THIN TILE SURFACES

Carrelages minces

Dünne Fliesenbeläge

K.H. BEST
Great Britain

On page 7 of Dr. Henderson's report there is a reference to the use of P. V. C. tiles on steel bridge decks. This brief contribution gives further information illustrated by one or two examples.

Several movable bridge decks in Britain have recently been surfaced with embossed Verynyl-P. V. C. tiles, 50 cm. square and 3. 2 mm. thick. The minimum thickness of the tiles at the root of the indentations is about 2 mm. and the upper surface is embossed with a 5 mm. grid in diamond pattern to give a maximum thickness of 3. 2 mm. The tiles are stuck on with a normal commercial adhesive known as Bostik C, but it is essential to apply this as thinly as possible.

The first slide,Figure 1, shows these tiles being laid on an old swing-bridge at Liverpool Docks where tracks for road traffic comprised bare steel plates which had worn smooth and were dangerous in wet weather. Some of the tiles were cut and fitted around projecting rivet heads. This illustration shows the adhesive being applied by steel trowel, both to the steel deck, and to the undersides of the tiles.

The next slide, Figure 2, illustrates a roll-on roll-off ferry terminal at Immingham on the north-east coast of England. These bridge ramps are welded steel box girders pivotted at the shore end and adjusted to level by hydraulic ramps at the ferry end. The dead weight of this material is very small, about 1 lb. per square foot of deck (4. 8 kg/M^2).

It is essential to ensure that the steel surface is thoroughly clean and dry when the adhesive is applied and trouble is inevitable if laying is carried out in damp weather or rain. The contract for this terminal was accelerated in order to meet a date for the berthing of a new ship to inaugurate the service and in the rush for early completion some of the surfacing was laid in damp weather. As a result some areas of the tiles subsequently slipped and were replaced.

Repair work on this type of surfacing is quite simple. The defective tiles can be heated, peeled off the deck surface, and new tiles re-laid. It is not essential to remove the old adhesive from the deck plate unless this is in a dirty condition.

The next slide, Figure 3, shows a recent addition to the Dover Cross Channel ferry terminal and the steel decks to the ramps have been surfaced with these tiles. As a result of experience the contractors now seal the joints between the tiles by injecting adhesive with a gun. This has been found necessary in order to avoid the tendency for tiles to lift at the edges.

The fourth slide, Figure 4, shows a bridge ramp at a ferry terminal at Southampton Docks which has been in operation for several years. It is not yet possible to state the life of this type of surfacing, but similar tiles used on pedestrian crossings on heavily trafficked roads have been found to last for seven years. Probably in the case of more lightly trafficked ferry ramps of this kind a ten year life would be expected. The cost of the surfacing is approximately 6/9d. per square foot. Where these tiles are used for surfacing walkways, as illustrated in the slide, the tiles should be kept back about 12 mm. from the face of the kerb to avoid disturbance by pneumatic tyres rubbing the top edge and displacing tiles.

The final slide, Figure 5, illustrates the British Transport Docks Board ferry terminal berths at Southampton where there are three bridge ramps, all of which are surfaced with P. V. C. tiles.

Experience to date has shown that this is a convenient method of surfacing steel deck plates for movable bridges and ferry bridge ramps, but it is perhaps too early to assess the durability and maintenance costs over a long period.

