WEST GATE BRIDGE – MOBILE BRIDGE INSPECTION PLATFORM

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ABSTRACT

Melbourne's 2.5km long West Gate Bridge includes two concrete box girder approach viaducts, 871m and 670m long, and an 848m central steel box girder portion over the Yarra River. Prior to the recent strengthening project four travelling gantries were permanently suspended off the steel spans for maintenance and inspections and there was no provision for access to the outside of the concrete spans, although a variety of temporary measures had been adopted from time to time. As part the strengthening project, which included the addition of a fifth lane to each carriageway, the gantries on the steel spans had to be replaced. Instead of replacing them with new suspended gantries, the decision was made to procure a Mobile Bridge Inspection Platform (MBIP) that could be used for the full length of the bridge. The MBIP is the biggest of its kind in Australia and includes a 20m long telescoping platform that can be extended under the bridge as far as the centreline of the bridge soffit. The MBIP stands on the roadway adjacent to the outer barrier. This paper summarises the investigation that lead to the decision to adopt an MBIP rather than permanent suspended platforms.

INTRODUCTION

The West Gate Bridge was first opened to traffic in 1978 and is arguably the most important major item of transport infrastructure in Australia. It provides a bridge crossing of Melbourne's Yarra River, connecting the eastern suburbs and the CBD with the western suburbs and carries some 200,000 vehicles per day.

In June 2011, following a major strengthening project, the number of lanes in each carriageway was increased from four to five by narrowing the lanes and eliminating the emergency lane.

This paper is concerned with the Mobile Bridge Inspection Platform (MBIP), the biggest of its kind in Australia, procured as part of the recent strengthening project for access to the outside of the bridge. It provides a description of the MBIP and the reasoning behind its adoption for bridge inspection and maintenance instead of replacing the bridge gantries.

The MBIP is truck mounted and when set up in the outer lane of the bridge deck, deploys a platform that extends under the bridge soffit just beyond the bridge centerline. It provides access to the sides and soffit of the bridge.

BRIDGE DESCRIPTION

The West Gate Bridge is 2.5km long. It includes a central 848m long cable-stayed box girder steel bridge with a 336m main central span over the river and two concrete box girder approach viaducts. The eastern viaduct is 871m long and the western viaduct is 670m long.

Figure 1 shows a typical cross-section of the steel box girder spans and Figure 2 shows a typical cross-section of the concrete viaducts. In each case, the cross-section also shows the lane arrangement. The pier height varies and the maximum pier height is 48m. Except for the portion over the river, practically the full length of the bridge is above vacant land and can be accessed from below by means of elevating work platforms.

