the addition of natural rubber did not lead to improvement in the performance of $1\frac{1}{2}$ in. (380 mm) of mastic asphalt.

The filled rubber bitumen under the rolled asphalt on Section 2B has probably contributed to the better condition of this Section compared with Section 2A. On both Sections the rolled asphalt has cracked most extensively between lines of stiffeners, which is contrary to the experience with mastic asphalt in earlier trials on deck panels reported by Trott and Wilson [1] where the cracking occurred over the stiffeners. Hennecke[3]. has advanced the explanation that the inter-stiffener cracking is caused by tensile stresses in the base of the asphalt at the interface with the steel and that it is preceded by flow of the asphalt from the region over the stiffener to the region in between, causing a longitudinal rut in the surfacing over the stiffener. This is not in accord with the behaviour of Section A, because in this case a rut of about $\frac{1}{4}$ in. (6 mm) deep developed between the webs of the trapezoidal stiffener under the near-side wheel track. The temperature differential effect referred to by Thul [4] would account for the position of the trough, but there seems no entirely satisfactory explanation of the crack development prior to the appearance of the rut.

One blister formed in the mastic asphalt on Section 2C, about 6 months after laying. Blister formation is sometimes an unfortunate feature of mastic asphalt surfacing and it seems to be associated with one or several of the following factors: the presence of water or of a volatile liquid, or of trapped air, relatively high temperatures and high temperature gradients. Blisters have not been widespread on steel decks in Britain hitherto, but where they hage occurred, they have been satisfactorily treated either by puncturing at the time of formation, resealing the puncture with sealing compound, or by cutting out and replacing the surfacing system.

Work is in progress to measure the strains over the steel decks caused by moving traffic. Some preliminary results show that the presence of $1\frac{1}{2}$ in (380 mm) of mastic asphalt leads to a reduction of at least 20% in the peak transverse stresses at about 20°C. The thermoplastic characteristics of the asphalt cause an increase in its structural effect as the temperature drops. This effect may be resolved into two parts: the one being a load spreading effect through the thickness of the asphalt, the other being the composite behaviour of the asphalt with the steel, with various degrees of interaction depending on the adhesion between deck and surfacing.

7. CONCLUSIONS

(1). Of the surfacing systems tested on the experimental deck panels laid in the highway, mastic asphalt has shown the greatest resistance to cracking and is generally in the best condition after almost five years of service under heavy traffic.

(2). The value of the insulating layer of filled-rubber bitumen under mastic asphalt cannot yet be fully assessed from this trial, but its adhesive and waterproofing qualities are generally beneficial. It probably contributed to a significant reduction in cracking in the rolled asphalt. To avoid problems with flow and sliding at high ambient temperatures, the thickness of the insulating layer should be kept to about 0.4 in(1 mm). An epoxy primer which cures in two stages may offer an alternative system in which the risk of flow is eliminated.

(3). The range of composition for asphalts to give satisfactory performance under various conditions of climate, traffic and deck design is very limited. It seems likely that brittleness and cracking at low temperatures and flow and deformation at high temperatures can be avoided in British conditions provided that the composition of the mastic asphalt complies with B.S. 1447, that the percentage and penetration of the asphaltic cement is near the centre of the permitted range and that bridge decks are not designed to be too flexible.

(4). A rolled asphalt could not be recommended for the type of deck used in this trial. But the performance of this material, laid on a filled rubber bitumen insulating layer, has been sufficiently encouraging to expect that a slightly thicker layer or improved adhesion may prove successful on a deck as flexible as the one used in the trials. There would obviously be a considerable advantage in being able to use a material such as rolled asphalt, which is normally laid by machine.