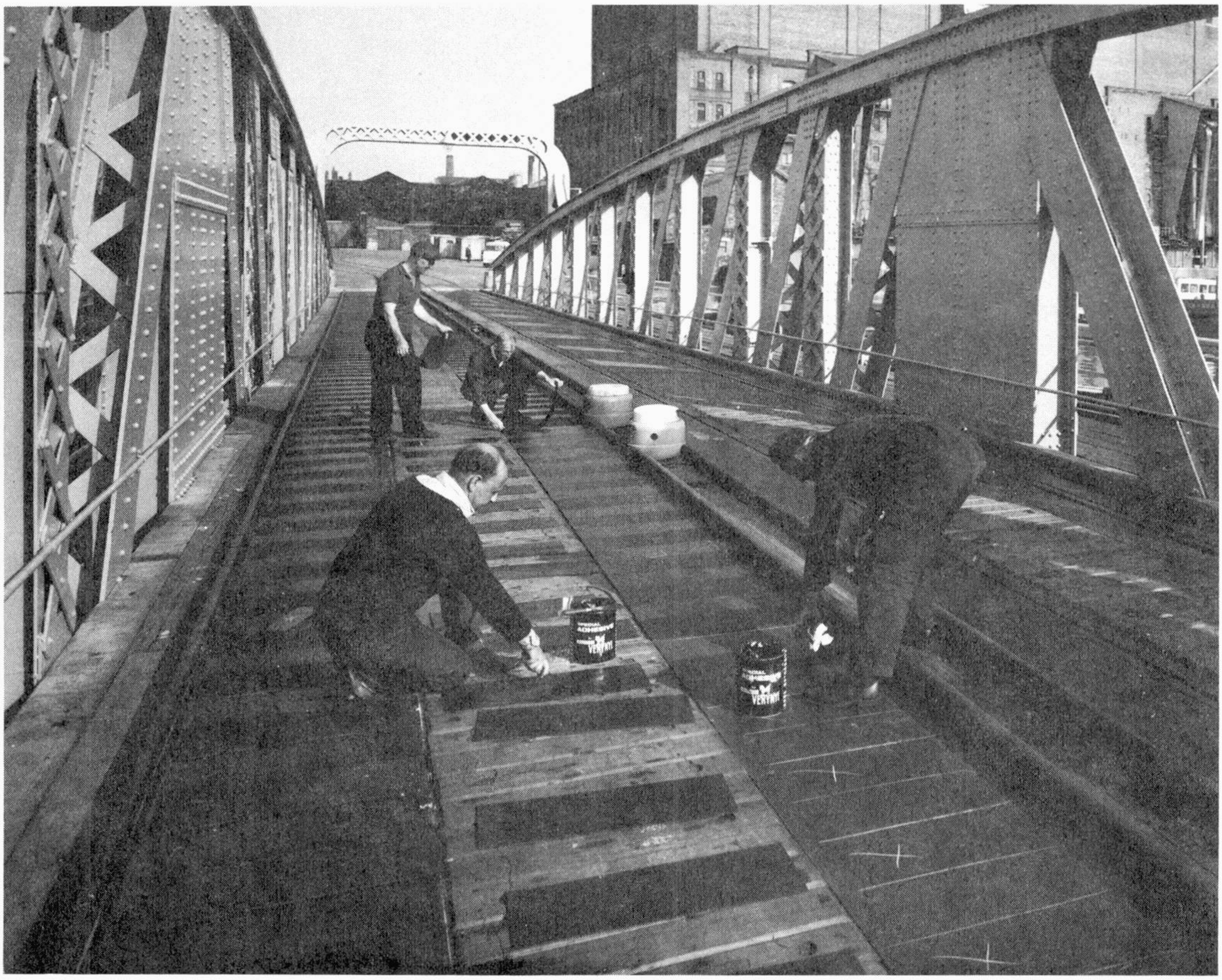

Figure 1

Figure 2

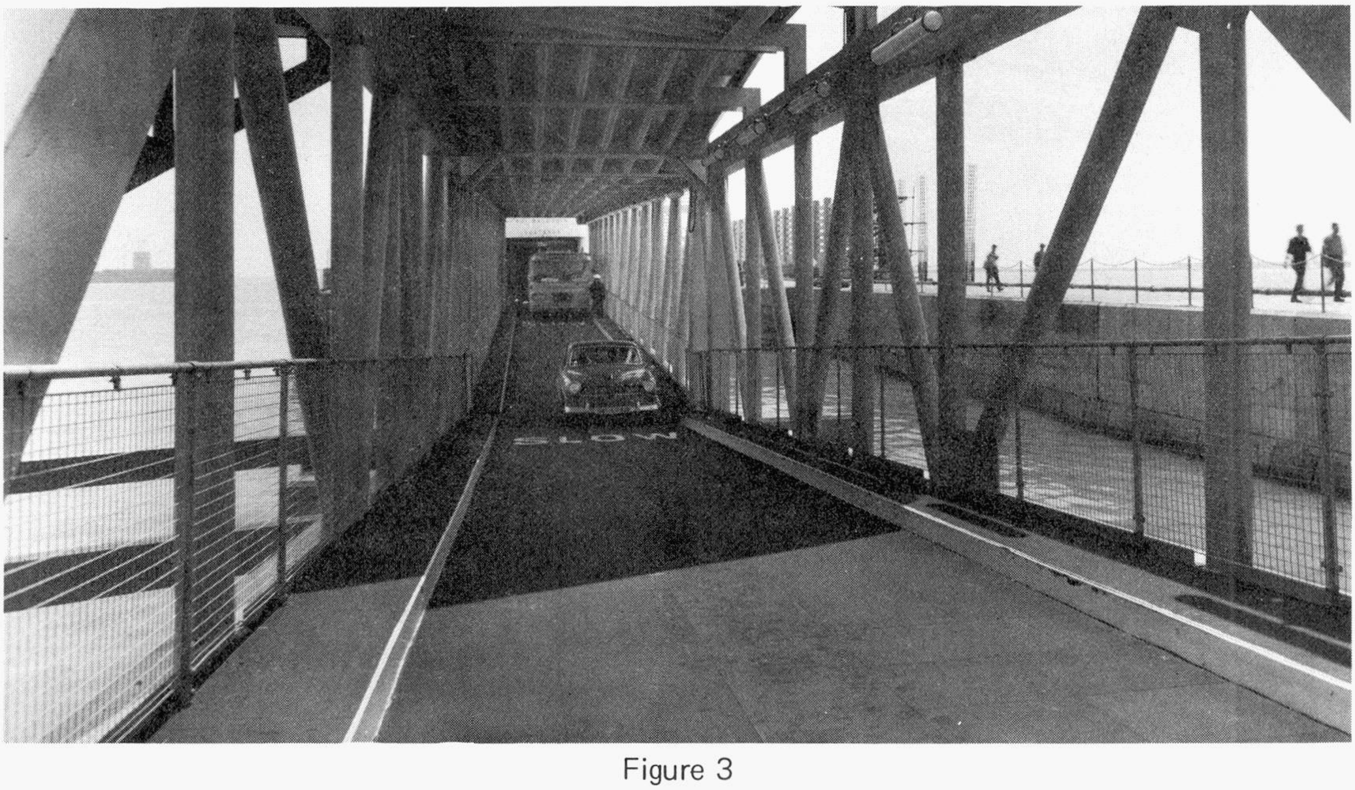

Figure 3

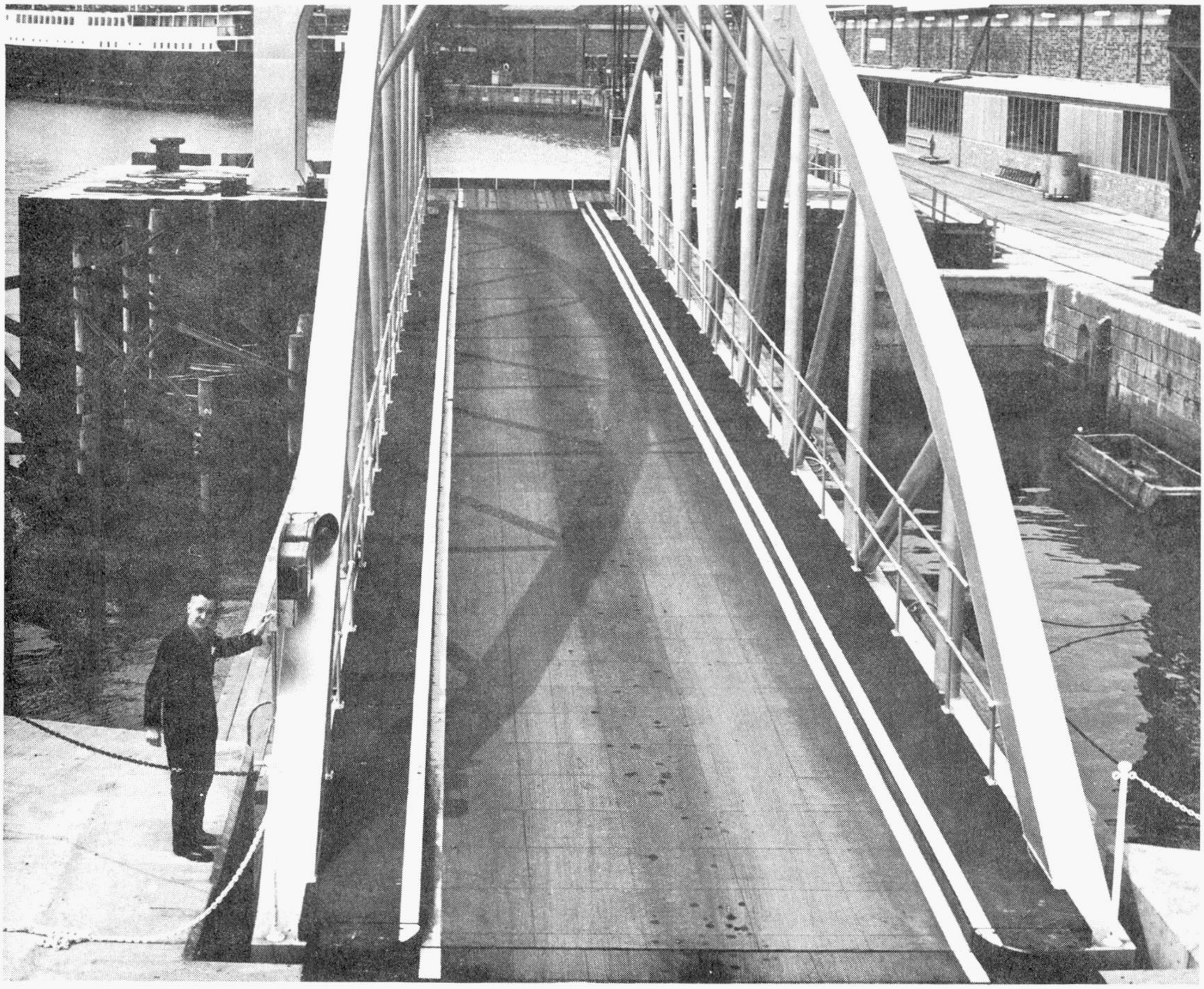

Figure 4

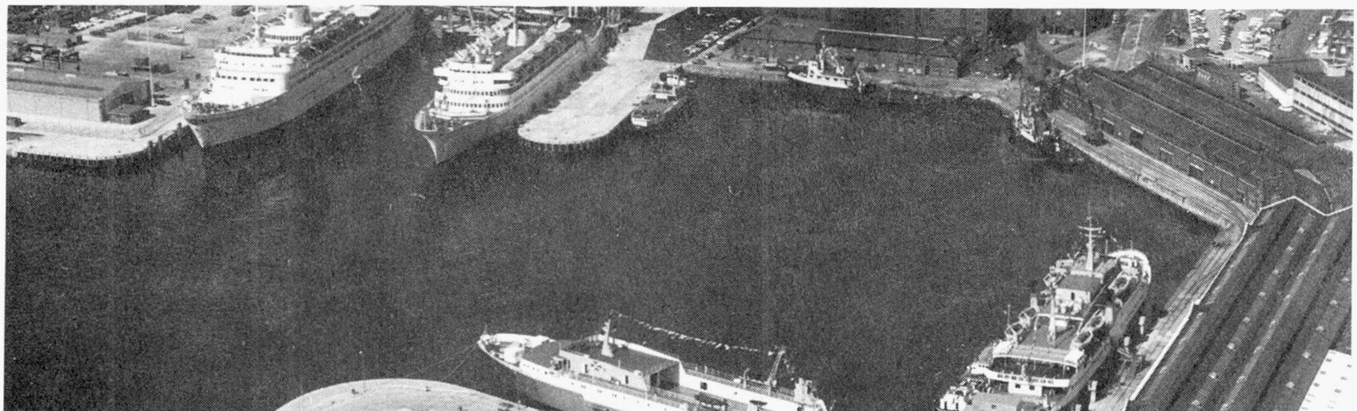

Figure 5

SUMMARY

This contribution describes and illustrates the use of Poly-Vinyl-Chloride tiles secured by adhesive to steel decks as a method of surfacing movable bridges.

RESUME

Cet article décrit et explique l'emploi de dalles en P.V.C., collées sur le tablier, comme revêtement routier très avantageux pour ponts mobiles.

ZUSAMMENFASSUNG

Dieser Beitrag beschreibt und veranschaulicht den Gebrauch von Poly-Vinyl-Chlorid-Fliesen, die durch Haftung auf den Stahlplatten gesichert sind, als Anwendung von Fahrbahnbelägen auf beweglichen Brücken.

STEEL GRID FLOORS

Tabliers en grilles d'acier

Stahlgitterdecken

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Steel grid floors have been used extensively in the United States for more than 40 years. The primary use for this material is on long span and movable bridges where weight is such a critical factor. Other applications have been found in the reconstruction or rehabilitation of older bridges for the purpose of maintaining or sometimes increasing the live load capacity of the structure. A special use has been found for long span suspension bridges where grid floor sections provide "wind slots" which contribute to the aerodynamic stability of the structure. The relative high cost of this floor system limits the application to these or other similar special conditions.

Originally the grid floors consisted of two basic designs, rectangular and hexagonal. The rectangular pattern resulted from the fabrication of a combination of flat rolled bars placed at right angles, in slots and welded to specially rolled I beams. The hexagonal pattern is the result of