Rehabilitation of a moveable highway bridge using orthotropic plate with thin wearing surface

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REHABILITATION OF A MOVEABLE HIGHWAY BRIDGE USING ORTHOTROPIC PLATE WITH THIN WEARING SURFACE

Réparation d'un pont-routier mobile au moyen de plaques orthotropiques avec revêtement mince

Ausbesserung einer beweglichen Straßenbrücke durch orthotrope Platten mit dünner Deckschicht

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The Hull River Bridge, near Beverley, Yorkshire, constructed in 1912, consists of two side spans (each of 17 ft.) and a central rolling retractable span of 33 ft. The central span tilts and rolls onto the West span and West abutment to allow passage of river craft.

The central span consisted of Hobson trough units formed by arch plates riveted to inverted tees at the bottom and spanning transversely between half through main girders spaced 25'9" apart. As constructed the troughs were filled with coke breeze concrete and a one inch asphalt layer provided the carriageway wearing carpet as shown in Fig. 1. There are two 9'6" lanes of roadway.

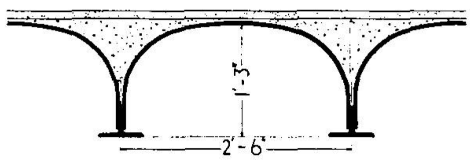

Fig.1.

In 1930 when repairs were required to the floor of the central span the concrete filling was removed from the crowns and from the valleys to a depth $3\frac{1}{2}$" below the crowns to accommodate longitudinal oak timbers of $6\frac{1}{2}$" maximum depth, shaped to the contour of the trough and valley concrete surfaces. The new wearing surface consisted of transverse elm boarding $1\frac{1}{2}$" thick nailed to the oak timbers as in Fig.2. This wearing surface was subsequently replaced by a 1" asphalt layer.

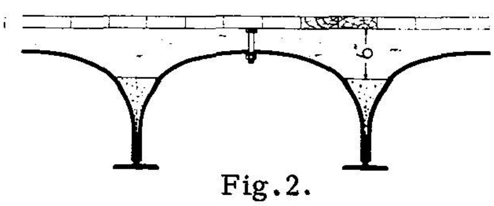

Fig.2.

Inspection of the bridge in 1961 disclosed marked vibration and racking under road traffic which had increased in weight and volume over the years. The bridge had become difficult to open and close on account of the added dead load due to water-logging of the floor timbers. Spot checks where timbers were temporarily lifted for inspection disclosed serious sporadic corrosion, aggravated by the timber and steel being in contact. An analysis of the strength of the bridge indicated overstress of the trough units both under a single 16 ton vehicle and two 10 ton vehicles, one per lane, allowing 25% for impact.

The analysis assumed that the troughs behaved independently under wheel loads but in fact considerable distribution by the timber infilling was revealed in tests.

It was decided to provide a new fixed bridge and approaches about 100 yards upstream of the drawbridge but before this can be done the drawbridge has to remain in continuous service and strengthening was essential.

In view of the extensive corrosion and other suspected hidden defects in the deck it was decided to provide an orthotropic steel deck after removing the timber filling. Fig. 3 shows a cross section of the deck after strengthening. The orthotropic deck consisted of a 7/16 in. thick mild steel plate stiffened below by 3" x 3" x $\frac{1}{4}$" longitudinal closed ribs cut from 6" x 3" hot finished seamless rectangular hollow sections. The use of hot finished sections reduced locked-in stresses induced by welding. Fig. 4.

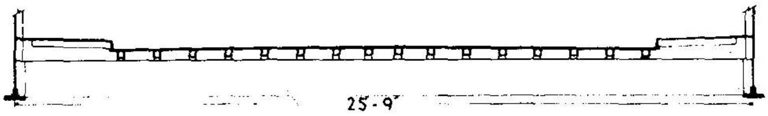

Fig. 3.

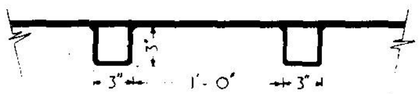

Fig. 4.

The deck was fixed with high strength bolts at the crowns of the troughs which still formed the floor beams. Valley stiffeners were welded to the troughs to maintain their stability. The bolts were inserted through holes in the top plate which were sealed by plugs welded in after the bolts had been tightened as shown in Figs. 4a and 4b.