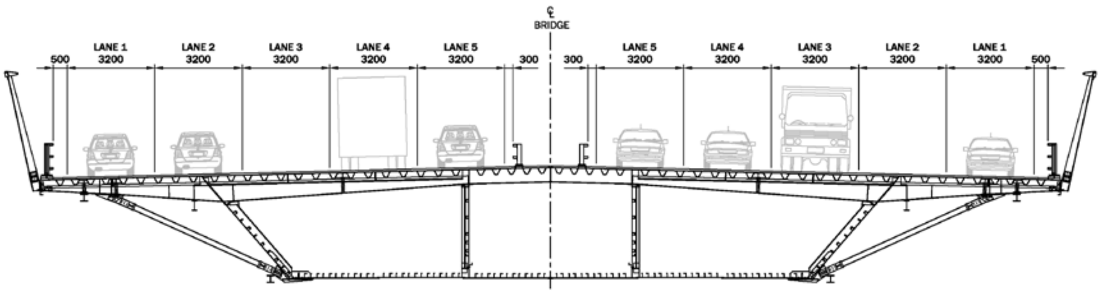

Figure 1 – Cross-section of steel bridge

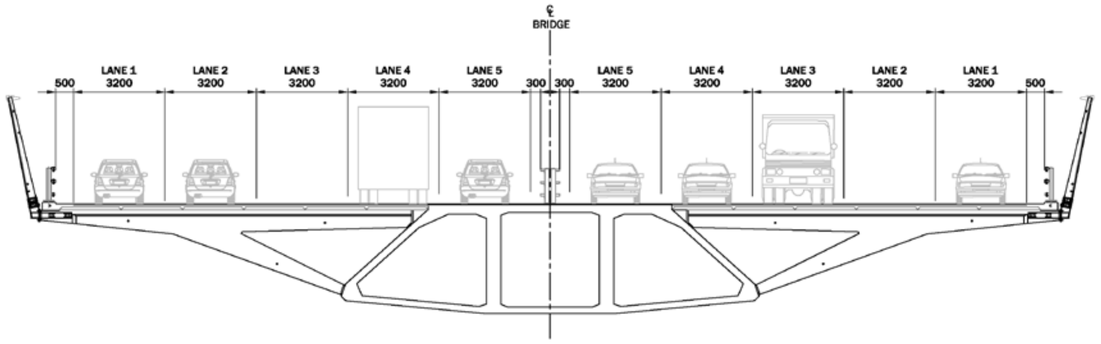

Figure 2 – Cross-section of concrete bridge

BACKGROUND

From the time it was originally opened to traffic in 1978, the steel bridge had maintenance platforms suspended from it (refer Figure 3), but maintenance access to the soffit and outer sides of the concrete box girder had been by means of elevating work platforms positioned on the ground under the bridge.

Figure 3 – Gantries suspended from steel bridge prior to recent strengthening project

More particularly, four permanent fixed maintenance platforms operated on the steel bridge and were used to conduct routine inspections (e.g. check for rusting, fatigue cracks and other imperfections) and minor works (e.g. washing and patch painting). Three of the platforms were the original bolting gantries used during the bridge's construction in the 1970s. The fourth was a comparatively new maintenance gantry installed in 1995. These gantries operated from only two runway beams fixed to the steel bridge cantilevers on each side of the bridge. However, the strengthening design and the additional lane of traffic required the installation of outrigger props to support the cantilevers which fouled the connection and operation of the original maintenance gantries as can be seen in Figure 4. In addition, although these gantries were upgraded to be used as part of the access system for the strengthening works (i.e. access for splice strengthening), they had reached the end of their economic life.

Figure 4 – Sloping props being installed to support steel bridge cantilever

Another important chapter in the chronology of platforms is that of the extensive access systems developed for the recent strengthening project. The strengthening project required a significant amount of work to be undertaken to the underside of the steel and concrete bridges. This work included placement of carbon fibre, installation of brackets for the public safety barrier for the full length of each side of the bridge, replacement and reinforcement of bolted splices and installation of cantilever props. With such extensive works, a system was required that would provide safe access to large areas and was easy to move. The project team worked closely with APS, a Melbourne based access specialist, to provide modular space frame access platforms to all the external areas on the bridge. An important observation from this exercise was the differing demands and hence the differing solutions between a platform required for a major works project and that required for routine inspections or minor maintenance in the longer term.

The platforms for the strengthening project were suspended on chains from the cantilever beams of the bridge; both concrete and steel bridges. The chains were connected to temporary runway beams mounted on the deck of the platform. When the platform needed to be moved, new chains were preinstalled ahead of the platform and then existing chains were unlocked to allow the platform to be winched forward. Once the platform reached the new position, the new chains were locked, the platform braced and work recommenced.

The platforms were designed to include all the requirements of a work site including:

- Generator, potable water, toilets and sewage tank
- Messing facilities with office
- Davit crane for lifting equipment from the construction lane onto the platform
- Storage areas for all permanent and temporary equipment
- Deck area to allow lifting equipment to operate
- Solid work deck to permit complete encapsulation during wet and dry blasting

With all these facilities, the work crew could remain on the platform for the whole shift leading to a very efficient operation. At the peak of production there were 16 platforms, of various configurations suspended from the bridge, providing a total of 7,000 square metres of platform area.