riveting flat rolled main longitudinal bars to specially bent spacer bars. Due to its lighter construction, the hexagonal design is used for short stringer spans and the heavier rectangular design is used for longer stringer spans. More recently a design was developed which added a diagonal member to the rectangular pattern.

The three basic designs are illustrated in the attached photographs. The grid floor sections are produced in a variety of weights and dimensions to fit almost any beam or stringer spacing. Metal grid flooring will support standard truck loading when placed on properly designed beams or stringer system.

If the bridge owner considers the increased tire noise or reduced traction objectionable the metal grid floor may be filled or overfilled with concrete. The effect of the increased weight can be partially reduced by using light weight aggregate in the concrete mixture. An additional advantage that can be considered in the concrete filled grid is the composite action that is developed between the floor and the supporting stringer. A flush filled grid floor can also be overlaid with bituminous concrete to produce a different texture for the wearing course.

Other methods for increasing the traction or skid resistance of the metal grid floor is to use serrated bars on the surface or to weld metal studs on the surface of existing grating. The 1/4-inch round welded studs are shown on a portion of the deck in photograph No. 5.

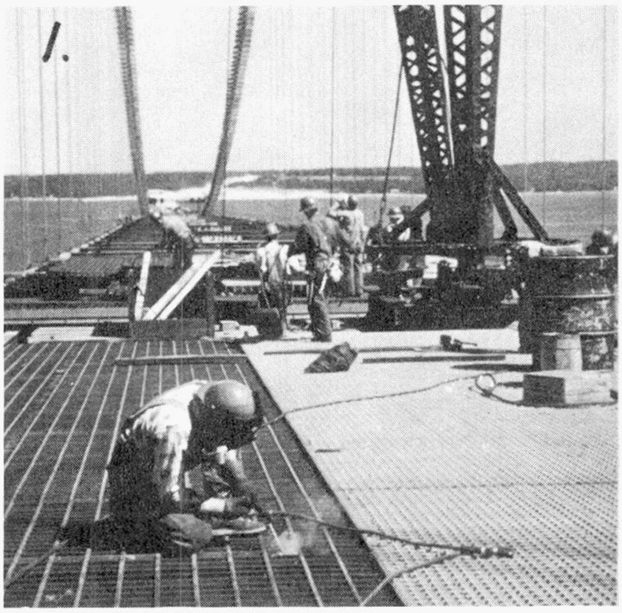
The fabrication of aluminum shapes into a grid floor system is of recent origin and is still in the development stage.

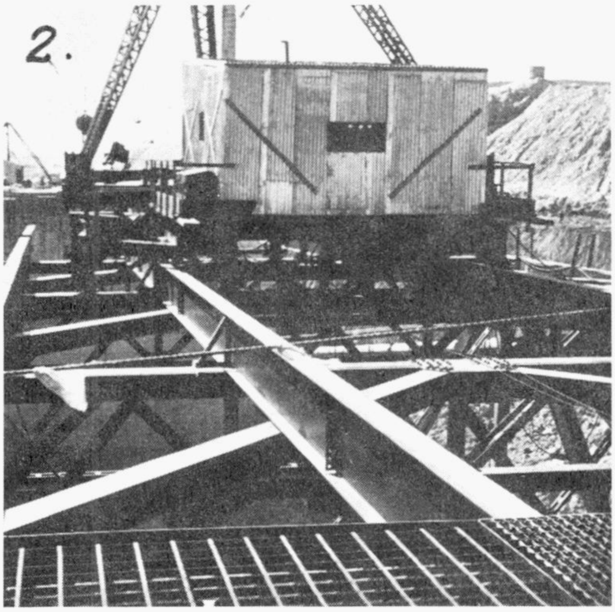
The preferred method of attachment of the grid flooring to the supporting members is by welding. However, metal clips, bolts and clamps have been devised to make these connections.

