Design for Reconstruction and Maintainability

Conception en vue d'une reconstruction et d'une maintenance faciles

Projektierung im Hinblick auf Instandhaltung und Wiederherstellung

Alan SIMPSON
Divisional Director
Mott, Hay & Anderson
Croydon, Surrey, UK

Jonathan WOOD
Divisional Director
Mott, Hay & Anderson
Croydon, Surrey, UK

Ashley JOHNSON
Senior Engineer
Mott, Hay & Anderson
Croydon, Surrey, UK

Alan Simpson was born in 1932 and has been involved in the design and construction of long span steel and concrete bridges. He worked on both the original designs and subsequent widening of major bridges and has been responsible for the reconstruction of others.

Jonathan Wood, born 1940, a Newcastle-Upon Tyne Civil Engineering Graduate, did his PH. D. research on silos. Subsequent work involved bridges and a variety of concrete durability problems. He is a member of several specialist committees.

Ashley Johnson, born 1942, obtained Membership of the Institution of Structural Engineers in 1971. He then worked on the design and site supervision of motorway structures. He joined the newly formed Special Services Division from the MHA Bridge Department in 1984.

SUMMARY
Replacement or modification of medium span bridge decks has become necessary with increasing regularity. The reasons include the need for greater width or strength and reconstruction because of deterioration. Two case studies are presented which highlight these causes, describe the methods of replacement and illustrate improvements made to facilitate easier maintenance. The need to minimise traffic disruption during reconstruction makes a strong case for designing the majority of short and medium span bridges in the form of longitudinal strips and with detailing to facilitate reconstruction.

RÉSUMÉ
Le remplacement ou la modification des tabliers de ponts de portée moyenne est devenue nécessaire avec une régularité sans cesse croissante. Parmi les raisons, il y a le besoin d'une plus grande largeur ou résistance, et la reconstruction à cause de détérioration. Deux études de cas sont présentées. Elles mettent en évidence ces causes, et les méthodes de remplacement y sont décrites. Elles illustrent, en outre, les améliorations apportées pour en faciliter la maintenance. La nécessité de réduire au minimum le dérangement de la circulation pendant la reconstruction, renforce l'argument en faveur de concevoir la majorité des ponts à portée courte ou moyenne sous la forme de bandes longitudinales, avec détails pour en faciliter la reconstruction.

ZUSAMMENFASSUNG
Der Ersatz oder die Wiederherstellung der Fahrbahnplatten von Brücken mittlerer Stützweiten wurde mit steigender Regelmässigkeit erforderlich. Die Gründe liegen unter anderem am Bedarf an grösserer Breite oder Tragfähigkeit sowie an der Verschlechterung des Zustands. Es werden zwei Fallstudien vorgestellt, die diese Ursachen unterstreichen und die Verfahren für den Ersatz beschreiben. Es werden Verbesserungen vorgeschlagen, um die Instandhaltung zu erleichtern. Die Notwendigkeit, während des Neubaus Verkehrsunterbrechungen auf ein Mindestmass zu beschränken, spricht für eine Konstruktion in Form von Längsstreifen mit konstruktiven Details zur Erleichterung von Erneuerungen.

1. INTRODUCTION

1.1 Background

During the last decade there has been a rapid increase in the number of modern bridge decks which have required replacement. This has been due largely to the effects of water ingress and the dissolved salts carried by it. The provision of wider roads and motorways has also necessitated the modification of superstructures.

The primary user of a highway must be considered when replacement or modification is required. It is essential that the highway is maintained during the contract period even though it may be of reduced width. For this reason it is suggested that the potential need for replacement or modification should be considered at the design stage, at least for small and medium span bridges and viaducts.

1.2 Reasons for reconstruction

The possibility of reconstruction can arise as a result of many causes. The following list, which applies mainly to concrete bridges, includes known examples of modification necessitated by:

- Widening to increase traffic capacity.
- Renewal to provide greater strength.
- Renewal or repair following major damage from vehicle or other impact.
- Renewal or repair of piers and abutments.
- Deterioration caused by chloride attack after using de–icing salts.
- Deterioration caused by alkali aggregate reaction.
- Deterioration caused by high creep or shrinkage effects or by corrosion of reinforcement or prestressing tendons.
- Increase in span or in superstructure level to accommodate alterations below.

Many bridge reconstructions become necessary as a result of highway improvements, the development of urban light rail projects and the renewal of railway overbridges. In addition, the greater priority now given to inspection and maintenance has tended to identify deterioration at earlier stages in the potential life of a bridge.