DECISION TO PROCURE MBIP

Introduction

Given the need to replace the gantries on the steel bridge, a study was undertaken to determine the best option for on-going maintenance and inspection access to the outside of the bridge. The options considered were:

- Provide new runway beams and a new platform (Fixed Bridge Inspection Platform or FBIP) permanently suspended from the steel bridge and continue to use hired elevating work platforms, when required, for access to the concrete bridge.
- Procure a Mobile Bridge Inspection Platform (MBIP) that could stand in the outer lane of either the steel bridge or the concrete bridge and deploy a platform over the side of the bridge.

The adopted option was the MBIP.

Fixed Bridge Inspection Option

The concept developed for the FBIP required two new monorails suspended from each side of the steel bridge, a total of four monorails. The platform itself would comprise two parts, one for the south side of the bridge and one for the north side of the bridge. They would each run on two monorails fixed to the bridge. Because of difficulties of access and expansion and contraction of the bridge, the installed lengths of monorail would be limited to approximately 3.2m to match the spacing of the bridge cantilevers.

Lateral wind loads on the FBIP and braking and acceleration loads resulting from the movement of the FBIP would generally be applied to the outer monorail. For this option, strengthening was required to the bridge cantilevers above the outer monorail support point, particularly to resist the FBIP longitudinal braking and acceleration loads. This strengthening took the form of stiffeners welded to the web of the cantilever and the adjacent bridge deck trough stiffeners. The installation of this stiffening was to be performed off temporary platforms used for installation of the props (refer Figure 4). In addition, there was some strengthening inside the box girder at the suspension point of the inner monorail where it was fixed to the outer web.

The monorails were essentially designed to carry the live load on the FBIP and its self-weight. There is a tendency for any element fixed to the bridge to be subjected to strains that are compatible with the adjacent bridge structure. If such strains were permitted to occur in the monorails, as temperature effects and traffic loading arise and the bridge flexes, the resulting stress in the monorail, in combination with the effect of the FBIP loading, would overstress the monorail. This effect would have been mitigated by having a PTFE sliding joint at one end of every length of monorail and a fixed connection at the other end.

The FBIP would give rise to a series of key dimensions for its effective operation. These are:

- The gap between abutting ends of monorail

There is a requirement to limit the gap between abutting ends of adjacent lengths of monorail. This requirement arises from the need to limit impact forces on the FBIP structure and the supporting bridge structure

- The step from one length of monorail to the next

The FBIP wheels run along the top face of the bottom flange of the monorails. If, at the point where two successive lengths of monorail abut one another, there is a level difference in the top face of the flange, the gantry wheel would be required to go up (or down) the resulting step and if the FBIP happened to stop at such a step, the driving mechanism for the FBIP may not be capable of restarting the FBIP travel. Furthermore, steps in the running surface on the monorail would cause progressive damage to the FBIP wheels and the monorail each time it crossed the step.

- The spacing of the monorails (i.e. gauge)

The FBIP comprised two sections, one each side of the bridge. This arrangement enabled the FBIP to pass the piers. Each section was supported on two monorails. Given that the FBIP is a rigid structure with two points of support there is a need for control over the spacing of the pair of monorails.

Compliance with all of these tolerances was complicated by the fact that the bridge is continually moving as the live load on the bridge fluctuates. Furthermore, the bridge is continually moving due to changes in temperature.

Clearly, to serve its function, the FBIP possesses a multitude of moving parts and mechanical components. Each of them is subject to deterioration due to wear and exposure to the elements as well as fluctuating load and vibration. Consequently the FBIP requires a maintenance regime that includes routine inspections, servicing and replacement of moving components to maintain the appropriate certification. The FBIP would have been custom-designed for this bridge and routine maintenance and servicing would have required inclusion in the bridge maintenance team of people who are able to manage this maintenance and the operation of the FBIP. Inspections and periodic re-certification would be dealt with by appropriately qualified specialists. The FBIP would have been predominantly a lattice structure, which, because of the lighter elements and the joint detailing, would have required a higher level of maintenance than a plate girder or box girder structure. The tendency for load fluctuation and vibration increases the potential for fatigue cracking and influences the inspection requirements.