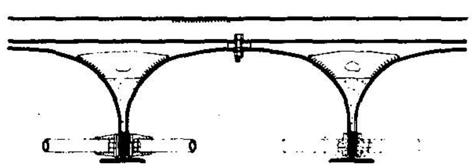

Fig.4a.

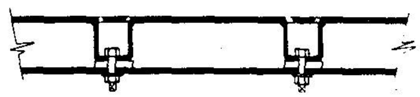

Fig.4b.

To increase the torsional resistance of the trough system and improve the capacity of the deck to distribute wheel loads, a tubular lacing system was applied in the horizontal plane of the tees as in Fig. 4a. Corroded portions of the troughs were made good by reinforcing plates welded to them.

A 3/8" thick epoxy wearing surface was applied directly to the steel deck at site under controlled temperature and humidity. A resin binder base coat was first laid at the rate of 1 lb. per square yard on the cleaned surface to the following composition:

Epikote 828	40% by weight
Orgol Coal tar	43% " "
Yarmol Pine Oil	8% " "
Phenol	2% " "
Dimethylene triamine	7% " "

The surfacing mixture consisting of 1 part resin binder to 4 parts of dry aggregate by weight was trowelled immediately over the base coat to a thickness of 3/8".

The composition of this binder was as follows:

Araldite F	44% by weight
Soft tar	22% " "
Versamid 125	21% " "
Thiskol LP3	2% " "
Hardner 956	2% " "
Hardner 960	2% " "
Butyl glycidyl ether	7% " "

The aggregate used consisted of:

Calcined bauxite	3/16" to No. 6 B.S.	sieve	30% by weight
" "	No.6 to No.10	" "	35% by weight
" "	No.10 to No.30	" "	15% " "
Silica sand	No.25 to No.100	" "	20% " "

The surface was lightly dusted with fine calcined bauxite No.10 to No.30 B.S. sieve at a rate not exceeding 400 sq.yd. per ton.

Work proceeded on one traffic lane at a time in order to avoid complete closure of the bridge.

Stresses were measured in the floor beams and main girders induced by test loads at critical stages of the work and at completion.

Two Matador lorries loaded with Atkinson gritter boxes were used as test loads. These were placed side by side three feet apart with their rear axles first over the crown of the trough at mid span and then at each adjacent valley.

An initial approximate study of stresses due to the test loads gave the maximum compressive and tensile live load bending stresses in the trough units as 4.27 ton/sq.in. and 8.06 ton/sq.in. respectively, and in the main girders as 1.68 ton/sq.in. A more recent study using the finite element technique has considered the deck as an orthotropic plate elastically supported on torsionally stiff transverse beams which frame into the main girders. This study has given live load stresses which are considerably below the original estimate. The maximum compressive and tensile bending stresses in the trough units are respectively 1.75 ton/sq.in. and 4.06 ton/sq.in. and the maximum main girder stresses are 1.22 ton/sq.in. in tension and compression.

Measured trough unit stresses are 84.5% in compression and 63% in tension of the calculated stresses. Main girder stresses are 100% in compression and 77% in tension of the calculated stresses. In analysing such a complex structure it is impossible to take account of all strength increasing factors. It is a tribute to modern techniques of analysis that observed and calculated stresses are as close as indicated above. Based on the results of the analysis alone the repaired bridge is shown to have a wide margin of safety under live load. A separate check has shown that there is also a wide margin of safety against stress fluctuation and reversal which occurs when the bridge is withdrawn for purposes of navigation.

The epoxy wearing surface remains in good condition after two years under heavy and almost continuous traffic.

I should express my thanks to Mr. L. F. Crossley, the East Riding of Yorkshire County Surveyor for his permission to make this contribution.

This repair and strengthening job was undertaken in close association with the Bridges Department of the British Ministry of Transport.

This department had already gathered experience in providing thin wearing surfaces to steel decks. Their recommendations were very largely followed in preparing the epoxy specification detailed above.