2. CASE HISTORIES

2.1 Widening of a motorway viaduct

This example concerns a motorway viaduct which was opened to traffic in 1961. A continuous increase in traffic volume has made it necessary to widen each carriageway so as to provide 3 lanes plus hard shoulder instead of 2 lanes plus verge.

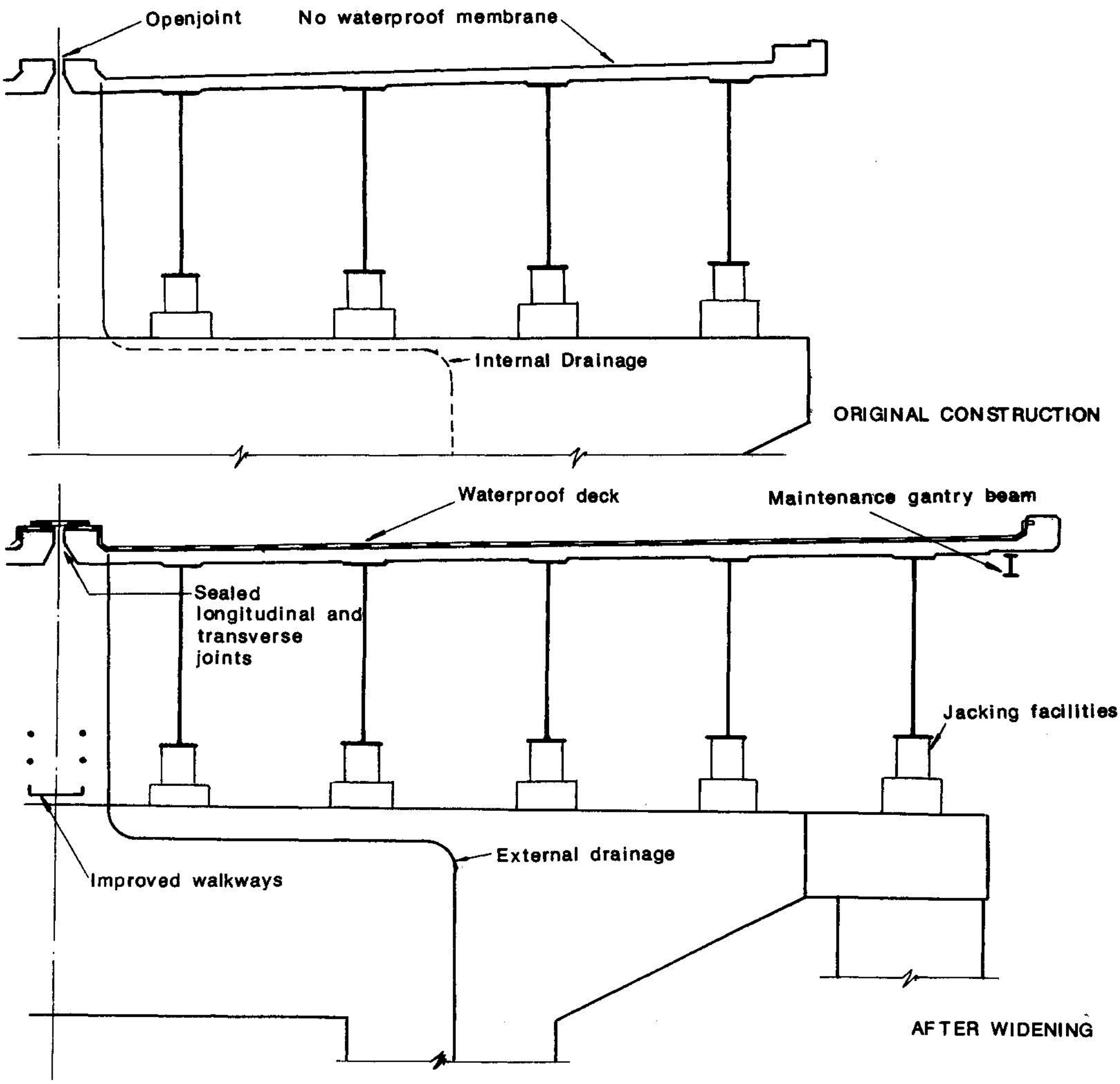
The superstructure consisted of 18 spans each comprising 8 rivetted plate girders acting compositely with the reinforced concrete slab. Widening is being achieved by adding a single welded plate girder to each side and extending the slab.

It was originally intended to retain the existing slab if this was in good condition. To confirm this, 118 cores were taken to provide samples for testing the concrete strength, carbonation depth, chloride content and cement content. Test results indicated adequate strength but high (up to 0.52%) chloride contents in the top 30–60mm of the slab. It was clear that this had accumulated during the early years of use when de–icing salts had been used prior to a waterproof membrane being installed.

