Bridge Strengthening Using Load Relieving Techniques

Renforcement de ponts en utilisant les techniques de relevage

Brückenverstärkung durch Entlastungstechniken

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SUMMARY

The paper describes several new techniques for strengthening existing bridges to withstand increased loading by imposing dead load relief or load sharing. The techniques cover external prestressing, the installation of extra shear connectors and the use of shock transmission units. They all benefit from requiring minimum, if any, traffic disruption.

RÉSUMÉ

L'article expose quelques techniques nouvelles pour le renforcement de ponts existants, dans le but de supporter un accroissement de charge en imposant à l'ouvrage des sollicitations de soulagement ou des charges réparties. Les techniques comprennent une pré-tension externe, l'installation de connecteurs qui travaillent au cisaillement et l'usage d'unités de transmission de choc. Le procédé ne nécessite qu'une interruption de trafic minimale.

ZUSAMMENFASSUNG

Der Beitrag beschreibt verschiedene Techniken zur Verstärkung bestehender Brücken auf höheren Nutzlasten durch Verminderung der Eigenlasten oder durch Lastaufteilung. Es handelt sich dabei um aussenliegende Vorspannung, den Einbau von zusätzlichen Schubverbindungsmitteln und die Verwendung von Schock-Uebertragungselementen. Der Vorteil dieser Massnahmen liegt in der minimalen Beeinträchtigung des Verkehrs.

1. INTRODUCTION

Strengthening of the world's bridge stock is a growth industry. This is inevitable as the years pass because existing bridges are expected to carry traffic of increasing loading and intensity for which they were not originally designed. The same passage of time also means that existing bridges are increasingly subjected to weakening environmental hazards, ranging from winter de-icing salt to polluted atmospheric carbonation. Strengthening of an existing bridge may become necessary because of increasingly apparent overloading or because major repairs are required and the opportunity is taken to strengthen the bridge to higher standards while traffic restrictions are in operation. The traffic restriction aspect is usually dominant and often precludes straight bridge replacement. It also strongly influences the method of repair and those methods which involve little or no traffic restriction are strongly favoured. Strengthening operations by various load relieving and sharing techniques fall into this category. Some new techniques for load relieving existing bridges with minimum, if any, traffic disruption are described.

2. DECK BENDING RELIEF BY EXTERNAL PRESTRESSING

2.1 General

Conventional prestressing of a bridge deck imposes a permanent direct compression together with a bending moment which counters the applied dead load moments. The two effects can be most beneficial to tension-weak concrete decks and together they allow the deck to carry further superimposed dead and live load moments without exceeding the permissible bending stresses or load factors.

The bending moment reduction effect of added prestressing can also be used to advantage in relieving dead load bending in existing overloaded decks of reinforced concrete, steel or composite concrete deck/steel girder structures. This dead load bending relief can be sufficient to reduce the deck bending under full dead and live loading to permissible limits. Alternatively a bridge deck can be upgraded to carry increased superimposed dead and/or live loading.

In general the direct compression effect of the added prestressing is not helpful. Reinforced concrete allowable compressive stresses are usually lower than with prestressed concrete and extra compression in steel structures can lead to plate stability problems. It is therefore beneficial to mobilise as much of the prestressing bending moment reduction as possible and there is every advantage in locating the prestressing tendons at the beam extremities or even beyond.

2.2 External Prestressing Applied to an Existing Composite Deck

Rakewood Viaduct carries the M62 motorway between Lancashire & Yorkshire across a 36m deep valley, Figure 1. The 256m long six span continuous deck, completed in 1969, consists of ten 3m deep steel plate girders carrying and composite with an insitu reinforced concrete deck slab. The viaduct required upgrading to cater for a proposed increase in traffic and the more onerous requirements of the newly introduced BS5400 bridge code. The main shortfall was identified as an approximate 40% overloading in the steel girder compression flanges over the piers. Upgrading by 'unloading', using external prestressing, was found to provide an economical strengthening procedure with minimal disruptions on this heavily trafficked motorway.