The relative weights of the various floor systems are as follows:

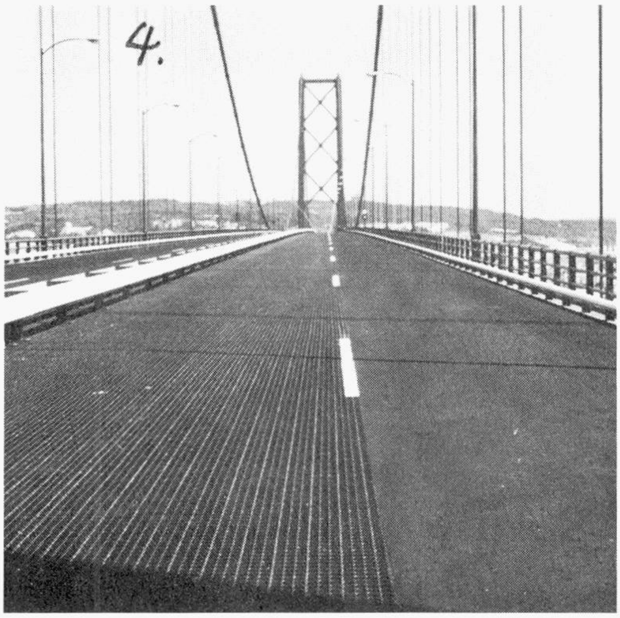
Type of Deck	Weight in Pounds per square foot
Aluminum type	10-12
Steel type	19-21
Concrete filled	38-54
Reinforced Concrete	75-100
Reinforced Lightweight Concrete	55-75

Due to the special nature and application of metal grid floors there is little meaningful cost data available except that the cost of the steel grid floor is approximately four times as costly as the conventional reinforced concrete bridge floor.



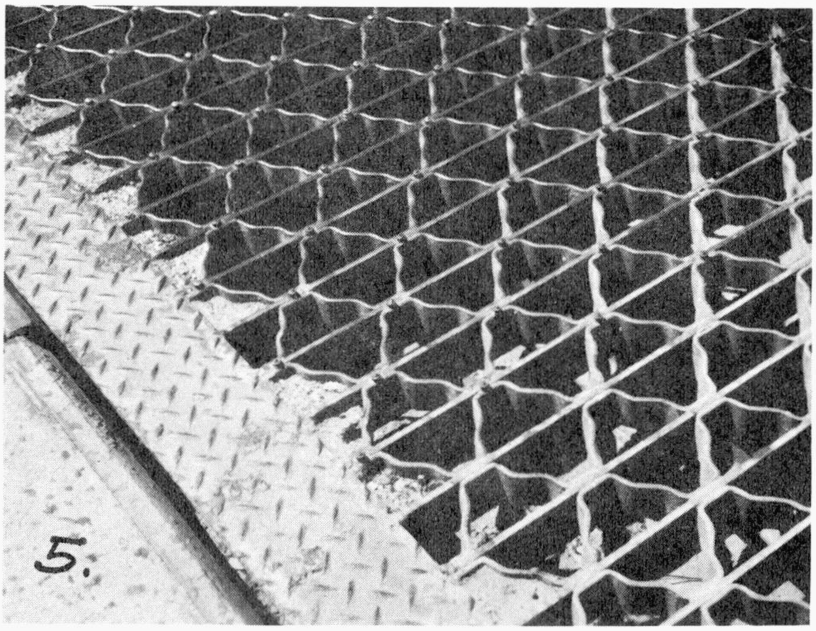


Photographs 1 and 2. Installation of steel grid floor for the Tagus River Bridge in Lisbon, Portugal. Two types of rectangular grid floor are shown. The close-spaced pattern on the right of each photograph is an open grid design and the panels on the left are to be concrete filled.



Photograph 3 shows some additional details of the grid floor which will be filled with concrete.

Photograph 4 shows the completed bridge deck of the Tagus River Bridge. The left lane has an open grid floor and the right lane has a concrete filled grid floor.



Photograph 5 shows an open grid on a bascule bridge in Connecticut which has a hexagonal pattern. This photograph also shows the modification which has been made to improve traction. One quarter inch round studs have been welded on the top of the longitudinal bars to give a rough texture. A portion of the floor on the lower right does not have the additional studs.

SUMMARY

Steel grid floors have been used in the United States for more than 40 years. The primary use is for long span or movable bridges where weight is critical. There are two basic designs; rectangular and hexagonal. In some applications the steel grid floors have been filled with concrete.

RESUME

Des tabliers de ponts en grilles métalliques ont été employés aux USA depuis plus de quarante ans. Leur poids léger les prédestine pour les ponts à grande portée ou les ponts mobiles. On distingue deux types de base: grilles rectangulaires et grilles hexagonales. Parfois, on remplit la grille avec du béton.

ZUSAMMENFASSUNG

In den Vereinigten Staaten werden Stahlgitterdecken seit mehr als 40 Jahren benutzt. Der hauptsächlichste Gebrauch liegt bei weitgespannten oder beweglichen Brücken, wo das Gewicht kritisch ist. Zwei Formen sind üblich: recht- und sechseckig. In einigen Fällen ist das Gitter mit Beton gefüllt worden.

THE DEVELOPMENT AND USE OF THE ROBINSON COMPOSITE DECK IN FRANCE

Développement et applications de la dalle Robinson en France

Entwicklung und Anwendung der Robinson-Verbunddecke in Frankreich

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I - INTRODUCTION

This Symposium is devoted to the examination of the carpets to be applied to the light steel decks of highway, bridges that is to say primarily to orthotropic decks.

As the rapporteur, Dr. W. Henderson, has stated, this type of deck is the latest version of many artifices introduced by bridge engineers in order to :

- reduce the dead weight of the bridge deck,
- employ the decking material as an element capable of resisting the bending induced in the superstructure as a whole,
- reduce the overall depth of the superstructure.

Nonetheless, there are decks other than orthotropic which fulfil all these functions. There is, for example, in France a thin concrete deck, reinforced by a continuous supporting steel plate, which was developed and tested in 1950 by J.R. Robinson (Technical adviser to the IABSE) and J.R. Courbon, and which is known as the "Robinson deck" (1).