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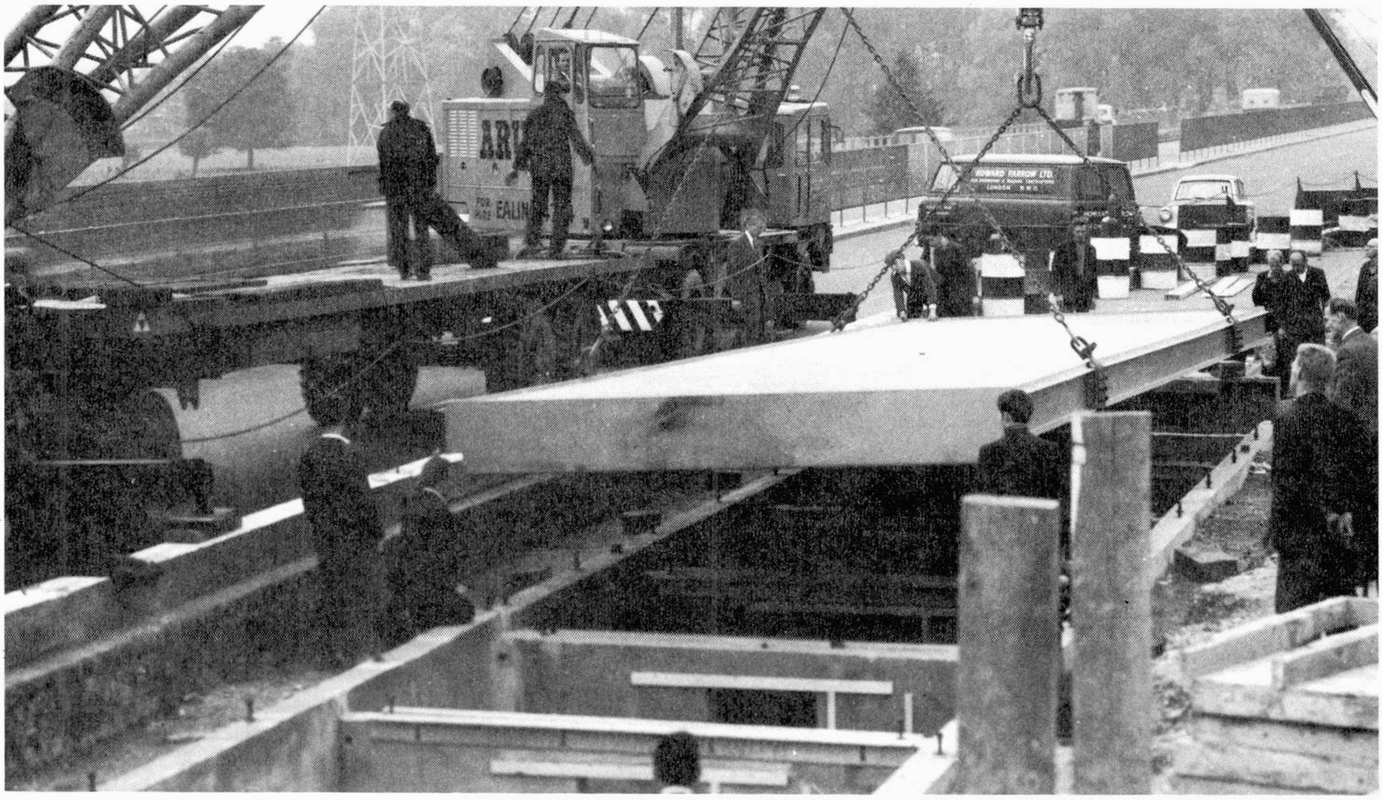