Figures 2 & 3 indicate the procedure, which first requires the attachment of fabricated steel anchors to the locally stiffened underside of each steel beam bottom flange by HSFG bolting. Three pairs of 50mm or 36mm diameter Macalloy prestressing bars of overlapping lengths are then attached under each flange between piers. Upon stressing, hogging bending is set up in the mid span regions of the beam. However, it is the parasitic sagging moment over the piers, caused by deck continuity, which performs the required 'unloading' to acceptable stress limits in the bottom girder flanges over the piers.

The dispersion of the high anchorage loads into the girder flanges and webs and the associated local design had been examined using three dimensional finite element techniques. Special consideration has also been given to the provision of intermediate supports to prevent wind vibration of the stressing bars and anti-corrosion protection.

It so happens that a similar deck unloading procedure is being applied to an understrength three span composite girder viaduct in Iowa State, USA this year. Prior experimental work on large scale models has already been undertaken and covered in several recent papers by Professor F.W. Klaiber and his colleagues at Iowa State University. It has been agreed by both parties to undertake and compare monitoring of prestressing bar loads during and after construction.

2.3 External Prestressing Applied to a Reinforced Concrete Deck

Figure 4 shows how a similar external prestressing technique was used to 'unload' the rectangular beams of an understrength two span continuous reinforced concrete deck in South Wales. In this case prestressing was by cables located on the sides of the beams and anchored and deflected by steel assemblies attached by epoxy grouted bolts passing through the beams.

3. SUBSTRUCTURE TRACTION & BRAKING LOAD RELIEF USING SHOCK TRANSMISSION UNITS (STUs)

3.1 General

A large number of our existing stock of viaducts feature long sequences of simply supported deck spans, often supported on a series of high & substantial piers. This is particularly evident in major river crossings where high navigation clearances require long approach viaducts, Figure 5. The piers under each simply supported span inevitably carry fixed bearings for one span alongside free bearings for the adjacent span. This means that the design longitudinal traction & braking plus wind forces must be individually applied to each deck span throughout the viaduct. Main resistance is offered by the pier carrying the fixed bearings of that particular span.

Current integrity assessments of a number of these viaducts often indicate that the piers are understrength due to increases in the deck longitudinal loading since original design, sometimes accompanied by damage generated by road salt, carbonation or ASR. A substructure of this type with, say, 10 equal height piers has a total resistance capacity of approximately 10 times the original deck design traction & braking longitudinal loads. This total resistance capacity can be mobilsed by providing load transfer mechanisms across the deck joints, ideally shock transmission units.

3.2 Shock Transmission Units (STUs)

STUs are mechanisms which are connected across movement joints between structural elements. They transmit slow joint movements like temperature and shrinkage with negligible resistance and, when required, transmit momentary impact forces like traction, braking & earthquake with negligible movement.

A simple, economical & minimum maintenance bridge STU was developed in the UK some years ago. Instead of oil the STU utilises the peculiar properties of 'bouncing putty', a silicone compound which will readily deform under slow pressure but becomes rigid under impact. The unit consists of a steel cylinder containing a loose fitting piston fixed to a transmission rod, the void round the piston being filled with the silicone putty. Under slow movement this putty is squeezed around the piston and displaced from one end of the cylinder to the other, Figure 7.

3.3 Load Relief using STUs for Viaduct Piers of the London Docklands Light Railway

The newly completed viaducts carrying London's Docklands Light Railway, Figure 6, were designed for a train service which, due to a breathtaking increase in adjacent development, will now require considerable expansion before 1990. This will mean heavier & more frequent trains, which will add braking & traction effects in excess of those originally catered for.

Figure 7 shows a typical as-built seven span deck unit, continuous between expansion joints. Train traction and braking loads are currently shared among the slender piers, which generally support the deck via rubber bearings. STUs are being installed at rail level between joints such that, when the new increased longitudinal traction & braking loading is applied to one particular seven span unit, load is beneficially transmitted and shared with adjacent seven span decks sufficient to require no pier and foundation strengthening in any substructure. This simple procedure represents a tremendous saving in cost and interference with the existing train service.