This deck has been used since then in dozens of French steel

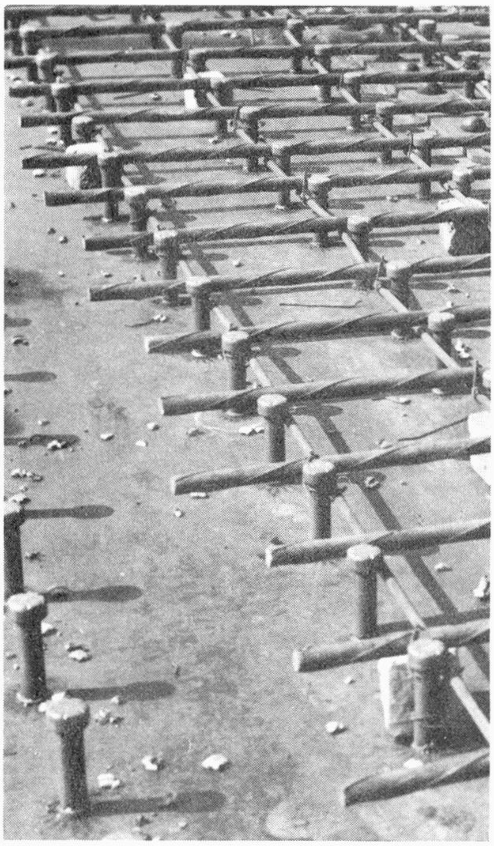
(1) See especially :
J.R. Robinson, Preliminary publication, 4th Congress, IABSE, Cambridge, 1952
A. Schmid, Platelages légers pour ponts-routes, 7th Congress, IABSE, Rio de Janeiro, 1964.

bridges, including some of the most spectacular and some whose headroom requirements were critical. None of these schemes have caused the slightest trouble from the point of view of surfacing or decking or the system adopted.

By contrast, problems concerning the adherence of the carpet are presented when aluminium decking, which is used in moving bridges in docks, or orthotropic decks are employed, although the latter have been little used in France because the obstacles to be crossed require relatively small spans.

II - DESCRIPTION OF THE ROBINSON DECK

The deck is of composite steel and concreteconstruction, consisting of :



- a continuous steel supporting plate the thickness which is at least 6 mm (2),
- a concrete slab, poured onto this plate, to which it is attached by shear connectors which are either :
  - studs which transfer the shear forces between the steel and the concrete, as in Fig.1, or,
  - strips, bent at 45°, the lower parts of which are welded to the steel plate and the upper presenting horizontal portions, to which the reinforcement rods are welded, thus absorbing the shear forces by bond to the concrete, as in Fig. 2

Fig. 1

(2) The French regulations for steel bridges (CPC-61-V) require that every structural element shall have a thickness of at least 8 mm, unless it is protected on one side (as is the case with the Robinson deck, thanks to the concrete slab), when it may be reduced to 6mm. Nevertheless, to limit the deflection in the plate under the load from the concrete and the effect of welding stud connectors, it is unusual to descend below 8 mm.

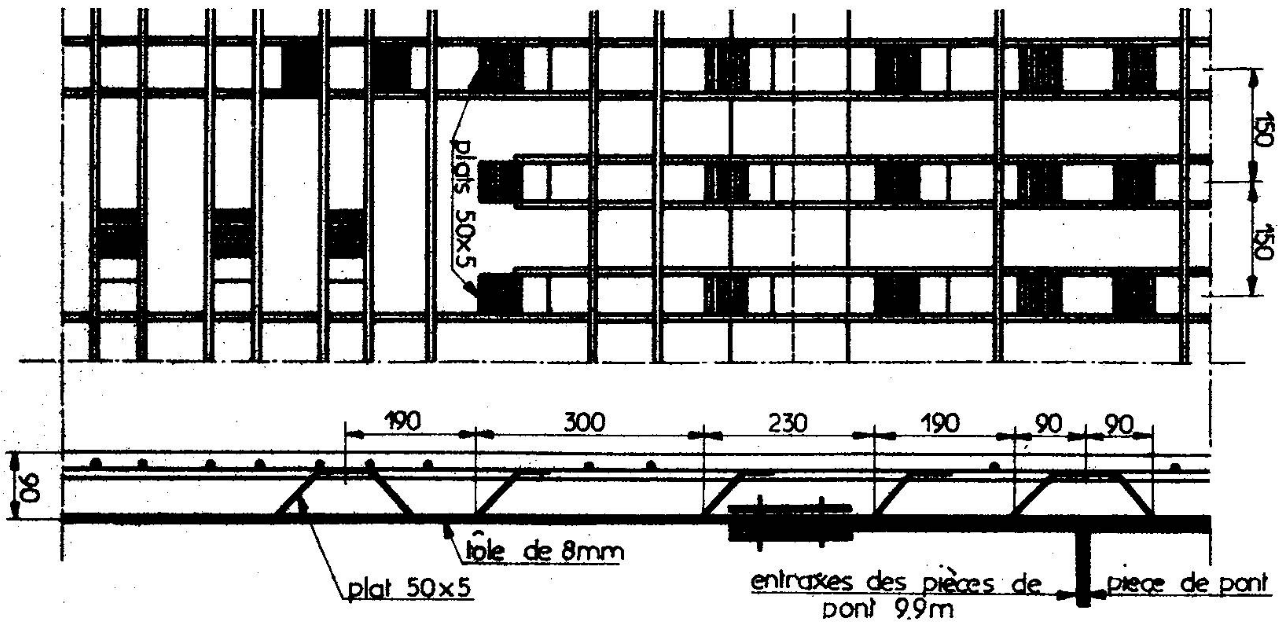


Fig. 2

The thickness of the concrete slab is considerably less than that required for a reinforced concrete slab, which on account of punching shear could scarcely descend below 16 cm.

By contrast, in the case of the Robinson deck, the continuous supporting steel plate, which is connected to the girders, acts as a membrane and avoids any risk of punching shear in the deck.

The minimum thickness of the slab is therefore fixed by the resistance to bending. Under the transverse bending moments between the girders, the compressive stress in the concrete must not exceed 0.6 σ_{28} (which in practice limits the stress to between 175 and 200 kg/sq.cm).

As the spacing of the stringers varies from 1.0 to 2.5 m, the thickness of the slab varies from 6 to 10 cm.

The supporting steel plate, like the upper plate of an orthotropic, deck, plays several rôles :

- it resists local transverse bending between the main girders (or the stringers)
- as it is connected to the main girders and to the stringers (if there are any), it acts as the top flange of these members

in resisting bending.

III - SPHERE OF USE

Comparison with other kinds of surfacing

Let us compare the weight per sq.m. of reinforced concrete, Robinson and orthotropic decks. In the first two cases, the wearing surface has a thickness varying from 4 cm (where it is necessary to keep the weight down, as in a swing or lifting bridge) to 6 cm. For orthotropic decks, a thickness of 7 cm is considered necessary. The densities considered are : 2.25 tons/cub.m for bituminous carpets, 2.5 tons/cub.m for concrete and 7.85 tons/cub.m for steel. Finally, the weight of the orthotropic deck is calculated by considering an "equivalent thickness" (12 mm thick plate + stringers and cross girders) of 25 mm.

Weight in kg/sq.m

Deck	Reinforced concrete	Robinson	Orthotropic
Surfacing	(0.04 to 0.06)x2250= ∿100	100	0.07x2250=∿150
Concrete	0.18x2500 = 450	0.08x2500=200	-
Steel	-	0.008x7850=65	0.025x7850=∿200
TOTAL	550	365	350

This comparison demonstrates that the Robinson deck and an orthotropic deck are of about the same weight.

It must be said, however, that :

- As far as general bending is concerned,all the steel section of the orthotropic deck acts, equally in tension as in compression, while, by contrast, only the bottom plate (of smaller section) of the Robinson deck can resist tension in the zones subjected to negative moments (and where the concrete is also in tension).