FIG. 1 TEST SITE UNDER CONSTRUCTION

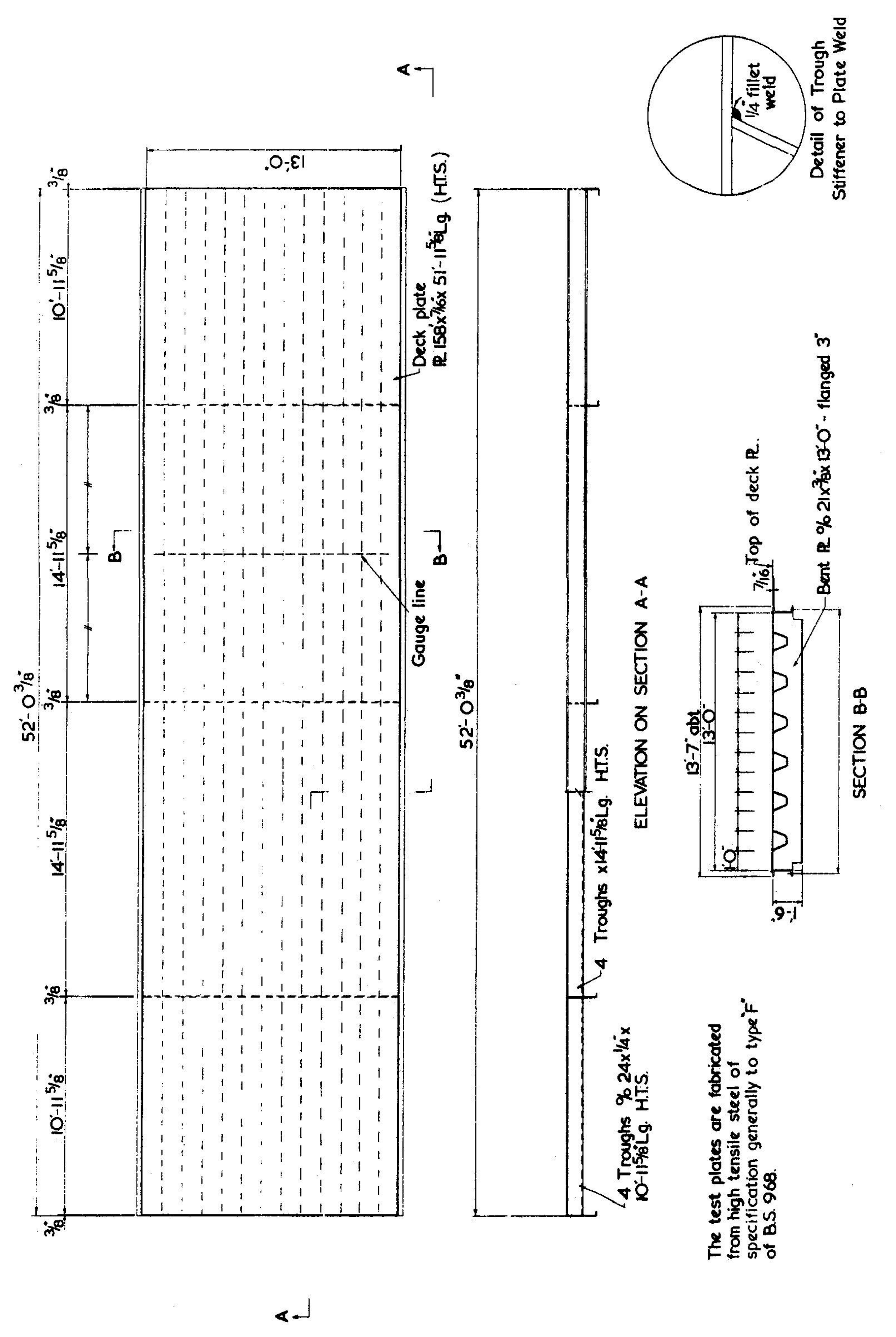