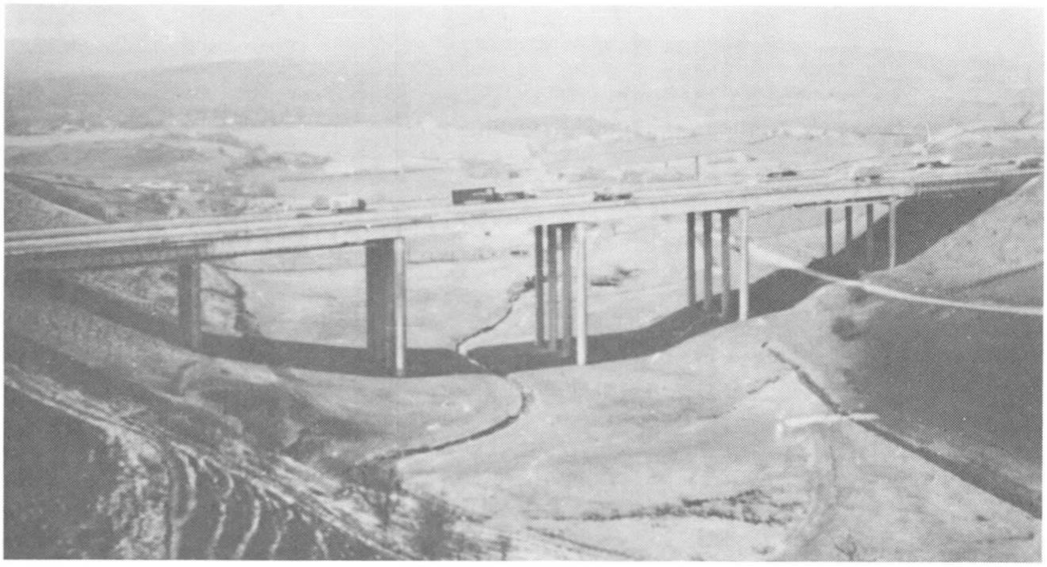

Fig. 1 Rakewood Viaduct

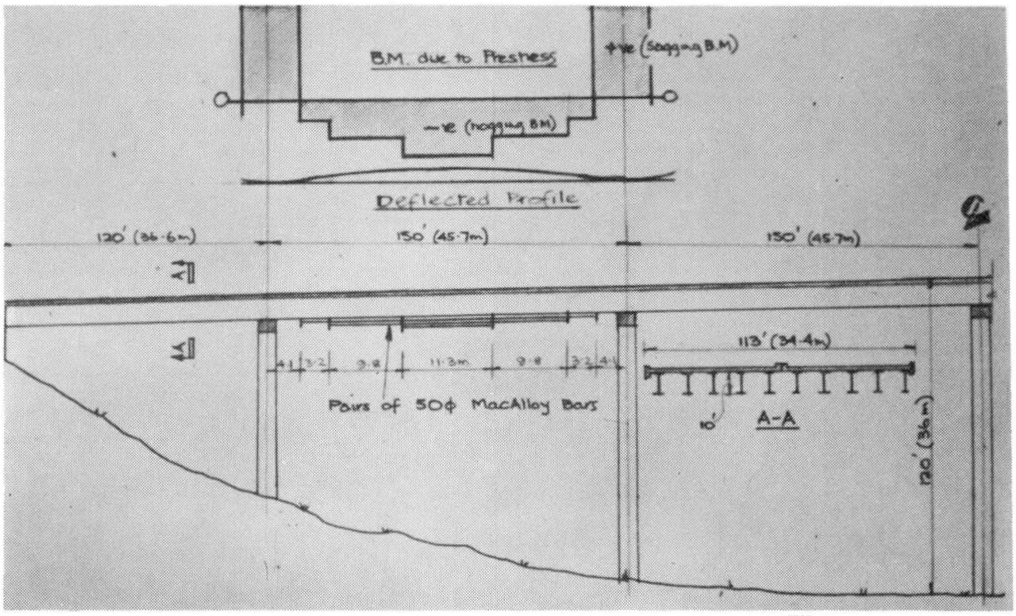

Fig. 2 External Prestressing

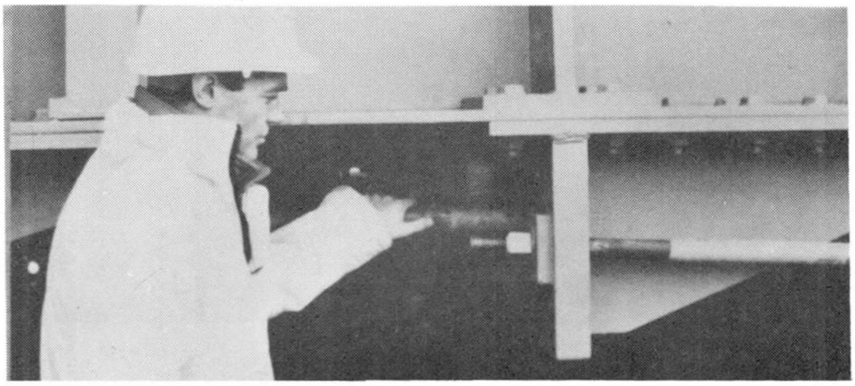