The wheels on the FBIP roll along the bottom flange of the monorail. Depending on the frequency of FBIP traverses, this contact results in accelerated deterioration of the protective treatment of the monorail bottom flange. Provided the protective treatment is regularly reinstated it should be possible to avoid significant section loss through corrosion. However, field applied coatings are commonly not as durable as the initial coating applied in the workshop. Significant maintenance and inspection effort needs to be applied to the monorails to ensure their structural integrity and it is not uncommon for monorails to have to be replaced, at intervals, due to deterioration. Accordingly, the connections would have been detailed to facilitate future replacement of the monorails.

Mobile Inspection Platform Option

MBIP Operation

The following provides a brief description of the MBIP and its operation. In addition, there is a video available on Moog GmbH’s website at http://www.moog-online.de/en/video.html showing a typical MBI 200 unit in operation.

Figure 5 MBIP deployed under bridge on Nagambie Bypass

The access system is mounted onto a standard truck chassis, the carrier vehicle (refer Figure 6). The access system comprises a combination of structural steel components and an aluminium extending boom. Two additional axles are fitted to the steel frame in the middle of the carrier vehicle. When the MBIP is being driven as a normal vehicle, these axles are raised above the road surface, similar to a normal truck lifting axle.

Figure 6 – MBIP ready for travel on road

The MBIP is driven into the required location on the bridge, approximately 100mm away from the parapet. The air suspension system of the truck is depressurized, causing the vehicle to lower on all its axles and the additional two auxiliary axles referred to above to come into contact with the road surface, thereby improving the stability of the vehicle. There are no outriggers. The wheels on one of the axles are driven by 200mm diameter rollers bearing on the top of the tyres and powered through the hydraulic system thereby causing the vehicle to creep forward under operator control. Clearly, this movement would not be possible if the unit required outriggers.

