ROAD RESEARCH LABORATORY

Ministry of Transport

RRL REPORT LR 271

A METHOD OF LAYING LOW VOLTAGE HEATING ELEMENTS IN A BRIDGE SURFACING

by

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A METHOD OF LAYING LOW VOLTAGE HEATING ELEMENTS IN A BRIDGE SURFACING

ABSTRACT

The report describes a method of incorporating a low-voltage heating grid in a bridge surfacing using steel strip heating elements laid beneath a mastic waterproofing membrane.

1. INTRODUCTION

In the construction of low-voltage road heating installations with steel mesh heating elements, engineering problems arise because of the difficulty in securing these elements to the road base. This is necessary in order to prevent distortion by road laying machinery and by the thermal expansion due to the application of hot asphalt. This problem is accentuated on bridges because of the presence of a waterproof membrane on the bridge deck which should not be punctured in securing the heating elements.

This report describes an attempt to solve the problem by using thin steel strip conductors laid beneath the waterproof membrane instead of steel mesh laid above it.

2. THE SITE

When the Laboratory's road heating experiment[1] on the old Harmondsworth Road was terminated in 1964 by the construction of Motorway M4, the county authorities offered a site for an experiment on the reconstructed road. This road is carried over the motorway on a bridge and the opportunity was taken to try a method of low-voltage grid construction, using elements in the form of thin steel strip which could be laid beneath the mastic waterproof membrane of the bridge deck.

The bridge is a pre-stressed concrete structure (Plate 1) with a span of 70 m between abutment joints, carrying a 9.15 m wide road way. A section through the deck at mid-span is shown in Fig. 1.

Heating was confined to the section of carriageway between the bridge joints.

3. HEATING ELEMENTS

The bridge was built with a waterproofing membrane of 20 mm of mastic asphalt, applied in two layers each 10 mm thick, and the elements were required to lay flat on the concrete surface of the deck so as not to impede the laying process.

Experience of the performance of heating installations in the area indicated that a heat output of about $130W/m^2$ would be required so that, with an element spacing of 150 mm, a heat dissipation of 19.5 W/m was required from the elements.

Steel strip was found to be readily available in a range of widths and thicknesses and a hard mild steel with a cross section 25 mm by 0.7 mm was found to have the required flexibility and electrical characteristics.

The current/voltage relationship for the strip, measured in the laboratory, and the derived dissipation/current relationship, are shown in Fig. 2. The current/voltage relationship is linear and the a.c. impedence and d.c. resistance of the element are the same, indicating the absence of any significant 'skin effect' in this form of conductor.

The laboratory measurement showed that the required dissipation of 19.5W/m was obtained with a current of 51A, at a potential drop of 0.375 V/m.

4. CONSTRUCTION OF THE GRID

The in-situ concrete of the bridge deck was float-finished to provide a smooth surface on which to lay the elements. These were laid along the deck to form three 3 m wide sections, each consisting of 20 elements spaced 150 m apart and connected in parallel at each end by welding to mild-steel terminal bars 3 m long and 56 mm by 6.35 mm in section.

The three sections of the grid were star-connected to a three-phase supply at one end of the bridge. Terminal bars at the supply end were bolted to the concrete during construction (Plate 2); those at the other end were held down by steel straps which permitted movement along the deck, so that thermal expansion of the elements which took place during the laying of the waterproof membrane could be taken up. Helical springs attached to the terminal bars at the sliding end and anchored to the deck maintained the elements in tension. (Plate 3).

Clearance was provided round manholes by welding the elements to rectangular mild-steel frames formed of 38 mm by 6.35 mm cross members and 25 mm by 6.35 mm longitudinal members.

All joints were made by arc-welding the strip along both edges across the full width of the terminal bars. (Plate 3). The strip was prevented from burning by using a copper heat sink 22 mm wide to press it in contact with the terminal bar. (Plate 4).

Copper bar of 38 mm by 3.2 mm section (Plate 2) was used to connect the grid to the supply cables which terminated under the footway of the bridge.

The mastic waterproofing layer was applied over one section of the grid at a time (Plate 5), beginning at the fixed end so that expansion could be taken up by movement of the free terminal bar. Occasionally excessive expansion of one element caused a loop to form which was removed by crimping the element (Plate 6).

When the membrane had been laid all fixings to the concrete deck were removed and the bolt holes were sealed. The surfacing was completed with a 50 mm layer of hot rolled asphalt.

5. ELECTRICITY SUPPLY

The grid is supplied with current from a 90 KVA, three-phase transformer with a 415V primary winding tapped to give a range of line to neutral secondary voltages from 28V to 32V in steps of 1V.