- Although the spacing of the main girders for orthotropic decks may be large, for the Robinson deck it must be limited. Alternatively, intermediate stringers may be used which of course increase the amount of steel employed beyond the figure mentioned above.

From the experience gained in competitions and in the structures erected in France, it is possible to say that at the present time in our country :

a) The Robinson deck is the type of deck to adopt for steel bridges required for spans of about 100 m or less, when the depths are less than 1/30 of the span (a reinforced concrete deck is too thick in comparison with the Robinson deck which allows a reduction in depth of about 10 cm).

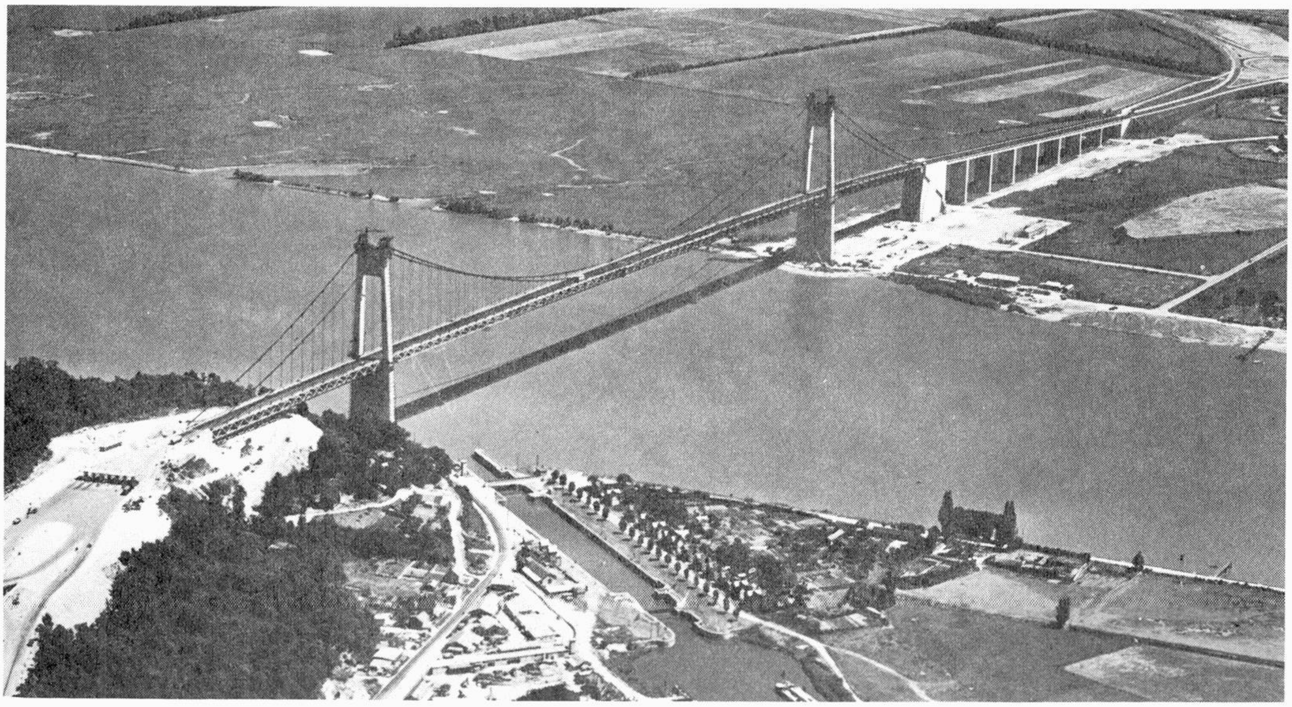
b) The orthotropic deck, intrinsically more expensive because of the price of steel, which is more than that of concrete, and of the expense of fabrication and multiple welds, is considered for structures whose spans are at least 150 m.

IV - PRACTICAL EXAMPLES

IV.1 - Suspension bridges

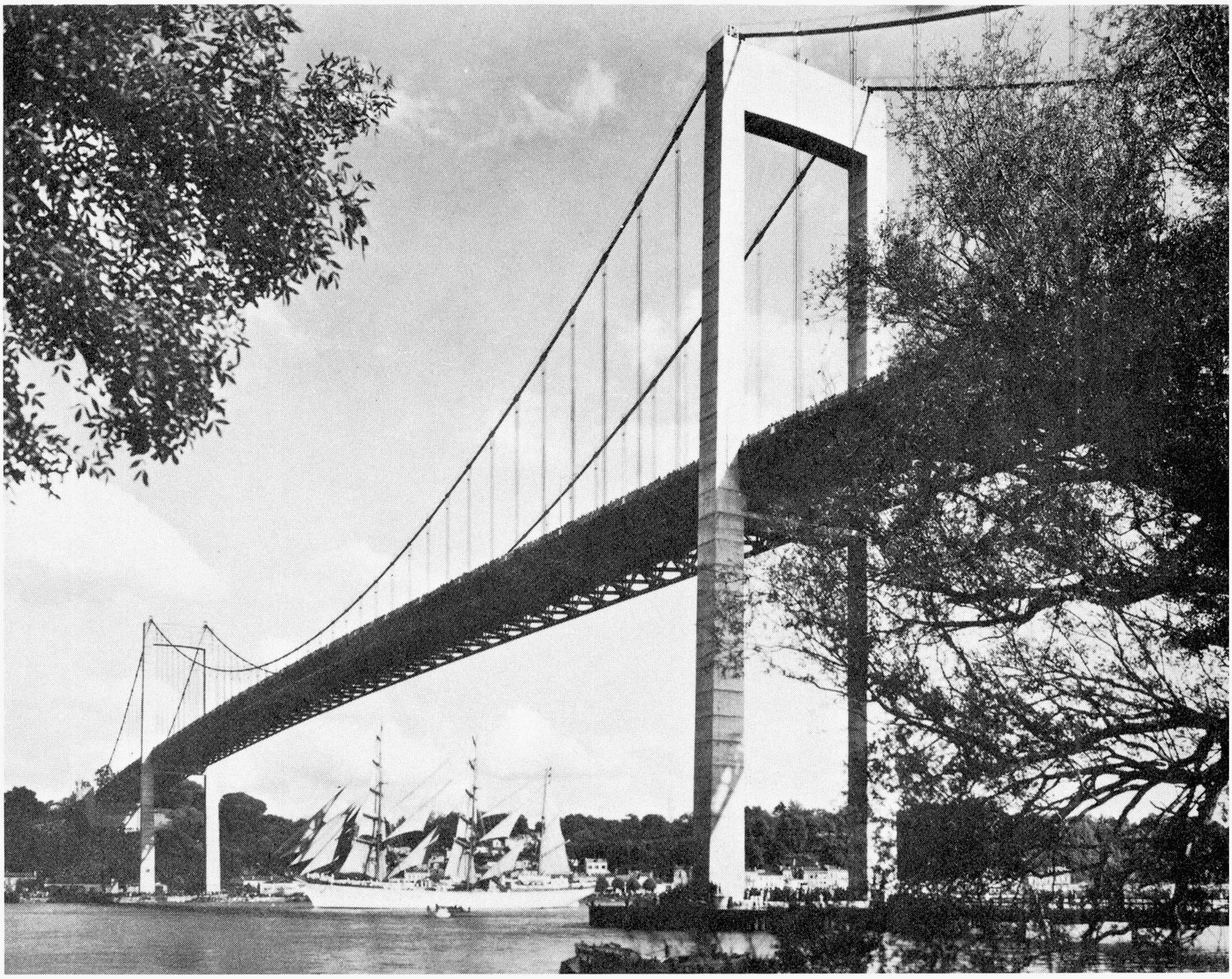
The two latest (and greatest) suspension bridges built in France have a Robinson deck.