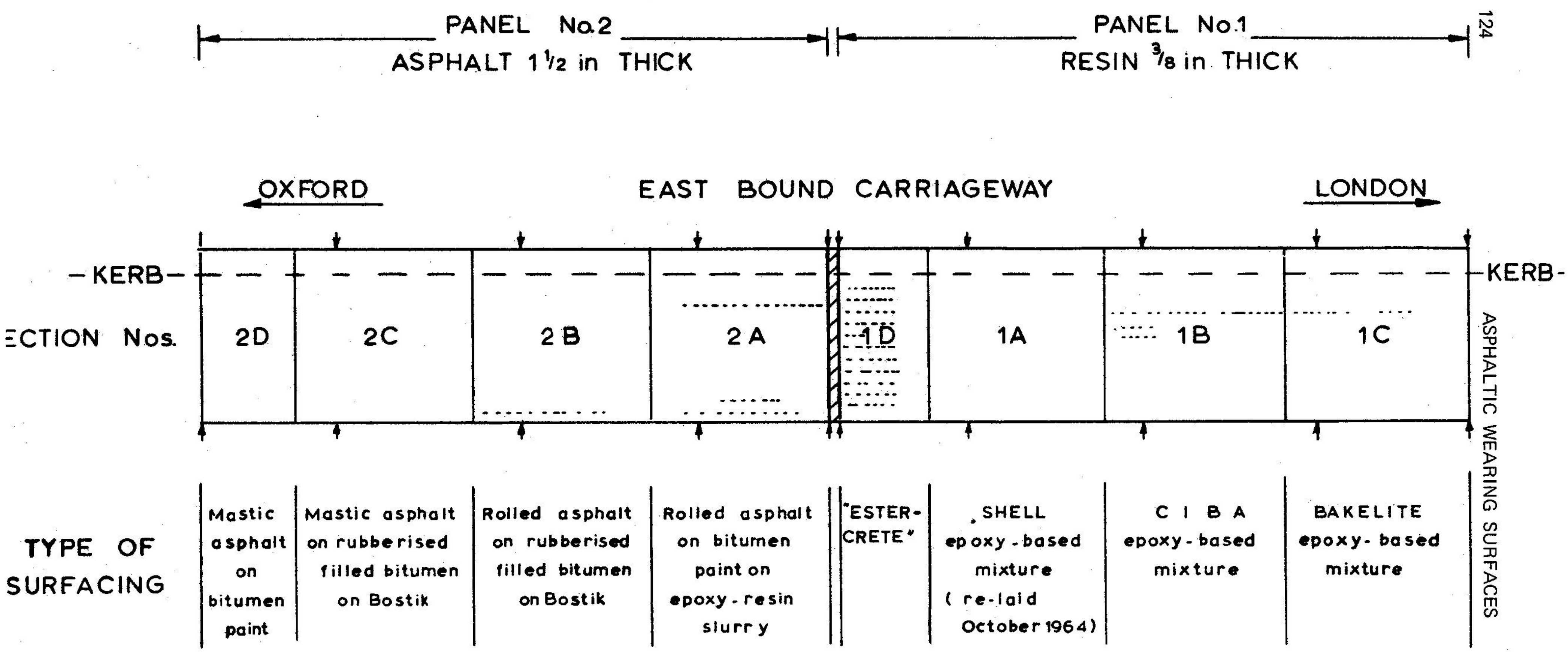