Fig. 3 Prestressing Anchorages

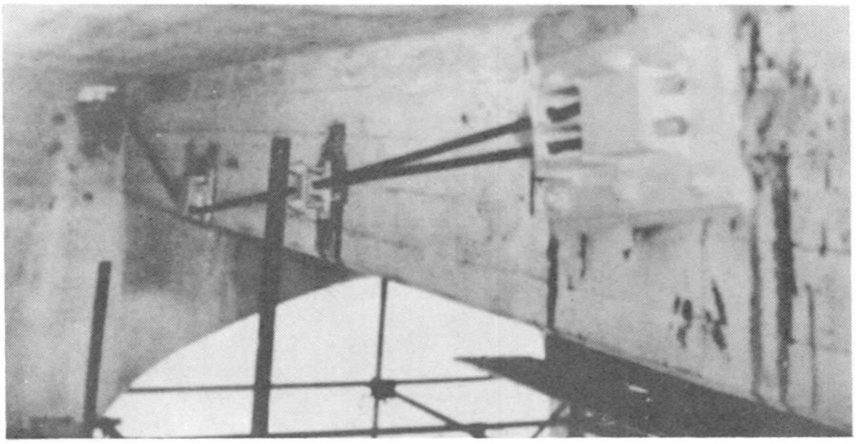

Fig. 4 External Prestressing of RC Beam

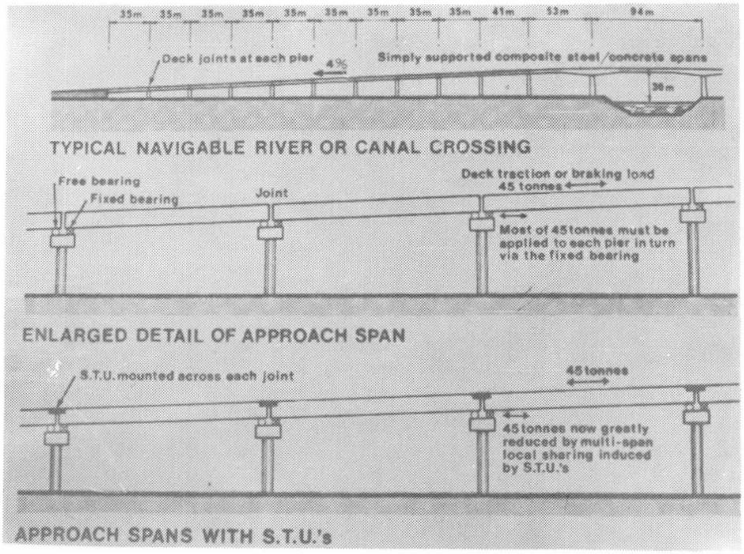

Fig. 5 Substructure Strengthening using STUs