Fig. 3



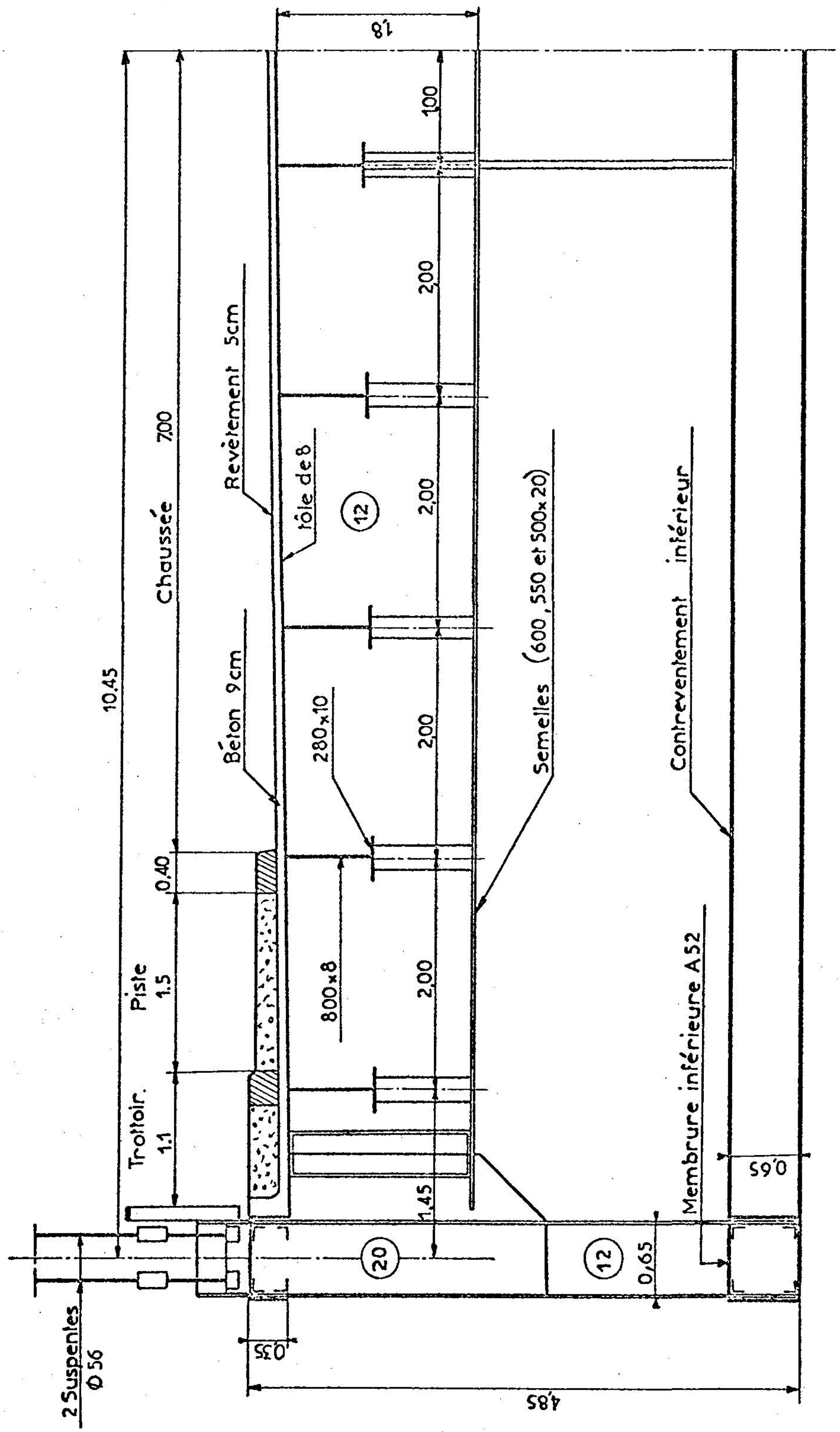
Bridges	Spans m	Spacing of stringers m	Thickness of decking		Connectors
			Plate cm	concrete cm	
Tancarville (Fig.3)	176+608+176	2.0	1.0	9.5	Studs
Bordeaux (Fig.4.5)	150+384+150	2.0	0.8	9.0	Strips at 45°