Connections to the grid were made with 91/2.052mm, 660/1100V grade, P.V.C. insulated, single core cables which were laid in ducts through the concrete approach slab and taken straight across the bridge joint to connect with the terminations under the footway.

6. ELECTRICAL MEASUREMENTS ON THE INSTALLATION

Maximum and minimum secondary line voltages, measured at the terminations beneath the footway, and the corresponding line currents, are recorded in Table 1. The measured power factor of the installation was 0.96.

Heat outputs calculated from these measurements are also shown in Table 1 and it will be seen that the maximum output falls short of the design value ($130 W/m^2$).

TABLE I

Values of voltage and current measured on the installation and calculated heat outputs

Transformer tap	Line marking	Line to line voltages V	Line current A	Mean dissipation W/m^2
1	Red	43.5	820	99
	Yellow	44.0	890	
	Blue	45.5	840	
5	Red	49.0	900	125
	Yellow	48.5	1020	
	Blue	51.6	970	

The resistances of the grid sections calculated from these current and voltage measurements are :-

Red phase	0.0296 ohms
Yellow phase	0.0296 ohms
Blue phase	0.0304 ohms

The resistance of a section calculated from laboratory measurements on the strip was 0.0254 ohms. It is possible that the difference is due to a resistance at the welded joints.

There has been no significant increase of resistance over the three years since the grid was constructed, indicating that the elements are not corroding.

7. COSTS

The main items in the capital cost of the installation are shown in Table 2.

TABLE 2

Main items in the capital cost of the installation (Area 630 m^2)

Item	Cost £	Cost per square metre £/m^2
Heating elements	60	0.095
Feeder cables	220	0.349
Transformer	420	0.666
Switchgear	84	0.133
Total	784	1.24

Construction of the grid was completed by a welder and two assistants in about three days.

8. CONCLUSIONS

The steel strip elements can be laid without difficulty in a mastic membrane and it is possibly of some advantage in the organisation of work on site to lay the heating grid at this stage of construction. Mastic laying by hand is slow and it is not necessary to prepare a long section of the grid in advance as it is when the surfacing is to be laid by a machine directly over the elements. The time of exposure of the elements to weather and possibility of accidental damage is therefore reduced.

The stiffness of the elements in the horizontal plane makes them less adaptable to roads with horizontal curvature than expanded metal mesh.

It is necessary to cover the elements with a hand-laid material to enable the thermal expansion to be taken up as the operation proceeds. A thin hand-laid course of sand asphalt could be used instead of a mastic membrane.