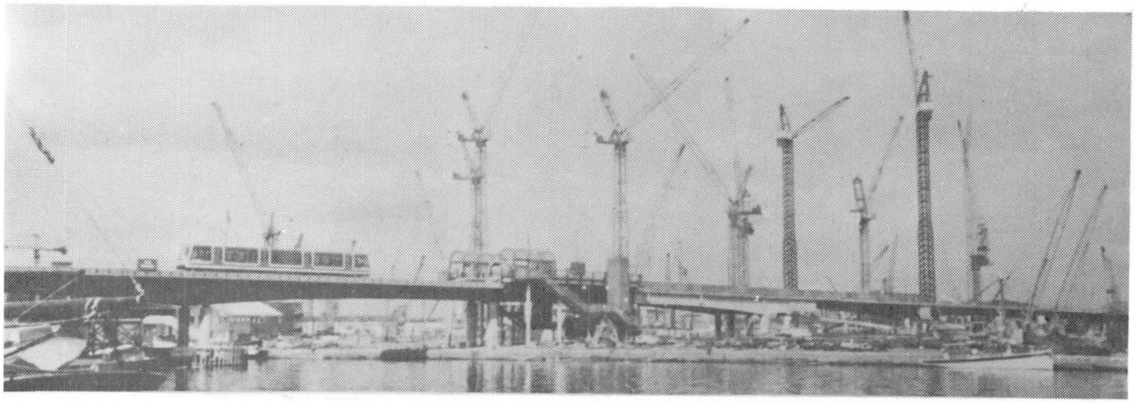

Fig. 6 Docklands Light Railway Strengthening

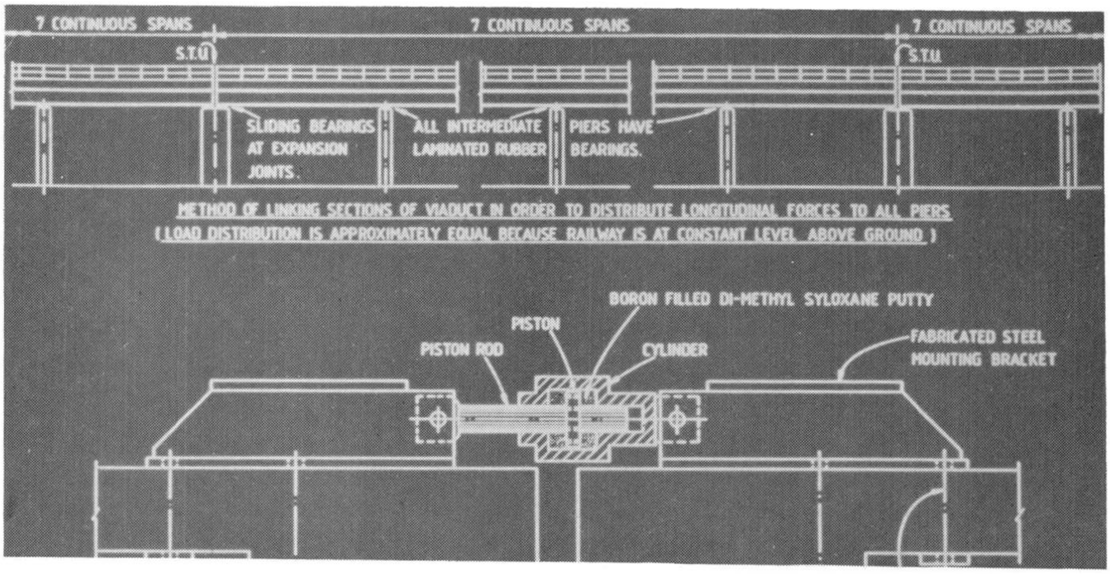

Fig. 7 Detail of STU & Mounting