Fig.4



PONT SUSPENDU DE BORDEAUX

Demi-coupe transversale



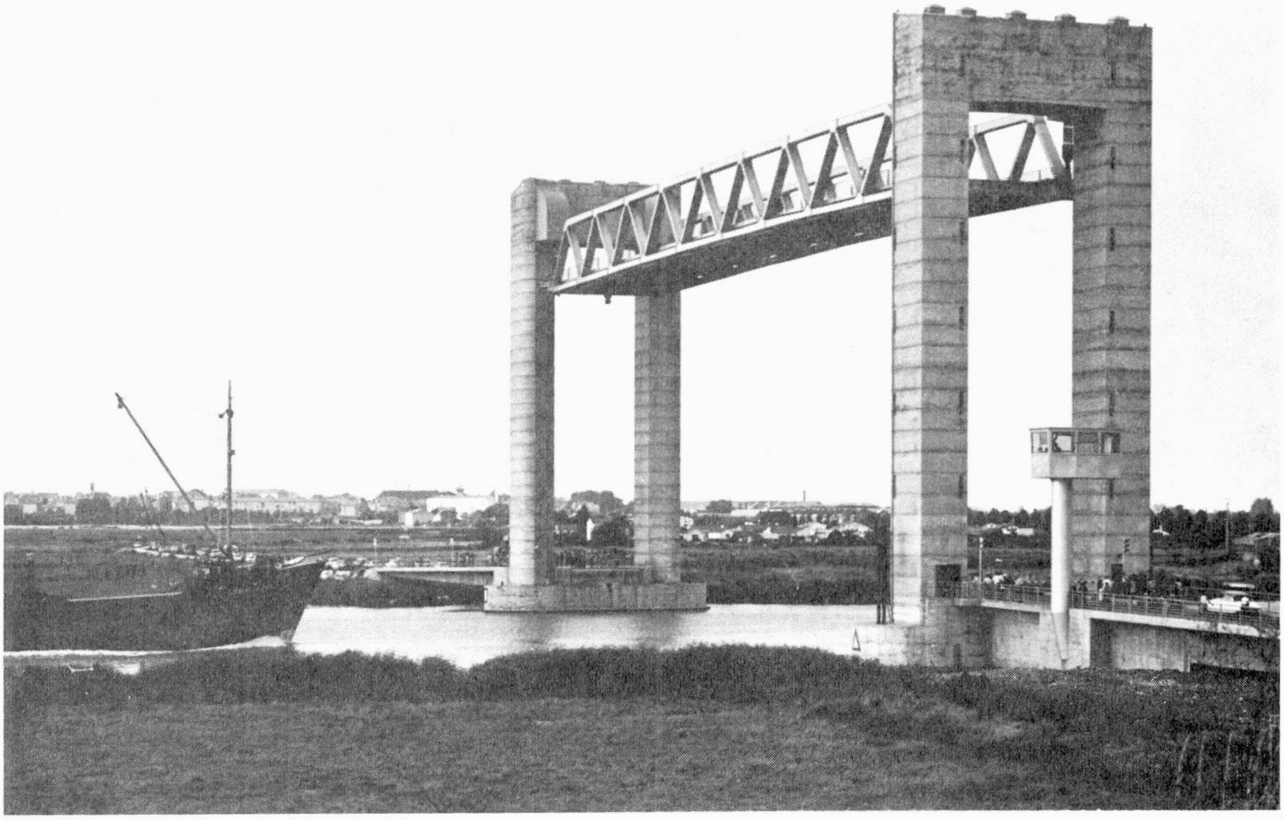


Fig.6

IV.2 - Moving bridges

The last two moving bridges built in France were lifting bridges. They are of the through type with Warren girders and a Robinson deck.

In the case of the bridge at Brest, the slab rests on a curved plate, the minimum thickness being above the girders and the maximum at mid-span.

Bridge	Span m	Spacing of stringers m	Thickness of decking		Total depth of superstructure
			Plate cm	Concrete cm	
Brest	87.50	1.50	0.6	5 to 9 (curved plates)	1.35
Martrou (Fig.6)	92.43	1.10 to 1.60	0.8	6 to 9	1.01

IV.3 - Slender bridges

Kind of bridge	Bridge	Span m	Total depth of superstructure m	Thickness	
				Plate	Concrete
Single span girder bridge	Attigny	21.5	0.575	1.2	5 to 9 (curved plates)
Continuous girders bridge	Lorient	63+95+63	3.70 to 2.18	0.8 to 2.0	6
Portal	Jeumont	32.9	0.69	1.0	5 to 18 (curved plates)
Triangulated through girder bridge	Rangiport	102.52	1.222	0.8	6 to 10 (curved plates

V - CONCLUSION

In the last twenty years many French steel bridges have been built with the Robinson composite steel and concrete deck, scarcely heavier than an orthotropic deck.

The thickness of the bituminous carpet, which is normally 6 cm, could be reduced to about 4 cm for moving or highly trafficked bridges.

There have been no difficulties connected with :

- the adherence of the surfacing (which is the same as that in current use for concrete bridges),

- the resistance of the supporting steel plate to corrosion. It seems that its top surface is protected by the concrete. In addition, as the plates are usually made continuous by welding, no water can pass through them.

SUMMARY

Light bridge decks in composite construction of the Robinson-type have been used in France for nearly 20 years, especially for bridges with spans up to 100 m and/or with relatively small depth, as well as for movable bridges.

A brief description of this type of deck and some examples of such structures are given.

RESUME

La dalle mixte légère, système Robinson, est employée en France depuis près de 20 ans, notamment pour des ponts à portées jusqu'à 100 m ou à hauteur de tablier relativement faible, ainsi que pour des ponts mobiles.

Une description sommaire de ce type de dalle ainsi que des exemples de ponts construits sont donnés.

ZUSAMMENFASSUNG

Die leichte Verbunddecke System Robinson wird in Frankreich seit fast 20 Jahren angewandt, und zwar hauptsächlich für Brücken mit Spannweiten bis zu etwa 100 m, und/oder mit relativ kleiner Bauhöhe sowie für bewegliche Brücken.

Eine kurze Beschreibung dieses Deckensystems und einige Anwendungsbeispiele werden angegeben.

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USE OF P.V.C. TILES BY PORT OF LONDON AUTHORITY

L'emploi de dalles en P.V.C. par la "Port of London Authority"

Anwendung der P.V.C.-Fliesen durch die Port of London Authority

R.E. WEST
Port of London Authority

The Port of London Authority are responsible for a number of bridges in the docks under its control and most of these are of moving type to permit the passage of shipping. To reduce the power required from the operating mechanism as much as possible all the dead-weight of the span has to be counter-balanced with the result that the loan on the supporting rollers or bearings is much higher than it otherwise would be.

Much has been done of recent years to reduce structural weight and considerable thought has also been given to deck surfacings. The P.L.A. have considered the use of various alternatives to rolled asphalt; which weighs some 11 lb. per sq. ft. for each inch of thickness, and for their new bridge which they have recently designed for the South Dock Entrance at India & Millwall Docks they intend to adopt a p.v.c. material containing ground mineral fillers. This will be 2.5 millimeters in thickness and weighs only 1 lb. per sq. ft.

This surfacing has been extensively used for a number of years as a road marking material and was first adopted by the P.L.A. for surfacing the lifting section of a covered footbridge which was completed in 1964.

The new bridge will have the sheeting on the road as well as on the pavements and the reasons which led to its adoption are perhaps of interest.

The carriage-ways will be formed from a welded battle deck structure which has been designed for full H.B. loading and some deflection of the $\frac{7}{8}$" road plating is of course expected. This deflection will not be much reduced by the use of a thin light-weight surfacing and the flexible tiles are therefore to be preferred to a material which has a hard setting characteristic, such as many epoxy compounds.

The sheeting has a highly non-skid triangular embossed surface and has good wear resistant properties, which have been amply proved by tests on trunk roads and pedestrian crossings in areas of intensive traffic. It will be laid in tiles 2' square and replacement will be an easy matter when eventually required.

An incidental advantage of the sheeting is that it is available in several colours including black and white making it possible to build carriageway lines etc. permanently into the surface.

It is obviously essential that the surfacing should adhere strongly to the deck plating and close attention has been given to this feature and to the necessity for protecting the steel-work from corrosion. This latter problem is aggravated by the necessity for leaving a gap of $\frac{1}{8}$" between the tiles when they are laid to allow for spread in service and these gaps have to be effectively sealed to prevent moisture seeping underneath.

It was originally intended to first prepare the deck by grit blasting followed by zinc spray with the tiles bonded to the zinc and sample plates for this treatment were made up for testing. It was found that the adhesion of the zinc to the steel was substantially less than of the tiles to the zinc and that better adhesion altogether was obtained by the grit blasting followed by a weldable primer only between the tiles and the steel. This treatment will be adopted for the new bridge and the joints between the tiles will be sealed with the adhesive.

SUMMARY

The author discusses the considerations leading to the adoption of polyvinyl chloride tiles as a carriageway surface on an opening bridge.

RESUME

L'auteur explique les raisons pour l'emploi de dalles en P.V.C. comme revêtement routier sur des ponts mobiles.

ZUSAMMENFASSUNG

Der Autor erklärt die Beweggründe, welche P.V.C.-Fliesen als besonders günstig für Straßendecken auf beweglichen Brücken erscheinen lassen.

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