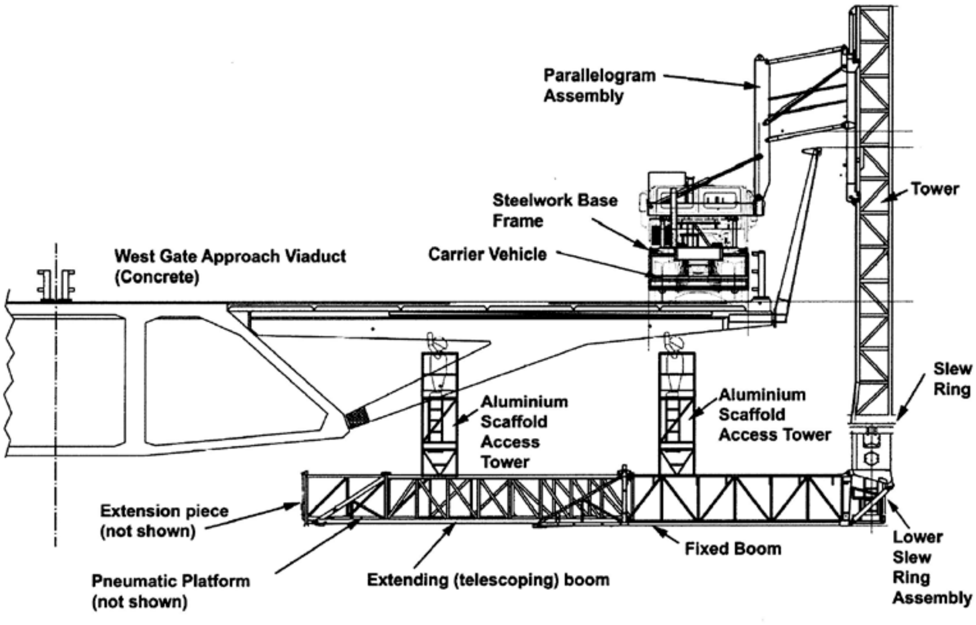

Figure 7 – Major Components of the MBIP

Once the unit has been lowered on its suspension, the access system can be deployed. Control is based on a relay logic system and limit switches mounted on each moving part of the access system. The system is hydraulically powered via the truck engine with a back-up on board generator. The parallelogram assembly (refer Figure 7) rotates on the steelwork frame and extends to allow the tower and boom to clear the parapet and the 4m high Public Safety Barrier and to move the tower and boom so that they are vertical and beyond the edge of the bridge. The tower is then telescoped to extend it downward, following which the boom is lowered by rotating it from its vertical position down to a horizontal position. At this point, with the boom cantilevered off the bottom end of the tower and parallel to and alongside the bridge, the control is switched from the control panel at the rear of the vehicle to a control panel on the boom adjacent to the bottom end of the tower. Once the boom is lowered and the control is transferred, it is rotated in plan using a lower slewing ring and telescoped to extend it under the bridge.

Figure 8 MBIP tower adjacent to 4m high Public Safety Barrier

Access to the boom is via the inside of the tower and through the slewing ring. The tower can be moved vertically to provide access to the bridge at various levels through apertures on the tower. Additional modular aluminium access scaffold is fixed at points along the boom to provide access up to various points on the bridge. This scaffold is erected onto the boom top structural rails. A pneumatic elevating platform is fitted to the extreme end of the boom to permit one person to be raised upwards from the boom floor level.

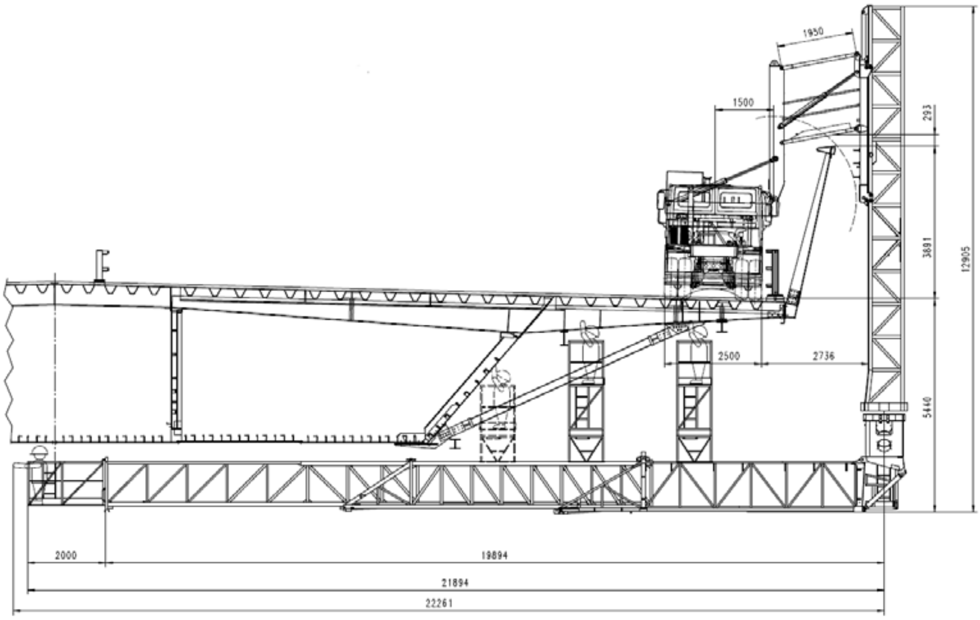

Figure 9 - MBIP fully deployed

The complete unit, with the tower and boom fully deployed can be crept along the bridge using the hydraulically driven rollers in contact with the tyres on one of the axles.

The return to the normal travelling position is the reverse of that detailed above. There is a compressor on the unit to repressurise the air suspension system of the truck.

The Merits of the MBIP

The key disadvantage of the MBIP is that it requires closure of two lanes to operate, the outer lane in which the MBIP is standing and the adjacent lane. However, the majority of inspections can be conducted during off-peak periods and at night which would have negligible impact on traffic over the 20 year economic life of the unit. The MBIP is provided with a lighting system sufficient to enable small cracks and defects to be identified under night conditions. The other implication of this constraint is the limitation on available working time. Traffic on the bridge is very heavy for most of the day and there is limited time available for lane closures if interference with traffic is to be kept to an acceptable level. The MBIP cannot be deployed until the outer two lanes are closed and sufficient time must be allowed at the end of the shift to permit the lane to be reopened within the available window.

