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SURFACING ON FORTH ROAD BRIDGE

Revêtement du tablier du pont routier de Forth

Fahrbahnbelag der Forth-Road-Brücke

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Construction

A considerable amount of testing of various types of surface was carried out by Road Research Laboratories under working conditions prior to the final adoption of the material laid on this bridge.

The deck consists of panels of orthotropic steel construction, some 60' (18.5m) long and 24' (7m.) wide in each carriageway. The panels were prefabricated in 8' (2.4m.) widths, site welded together to complete the full carriageway width. The deck plate is $\frac{1}{2}$" (1.25cm) thick, stiffened longitudinally with steel troughs which provide stiffening webs at approximately $13\frac{1}{2}$" (34cm) centres. These stiffeners span between cross members at approximately 10' centres (3m) which in turn are supported by stringers at 8' (2.4m) centres resting on the main truss cross girders at 30' (9m) centres. The stringers are in general continuous over two cross girders, joints being provided 5' (1.5m) from the main cross girders where the short cantilever of one stringer supports the 25' (7.5m) projection of the next. All of the steel in the deck is mild steel to B.S.15 since it was considered desirable to limit local deflection by using lower stresses in the interest of the road surface.

All of the steelwork on the bridge was grit blasted and zinc sprayed to a minimum thickness of .003 inches (0.76mm) in shop conditions under cover, the utmost care being taken to ensure that one process followed another without undue delay. The steelwork was then painted under factory conditions. On the steel plate surface to be covered with asphalt, the surface was painted with one coat of etch primer followed by a priming coat of bitumen paint, partly to protect the surface until such time as it was surfaced and partly as a key for the future surface. During the period of upwards of a year from the time of application of this bitumen paint until surfacing commenced, it was found that chemical changes had taken place which left it in a condition that nothing would adhere to it and it was necessary to remove the paint by light grit blasting.

Following closely on this cleaning process and on a thoroughly dust free surface, the steel plate was primed with a rubber/bitumen solvent primer

(Bostik 1255) at a coverage of 25 sq. yds. per gallon (4.5s.m/litre).

On this priming was laid a $\frac{1}{8}$" (.32cm) thick hot rubber bitumen compound having the following specification;

25% to 30% Bitumen (Penetration 90-110)
70% to 75% Limestone Filler (85% passing 200 mesh)
1.3% to 1.5% Pulvatex rubber powder to bring the softening point to approximately 95°C.

The final surface consisted of $1\frac{3}{8}$" (3.5cm) thickness of Lithocrete mastic asphalt filled with 40% to 45% of $\frac{3}{8}$" (1cm) crushed granite, to make the total thickness $1\frac{1}{2}$" (3.8cm).

The specification for this mastic asphalt which was, of course, hand laid was;

Penetration at 25°C 10-15
Loss on heating at 163°C for 5 hours 1% max.
Melting Point 65-70°C
Mineral Content 20-25%
Ductility at 25°C 0.5cm min.
Specific Gravity at 25°C 1.2 to 1.3

The limestone aggregate to be ground so that the following grading is met

Passes	7	mesh	sieve	and	retained	on	25	mesh	sieve	15-25%
"	25	"	"	"	"	"	72	"	"	10-30%
"	72	"	"	"	"	"	200	"	"	10-25%
"	200	"	"	----------						40-55%

The soluble bitumen content of the asphalt before filling with crushed granite to be 14-15%.

At the ends of each deck panel $1\frac{1}{2}$" (3.8cm) high steel asphalt stops are provided while at the sides steel kerbs perform the same function. A $\frac{1}{2}$" (1.25cm) wide rubber bitumen compound was used to seal the asphalt against the vertical steel surface.

Behaviour in use

The finished running surface has provided excellent riding quality and a high standard of skid resistance during the four years it has been in use. There is a marked tendency for vehicles to follow very closely the same tracks (no doubt the inclined protective railing on each side of each carriageway tends to discipline drivers to follow a more uniform position in lane than usual), but up to date there is no perceptible wear, polishing, or depression of the surface in these tracks.

Total annual traffic using the bridge has been;

1st year	4,665,000
2nd year	4,838,000
3rd year	5,378,000
4th year (9 months)	4,500,000

This has been made up of a fairly normal distribution of private cars, public service vehicles and heavy trucks.

In addition there has been a fairly large number of abnormal loads ranging from above 30 tons gross on the vehicle up to some 280 tons gross. The wheel loads on these vehicles range from 6 to approximately 9 tons.