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SUMMARY

The floor of a two lane half through steel retractable highway bridge constructed in 1912 was formed of transverse troughs built of arch plates riveted to inverted tees at the bottom. Signs of overstress in the floor became apparent with increase of live load and strain gauge measurements indicated the extent of overstress. Traffic had to be maintained during rehabilitation but single lane working was allowed. After removal of shaped timber and concrete infilling from trough valleys an orthotropic steel deck system with thin epoxy wearing surface was superimposed one lane at a time, attached to the troughs by high strength bolts at the arch crowns and a tubular lacing system was applied in the horizontal plane of the tees to improve torsional resistance of the troughs, so improving longitudinal distribution of wheel loads. The wearing surface was applied at site under controlled temperature and humidity. Live load strain measurements were made in floor and main girders under test loads at critical stages of the work and after completion.

The bridge now has a substantial margin of strength and fatigue resistance and with little increase in dead weight. The epoxy wearing surface remains in good condition after two years heavy and almost continuous traffic.

RESUME

Le plancher d'un pont-routier escamotable en acier à deux voies et à tablier inférieur construit en 1912, était constitué d'auges transversales formées de plaques courbées rivées à leur extrémités inférieures à des Tés renversés. Des signes de surcharge se sont manifestées par suite de l'augmentation des charges appliquées. Le degré de la surcharge a été mesuré au moyen de jauges de déformation. Il fallait maintenir la circulation pendant la réparation, toutefois il fut possible de travailler sur une voie. Après avoir enlevé le plancher en bois taillé et le béton contenu dans le creux des auges, on plaça un plancher orthotropique en acier et une surface frottante mince en époxy. Le placement s'effectua voie par voie. Le plancher orthotropique fut fixé aux sommets des auges au moyen de boulons de haute résistance. Une structure tubulaire fut placée dans le plan horizontal des Tés, et ceci afin d'augmenter la résistance des auges à la torsion. En même temps, la distribution longitudinale des charges des essieux fut améliorée. La surface frottante fut appliquée sur le chantier même. Pendant l'application on contrôla la température et le degré d'humidité. Des tests par poids roulant ont été effectués à certaines étapes critiques du travail ainsi qu'à son achèvement, ceci pour mesurer la déformation du plancher et des poutres maîtresses.

Malgré une légère augmentation du poids mort du pont, il y a maintenant une marge substantielle de résistance et une résistance plus effective à la fatigue. La surface frottante d'époxy se maintient en bon état et ceci après deux années de circulation intense et pratiquement continuelle.

ZUSAMMENFASSUNG

Die untenliegende Fahrbahn einer 1912 erbauten zweispurigen und zurückziehbaren Stahlträgerstraßenbrücke bestand aus querlaufenden Trögen, die aus halbrunden Blechen zusammengesetzt waren, welche auf ihren unteren Kanten an umgekehrte T-Profile genietet waren.

Mit zunehmender Verkehrslast zeigte sich eine Überbeanspruchung der Fahrbahn und Messungen mit Spannung-Dehnung-Messern zeigten die Größe dieser Überbeanspruchung. Während der Ausbesserungsarbeiten mußte der Verkehr aufrecht erhalten bleiben, jedoch war es gestattet, jeweils nur an einer Fahrbahn zu arbeiten. Nach der Entfernung des Holzes und der Betonausfüllung der Trogtäler wurde ein orthotropes Stahlfahrbahnsystem mit dünner Epoxyddeckschicht jeweils über einer Fahrbahn aufmontiert. Dieses System wurde an den Trögen durch hochfeste Bolzen an den Bogenscheiteln befestigt und eine Rohrvergitterung wurde in der Horizontalebene der T-Profile angebracht, um den Drillwiderstand der Tröge zu erhöhen und dadurch die Längsverteilung der Radlasten zu verbessern. Der Belag wurde auf der Baustelle bei kontrollierter Temperatur und Feuchtigkeit aufgebracht. Während kritischer Arbeitstufen und nach Abschluß der Arbeit wurden Messungen der Nutzlastspannung in den Fahrbahn- und Hauptträgern unter Probelasten gemacht.

Die Brücke hat jetzt wesentliche Festigkeits- und Ermüdungsfestigkeitsreserven ohne große Zunahme des Eigengewichts. Die Epoxydfahrbahndecke bleibt nach zwei Jahren starken und fast ständigen Verkehrs in gutem Zustand.

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