A key advantage of going to a mobile solution is that it provides inspection capabilities on the concrete viaducts and could be used for inspections and minor maintenance on other bridges as well. The recent strengthening of the concrete viaducts utilized external carbon fibre, which requires a regular regime of inspections. The FBIP would only have provided an access system for the 850metre steel bridge whereas the MBIP provides an access system for the full 2.5km length of the bridge.

An advantage of the FBIP over the MBIP is that it would provide a quicker means of getting access to the outer surfaces of the steel bridge (e.g. approx. 1 hour to set up MBIP). This was not considered a major issue however, as there would be very few scenarios, with extremely low probabilities of occurrence, that would necessitate access in less than one hour.

The Decision

The detailed cost benefit analysis showed that the MBIP was clearly the more economic option, the principal reason for the decision to adopt the MBIP. For the FBIP, the capital cost of the platform itself and the monorails made up the majority of the cost while for the MBIP, the majority of the cost was the purchase cost of the unit and the present day cost of lane closures for the inspections to be performed during the economic life of the unit, assumed to be 20 years. The comparative cost analysis did not include any allowance for revenue earned by hiring the unit out to other organisations. Furthermore, the beneficial effect, for the appearance of the bridge, of not having gantries permanently suspended from the bridge is simply regarded as a bonus and was not included in the costings.

The option still remains, in the unlikely event circumstances change in the future, to install a permanently suspended mobile platform under the bridge. Allowance has been included in the loads adopted for the bridge strengthening to cover the future addition of a suspended gantry. It is likely that such a gantry would be designed such that it can be used for the initial progressive installation of the monorails and when monorails and gantry installation is complete, for the bridge inspection.

An important conclusion from the study and the experience with the strengthening project is that either an MBIP or an FBIP would only be used for inspections and light duty works. For more significant maintenance or repairs, such as repainting of the exterior of the bridge, special temporary suspended working platforms would be more appropriate. While the FBIP or MBIP can be very speedily deployed, it commonly provides access to only a limited area of the bridge soffit at any one time and may tend to have a limited life if pressed into the type of service required for a major maintenance or repair project.

DESCRIPTION OF MBIP

The Mobile Bridge Inspection Platform procured is a custom designed MOOG model MBI 200-1.5S mounted on a Scania chassis 8x4. It comprises telescoping vertical tower and horizontal platform. The maximum horizontal range of the platform is 20m under the bridge and the maximum lowering depth of the tower is 8.4m. With the MBIP set up in the outer lane on one side of the bridge it provides access to one side of the box girder and the soffit to 500mm beyond the bridge centerline. It has a capacity of 785kg and sufficient platform area for several people simultaneously. It is currently the biggest such bridge inspection unit in Australia.

Non-standard components of the MBIP

The MBIP was customised to suit the particular maintenance requirements of the WGB. The non-standard components include:

a. Power capability to provide 415 and 240 volts to a capacity of 12Kva. This allows tools such magnetic drills and welding equipment to be used from the boom. The power capabilities also cater for tools requiring from three phase power;

b. LED lights to allow for night inspections utilising light fittings with low power consumption and high illumination. The lights can be used for a period of twelve hours without the need to have the engine running thus saving fuel. The emergency safety lights are also LED type hence further reducing the need for power during operation;

c. Air compressor capability has been provided to allow the use of air tools required for maintenance works. The capacity of the air compressor is 18litres/sec at 700Kpa at three locations along the boom with a 100 litre air storage tank;

d. Water tank and water pump capability. This allows for any concrete saw cutting to take place along with small cleaning operations. A 100 litre water tank with a water pump has been fitted;

e. A customised attachment to the end of the telescopic boom specifically fabricated to match the concrete and steel outer slopping web; and

f. A hydraulically operated telescopic lift to provide for access to areas on the WGB where accessibility is particularly difficult and manoeuvrability is restricted. The platform is removable from the boom and can also be stored on the MBIP in transport mode.