About eight months after the bridge was opened to traffic it was observed that fine longitudal cracks were beginning to appear in the slow lane, some 8 ft (2.4m) from the outer kerb. These fine cracks extended rapidly to form a more or less continuous line along the full length of the main span decked with orthotropic plates. The location of this crack coincided with the position of high negative bending at a stringer. Further fine longitudinal cracks appeared close to the kerb of the slow lane at points where the corresponding stringer passed over the main cross girder. These cracks were generally some 9" (23cm) to 18" (46cm) long. At these points the stringer webs are stiffened with bearing stiffeners and so stiffer than elsewhere.

Some three to four months later similar fine cracks appeared some 8' (2.4m) from the kerb of the fast, less heavily used lane, again over a stringer, and close to the kerb at the point of support of the outer stringer over the cross girder.

In the case of each of the main longitudinal cracks, the tracks of vehicles straddle the stringers almost symmetrically and the location of these members is such that actual traffic takes up the position of causing maximum negative movement over this support. On these cracks, too, there was a tendency, where the stringer passes over the main cross girder and is reinforced with bearing stiffeners, for two short cracks to form on either side of the main longitudinal crack for a distance of 9" (23cm) to 18" (46cm) and then to return into it at an angle (Fig.1). In other cases the central crack terminated between the apices of these hexagons (Fig.2).

Careful examination showed that the bond between the asphalt, and the steel was not impaired. An area of asphalt was removed for inspection and it may be of some interest to note that over small patches the zinc spray applied to the steel surface pulled off with the asphalt.

Remedial measures were put in hand quickly; these consisted of making a "saw" cut ~~in~~ $\frac{1}{2}$" (1.25cm) wide along the line of each crack to a depth of 1" (2.5cms). This cut was freed from dust by blowing out with compressed air and then filled by pouring in a sealant conforming with the current British Standard 2499(55), and with the American Federal Specification SS/S 164. The actual material used is a proprietory known as Expandite Pliastic 55.

This treatment has been eminently successful. The carriageway surfacing has been kept under regular surveillance and in general the sealant is serving its dual purpose of allowing flexure and at the same time preventing ingress of water. The two cuts 8' (2.4m) in from the sides of the deck are traversed from time to time by wheels which undoubtedly have had the effect of packing and consolidating the sealant into the "saw" cuts in the most effective way.

At a recent inspection of the deck in July of this year, following a spell of warm weather, it was found that in some places the sealant in the short cracks at the sides of the carriageway was being squeezed out, or had become detached from the sides of the "saw" cut. In these locations it is very unusual for wheels to travel and it has been concluded that this is the main reason for this deterioration.

Elsewhere, in a comparatively few places, fresh hair cracks have been found developing from the ends of these original short cracks, or from the

corners of some of the hexagonal patterns for a few inches, or again, where the full hexagonal pattern had not completed itself it is now tending to do so. None of this is either extensive or serious. Measures are in hand to make fresh "saw" cuts along the length of the new cracks and to clean out those where the sealant has become detached from the sides of the cuts. In these areas where traffic will only infrequently roll on the filler it is proposed to attempt to pack the material firmly against the sides of the saw cut by tamping it with a hard wood tool after it has to some degree solidified.

In the foregoing a good deal more has been written about what could be regarded as comparatively minor defects than may appear to be justified. It is considered, however, that the wisest approach to ensuring long term economy and continuing good quality on carriageway surfaces supported on this type of deck is to maintain a vigilant inspection for early signs of defects and to take remedial action promptly. The general impression to be gained at this stage in the behaviour of the surfacing on Forth Bridge is that the amount of necessary remedial work of the sort described is now rapidly diminishing and the surfacing has a considerable life ahead of it. It is possible that the development of these cracks could have been anticipated at the outset and suitable provision made. This would have been no different to what has now been done and there is much to be said for allowing the cracks to develop in the more brittle material, thus defining the precise location required for the more ductile sealant insertion. The amount of labour involved is not very different whichever approach is adopted.