This situation made the risk of future corrosion in reinforcement and shear connectors, and of concrete deterioration too high to accept. It was then decided to remove and replace the existing slab as part of the widening contract. By defining the traffic management stages in conjunction with demolition and reconstruction phases, it was possible to maintain two lanes of traffic in each direction during the majority of the contract period. The key to this process was to work in a series of longitudinal strips (which included construction of new abutments and additional pier columns) extending for the 726m length of the viaduct.

Deterioration of the surface water drainage system had caused chloride laden water to enter the joints at the end of each span and to collect on the pier tops below. This in turn overflowed down the faces of the piers where high chloride concentrations were again found. However, in this case a half-cell potential survey indicated only small areas where corrosion of reinforcement might become a problem. A further difficulty was the discovery that the aggregate was potentially subject to alkali aggregate reaction. This led to a decision not to encase the existing piers with a new "jacket", extended at its upper level so as to provide cantilever support for the new girders. Instead, additional independent columns were built, thus leaving the existing piers intact so that inspection, height adjustment by jacking, and even future replacement could be carried out.

During design and reconstruction, very careful attention was paid to the control of surface water and the need for improved access to all parts of the superstructure. The provision of a waterproof membrane covering the whole area of the deck was an obvious requirement but this had to be carefully integrated with both transverse and longitudinal deck joints to ensure that chloride laden water would not reach the new slab. In addition, all surface water was piped to ground level in such a manner that failure of a pipe would not cause uncontrolled discharge of water to the interiors of piers but would be clearly visible by external inspection only. This latter activity would be facilitated by the provision of additional transverse and longitudinal permanent walkways below the superstructure slab and by runway beams to support a full-width travelling gantry for inspection and maintenance. Existing and future cross sections are shown below.



This example illustrates the relative simplicity with which a bridge having a number of main members spanning longitudinally can be modified or replaced while maintaining the flow of road traffic using it. The same is unlikely to be true of a superstructure which consists of a single main member supporting secondary transverse members, or a structure which is dependent on transverse load distribution to adjacent members for its strength.

2.2 Replacement of Motorway Overbridge Superstructure

This second example describes a two span bridge originally built between 1969 and 1971. In 1983 it was discovered that the deck and central pier were severely affected by Alkali-Aggregate Reaction (AAR).

The bridge deck was an insitu beam and slab, and had been designed to accommodate mining subsidence which actually took place 1974 to 1976. The design was two 27 m simply supported spans. Articulation was provided by 1.8 m high rocker columns at abutments and with beams dowelled to the pier to provide fixity and carry braking forces.

An AAR investigation was commenced in 1984 and concluded that: concluded that:

- The central pier corbel required immediate strengthening.
- Even a strengthened pier could have only 5 years life under its heavy loading.
- The deck was in danger of becoming an unpredictable hazard within 5 years.
- The abutments should have 20 years life, but the tops needed strengthening.

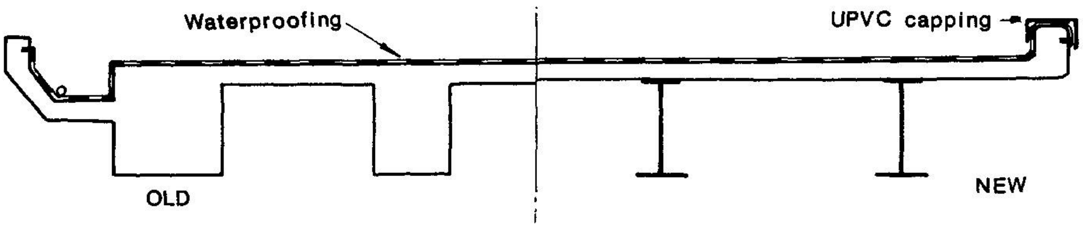
A decision was made to replace the deck during a planned 14 week carriageway reconstruction programme commencing in 1985.

The new design was to incorporate a lighter composite steel beam/concrete deck slab. Each span would be separately fixed to each abutment via rocker bearings attached to new precast bearing shelf units. Compact sliding bearings on the strengthened pier were necessary to reduce the eccentricity of loading on AAR affected corbels. By this means the remaining AAR concrete parts of the pier could be given the probability of an additional 15 years life. The transfer of braking forces to the abutments, coupled with reduced deck self-weight still enabled a forecast that the abutments should remain serviceable for over 20 years, although, as with the pier, frequent monitoring, (every 6 months), is recommended for the foreseeable future of the AAR affected parts.