Fig 2 DETAILS OF DECK PANELS INSTALLED ON TEST SITE



NOTE: The small arrows show position of the transverse stiffener.
The cracks visible in the surfacings in April 1965 are shown thus........

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

FIG. 4 CRACKING ON ROLLED ASPHALT OVER GRITTED EPOXY RESIN, NOVEMBER, 1967

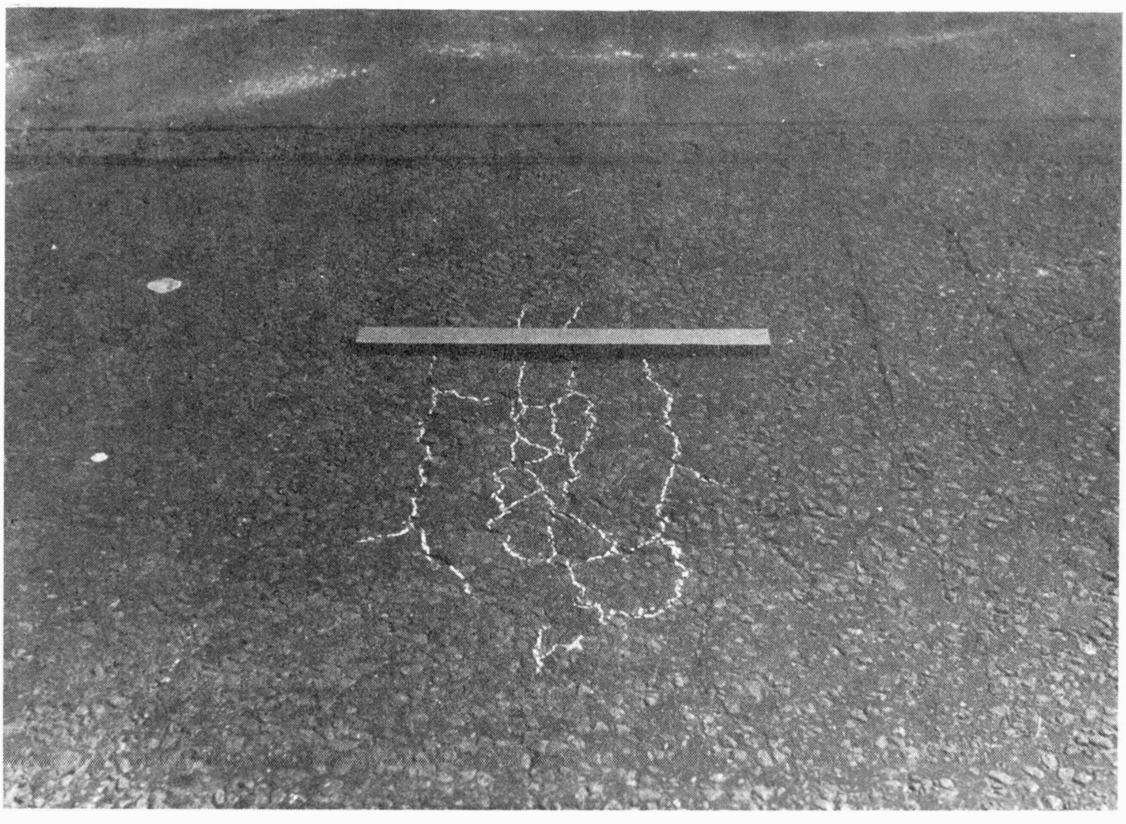


FIG. 5 DEFORMATION AND CRACKING IN ROLLED ASPHALT OVER GRITTED EPOXY RESIN, (SECTION 2A) JULY, 1968

FIG. 6 CRACKING IN ROLLED ASPHALT ON FILLED RUBBER BITUMEN, NOVEMBER, 1967

FIG. 7 MASTIC ASPHALT ON FILLED RUBBER BITUMEN, NOVEMBER, 1967

SUMMARY

Trials with asphaltic and resin-based surfacing materials on bridge deck panels laid into the highway are described. After almost five years of heavy traffic, a mastic asphalt, 1 1/2 in. (38 mm) thick, has given the best performance in terms of freedom from cracking and deformation. The value of an insulating layer of filled rubber bitumen, 0.1 in. (2.5 mm) thick, under the asphalt has not yet been proven, but a similar layer under a rolled asphalt wearing surface, 1 1/2 in. (38 mm) thick, has reduced the amount of cracking and deformation of this asphalt compared with a gritted epoxy underlayer.

RESUME

Des essais de différents matériaux de revêtement à base d'asphaltes et de résines pour tabliers de ponts routiers ont été faits. Après presque cinq années de trafic lourd, on a obtenu les meilleurs résultats concernant le fissurage et les déformations, avec un asphalte coulé de 38 mm d'épaisseur. L'amélioration due à une couche d'isolation de bitume caoutchouté renforcée par du gravier, d'une épaisseur de 2,5 mm, n'a pas encore été démontrée avec l'asphalte, mais une couche semblable sous une couche d'asphalte cylindré de 38 mm a réduit le fissurage et les déformations par rapport à une base d'époxy avec gravier.

ZUSAMMENFASSUNG

Es werden Versuche mit Asphaltbelägen und solchen auf Harzgrundlage, welche auf einer Prüfdecke in eine Straßenbrücke eingelegt worden sind, beschrieben. Nach beinahe fünf Jahren schweren Verkehrs, erwies eine 38 mm dicke Gußasphaltdecke das beste Verhalten in bezug auf die Freiheitsgrade durch Risse und Verformungen. Der Wert einer Isolationsschicht aus splittverfestigtem Gummibitumen von 2,5 mm Dicke unter dem Asphalt konnte bis jetzt noch nicht geprüft werden, hingegen hat eine ähnliche Lage unter einem Walzasphaltbelag von 38 mm Dicke das Auftreten der Risse und Verformungen dieses Asphalts verringert im Vergleich mit einer aufgerauhten Epoxydunterlage.