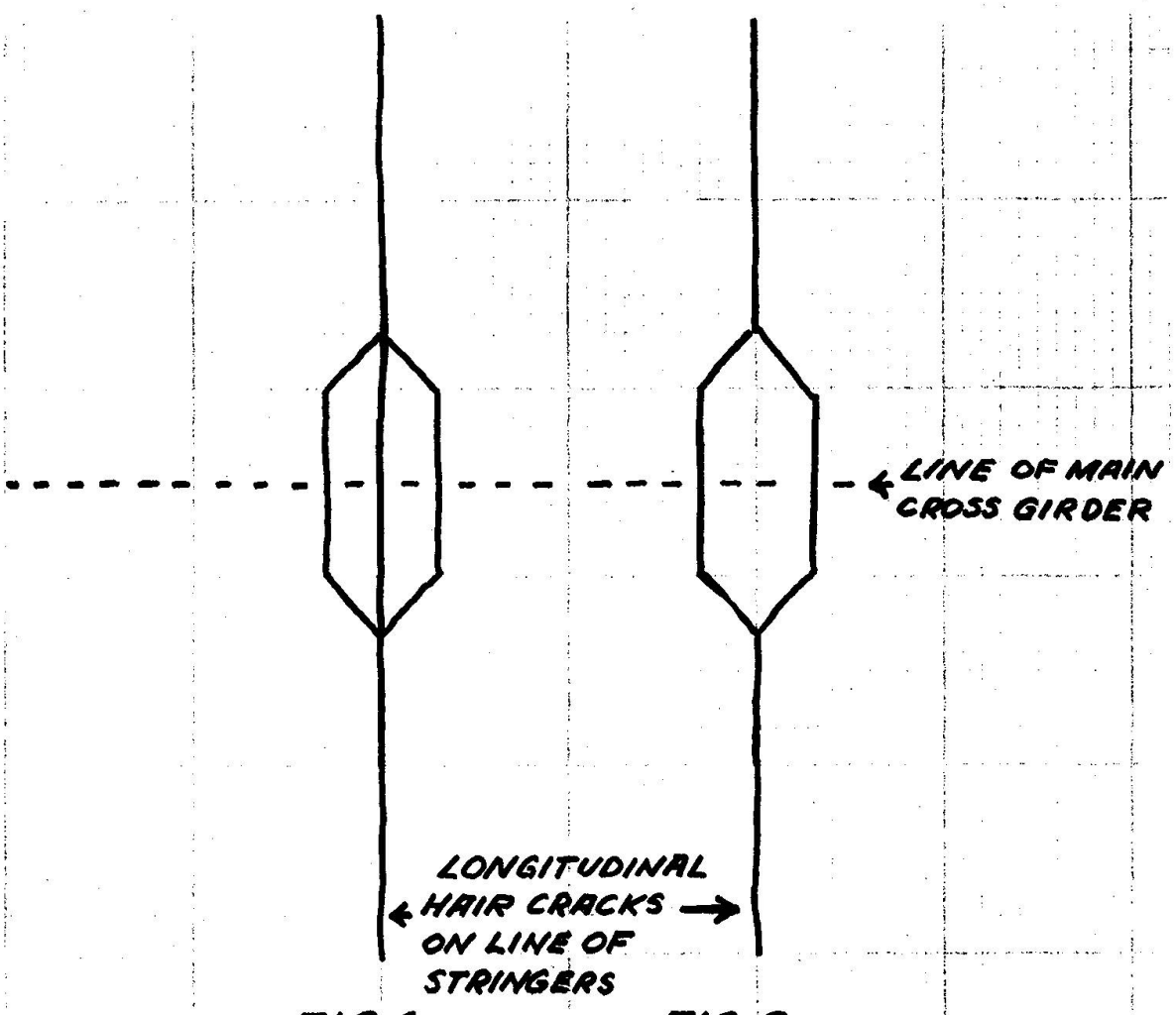

FIG.1. FIG.2.

SUMMARY

The contributor describes the nature and conditions of the mastic asphalt surface on the orthotropic steel deck of Forth Road Bridge. Specifications are given together with details of minor defects which have arisen in four years of use and the remedial measures taken.

RESUME

L'auteur décrit la composition et les conditions d'usage du revêtement en asphalte coulé sur le tablier orthotrope du pont routier de Forth. Il donne des spécifications ainsi que les détails de dégâts mineurs survenus après quatre années de service, et les mesures prises pour y remédier.

ZUSAMMENFASSUNG

Der Verfasser beschreibt das Verhalten und die Bedingungen des Gußasphaltbelages auf der orthotropen Stahlplatte der Forth-Road-Brücke. Erläuterungen zusammen mit Details kleiner Schäden, welche in den vier Jahren Gebrauch entstanden sind, sowie die getroffenen Verbesserungen werden angegeben.

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