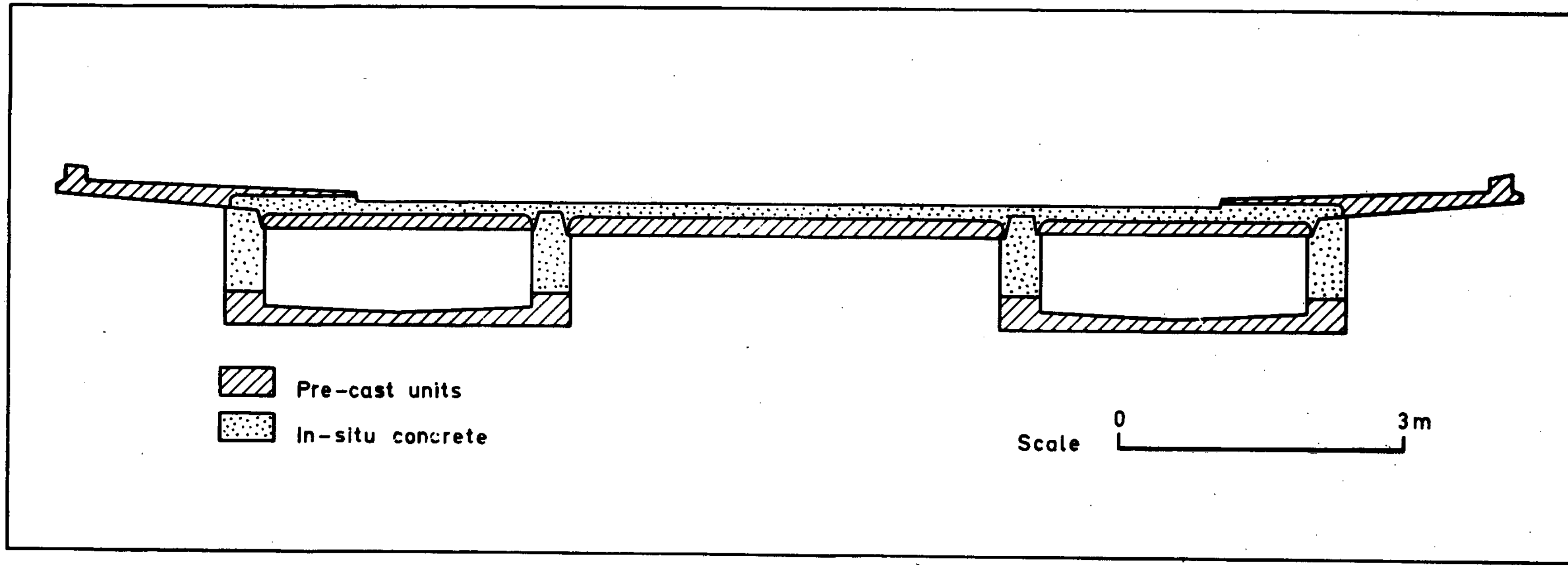

Fig. 1. SECTION OF THE BRIDGE AT MID-SPAN

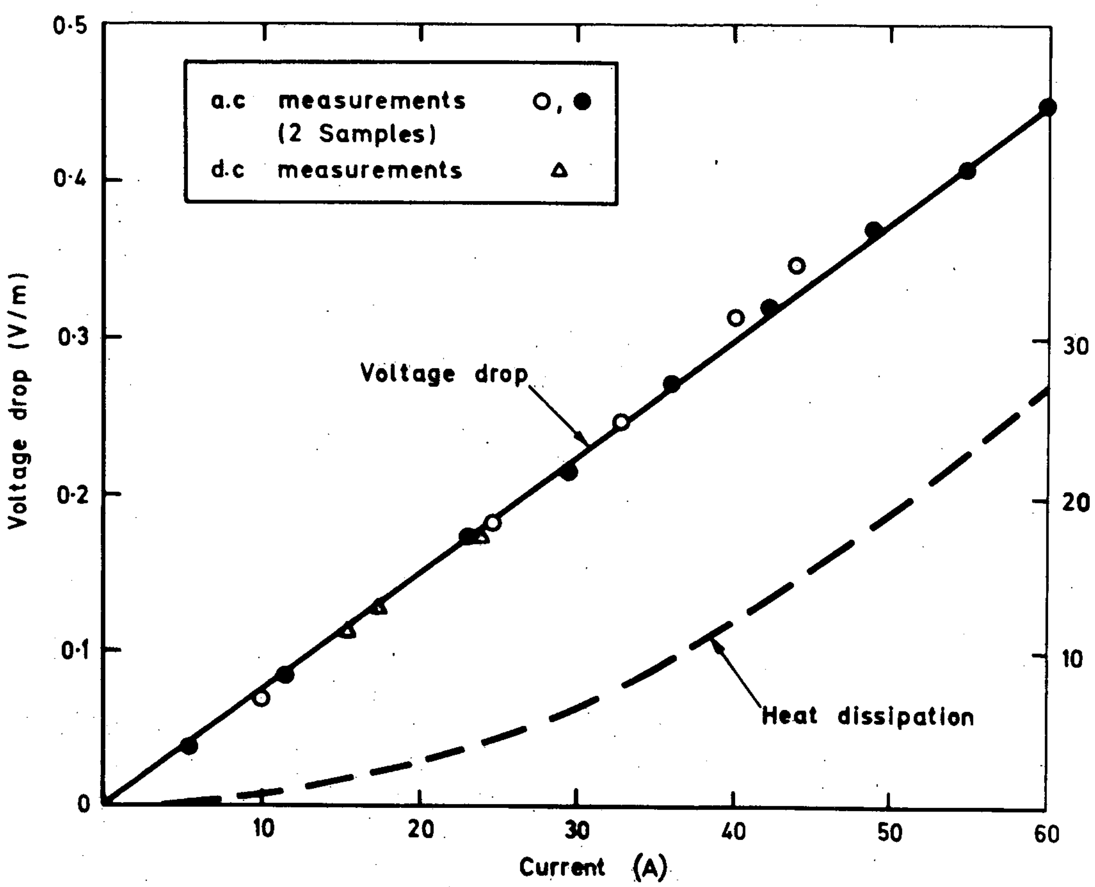

Fig. 2. THE RELATIONSHIP BETWEEN CURRENT FLOWING IN AN ELEMENT AND THE VOLTAGE DROP AND HEAT DISSIPATION PER UNIT LENGTH

Plate 1 Harmondsworth Road bridge over M4 Neg. No. B896/67

Plate 2 Neg. No. A4850/2

Terminal bars at the end of the grid connected to the electricity supply

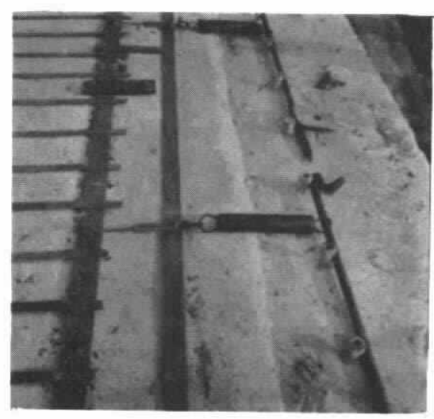

Plate 3 Neg. No. A4850/4

Terminal bars at the star point connection of the grid

Plate 4 Neg. No. A4846/3

Copper heat sink used to prevent burning of the steel strip during welding

Plate 5 Application of the first 10 mm ($\frac{3}{8}$ in) layer of mastic asphalt Neg. No. B6380/64