Provision had to be made for possible future replacement of the central pier and refacing the abutments, some time after the new deck had been built. This was done by providing stiffeners in the deck steelwork, (adjacent to the pier and abutment), corresponding to 'convenient' positions for military trestling, that would support the deck while the substructure was reconstructed. Many options were considered for the sequence of construction; such as constructing one span at a time or in two longitudinal strips. The former was chosen as there was an alternative route for traffic on the side road and it could be easily phased in with the contractor's possession of the site for the major roadworks. Schemes for launching a new deck from an abutment or for building a new superstructure alongside the old and sliding it into place were investigated but had fewer advantages in this case.

In the detailed design of the new deck it was felt that special measures were justified to achieve a high degree of protection to the new concrete which would necessarily contain potentially reactive aggregates; albeit with a much reduced cement alkali content. Efforts would also be made to protect the old parts of the structure from surface water run-off.

A comparison between the old and new deck cross-sections is shown below.



OVERBRIDGE CROSS SECTIONS

The major differences between the protection given to the two structures is shown below:-

Item	Old Deck	New Deck
Waterproofing	Mastic Asphalt between inside faces of copings	Heavy Duty Flexible sheeting full width including over and down coping sides
Deck Edges and Copings	Standard Concrete mix Exposed sloping tops	Air Entrained Concrete Preformed UPVC covers fixed over top
Service Bays	Deep troughs with Limestone fill, drained by perforated pipes and weepholes in slab	Services in Footways, with light-weight rounded fill
Expansion Joints	Cantilevered bolted plates	Flexible bedded and bolted 'sealed' type, in short sections
Deck Ends	Exposed Concrete	GRP Sheets and angles, resin glued
Drainage	On bearing areas to fall to pipes within abutments	Collected in gutters and exposed pipes at both abutments and pier.

3. DESIGN FOR EASE OF MAINTENANCE

The following improvements are commended for consideration:

- Accept that joints will leak and therefore waterproof the concrete or steelwork below. Plastic sheets, 3mm thick have been successfully resin glued to deck ends and abutment headwalls, but access to both sides of expansion gaps is necessary.
- Design joints so they can be replaced without closing more than one lane. Continuous joints seem attractive but if the fixings corrode it can necessitate total carriageway closure for remedial works. See advice on protection in item above.
- Do not put road gullies on bridge decks unless it is necessary to prevent flooding. They invariably leak and bring chlorides into the structure leading to pitting corrosion of reinforcement. Likewise, do not put drainage channels along decks, especially grooves recessed into the structural concrete.
- Do not leave holes or cast pipes into structures where they cannot be maintained or problems are out of sight.
- Avoid half-joints and hinges, both of which are vulnerable to chloride ingress and reinforcement corrosion.
- Design bridge bearings for easy inspection and replacement. Have a standard range of bearing heights to enable new ones to be slid in without plinth or downstand reconstruction.
- Where possible include with the bridge design equipment to ease maintenance and inspection. Smaller structures may not justify permanent cradles and runway beams, but portable, 'over the side' inspection and repair platforms can save scaffold erection and be moved as required.
- Ensure that all materials are of a quality and finish not to require frequent renewal. Be sure that the work force has the necessary expertise in the use of the materials.
- At the design stage, consider how the bridge deck could be replaced while maintaining reduced traffic flow.

Some 20 years experience of maintenance of modern highway structures should be used to avoid future problems by better design for durability.

4. CONCLUSIONS

Bridges are always likely to require modification as a result of changes in highway requirements. They are also likely to need repair when the concrete or steel materials fail under severe loading, or deficiencies in their construction become apparent. Examples of degradation have included:-

- deterioriation of high alumina cement precast concrete.
- deterioration of concrete from alkali-aggregate reaction.
- deterioration of concrete by chloride attack from de-icing salts.
- corrosion of prestressing cables caused by inadequate protection or grouting.
- break down of waterproofing, joints, fixings and repairs.
- fatigue damage.

We must assume that while new developments will bring undoubted advantages there will also be disadvantages which will be unsuspected at the time of their adoption.

It seems clear from rapid repair and reconstruction work already carried out, that confining areas of working to longitudinal strips of a bridge will enable improvements or essential maintenance to be completed with the minimum of disruption to traffic. It is therefore proposed that serious consideration should be given to the potential need for reconstruction at the conceptual design stage and that this can be most effectively provided for if the bridge deck consists of a number of longitudinal beams each supporting approximately one lane of traffic. Such a concept is relatively easy to adopt for the majority of short and medium span bridges.

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