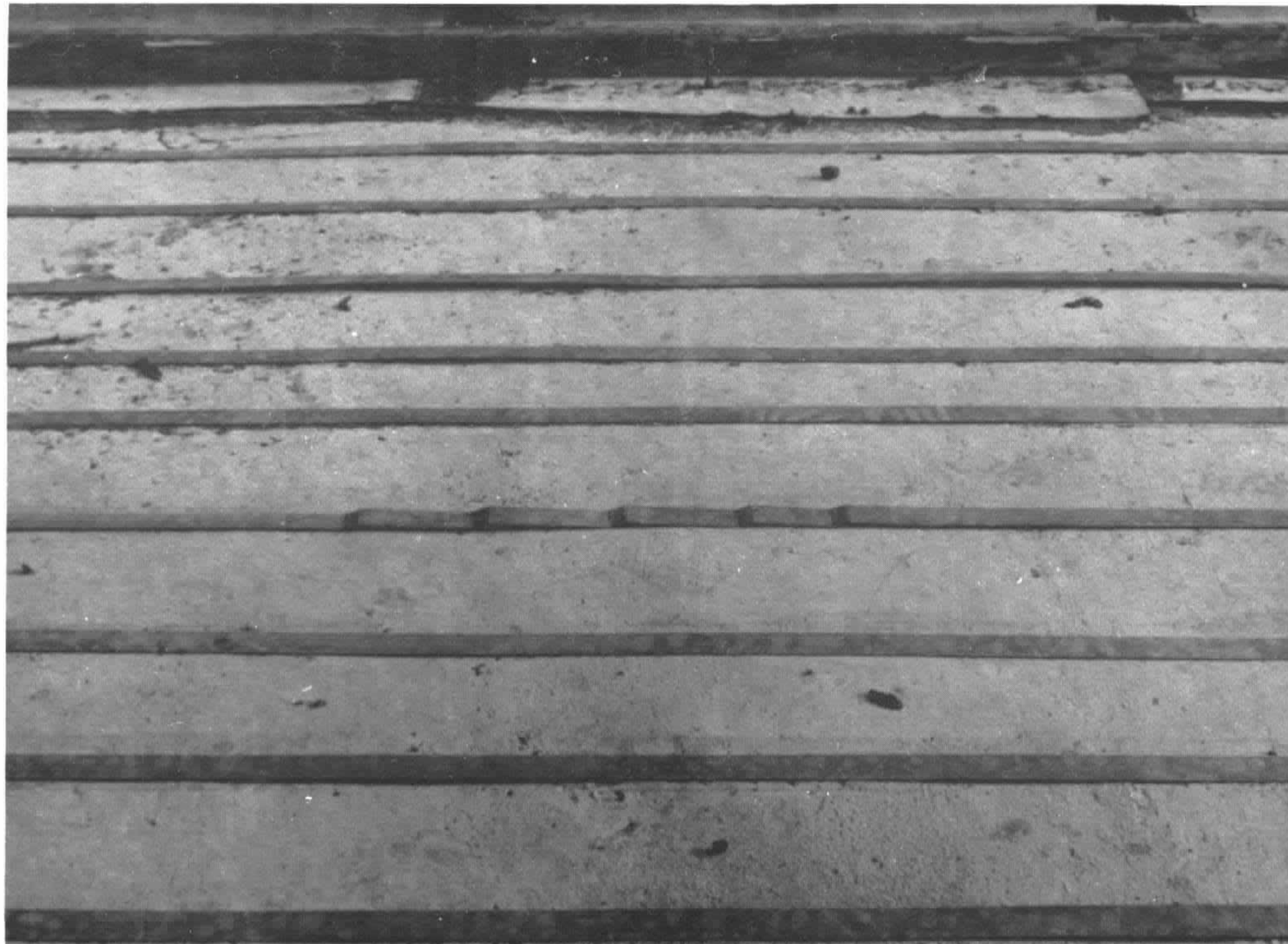

Plate 6 Expansion loop removed by crimping Neg. No. B6379/64

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