The installation of the above components provides the unit with a greater degree of flexibility. Without these components in place other plant would have been required to undertake some of the maintenance tasks required.

With the platform fully deployed and personnel standing on the platform, the MBIP is able to travel along the bridge at crawl speed. When it reaches a pier, the horizontal platform rotates in the horizontal plane to permit it to pass the pier, following which the platform rotates back under the bridge to permit the inspection to continue.

The overall stored and travelling width of the MBIP is 2.5m and the height is 4.4m. It can travel on the road at a speed of 100km/h with all accessories and with the carrier vehicle fully loaded.

KEY DESIGN CONSIDERATIONS

Clearances

In addition to providing access to all areas under the bridge, including the soffit of the deck cantilever, while being launched and when in position, the MBIP is required to clear a 4m high sloping public safety barrier along each side of the bridge.

Loading

The bridge, incorporating the 2011 strengthening, has the capacity to carry current traffic loadings with currently codified load and materials factors. This loading is of a similar order of magnitude to the T44 loading, but is less than SM1600. It was necessary to confirm that, at no stage during the MBIP operation, the capacity of the bridge is exceeded. Three stages were checked, travelling mode, operating mode and deployment mode.

For the deployment of the access system, the worst loading condition is when the boom is parallel to the bridge, this condition has been assumed to occur for a reasonably short duration during the deployment, and when in use the platform will be perpendicular to the longitudinal axis of the bridge, and largely under the bridge deck.

For West Gate Bridge, the applied loadings were found to be acceptable, subject to the following

- Lane 2 must be closed to all traffic including emergency and works vehicles whilst the MBIP is parked, deploying or operational
- The MBIP must not be operated or deployed in the same region as any underdeck gantry
- The weight of the MBIP must be very strictly controlled. It should be weighed annually and if used elsewhere, before use on the West Gate Bridge to ensure its axle loads have not changed from the manufacturers loads;
- The operating procedures must be fully documented in a manual and strictly adhered to, particularly in terms of payload and limiting operational wind speed. In this respect the manufacturer's limitations must be fully understood and appropriate instrumentation used to measure and forecast site conditions.

MBIP OPERATION

Manuals

The operation of the MBIP of governed by two documents:

- The Operation Manual provides the information required to operate the equipment safely, properly, and efficiently and was provided by Moog. It details the requirements for inspection and repair of the unit and is supported by a collection of supplier manuals for each item of equipment (e.g. compressor) installed on the unit.
- The Operational Deployment Manual which details the roles and responsibility for the operators and supervisors of the MBIP was prepared by the VicRoads bridge management team. It details requirements relating to operator qualifications, training and certification, permits, traffic management plans and the requirement for Safe Work Method Statements. Incorporated in this manual is a series of forms and checklists to cover the various procedures associated with the safe operation of the MBIP.

Current Usage

Since it was purchased towards the end of 2012, the MBIP has been fully engaged on works associated with West Gate Bridge. It has been utilized for a variety of purposes, the majority of which have been concerned with the inspection of the steel bridge and the concrete bridge. The first few months were largely taken up with training, certification of the device and refining the way in which lane closures are coordinated.

Storage Shed

A 20 m (L) by 10 m (W) by 6 m (H) storage shed was constructed for the MBIP on the bridge site and it is therefore out of the weather for the majority of the time. It is expected that virtually all maintenance work on the unit will be performed off-site.

SUMMARY AND CONCLUSIONS

Commonly, large steel box girder bridges have been equipped with steel gantries that run along steel monorails suspended under the bridge and this, until recently, was the case with the steel spans of West Gate Bridge. The increase in the number of lanes and the associated strengthening meant the original gantries could no longer be used and had to be replaced. Following a detailed investigation it was determined that the use of a mobile truck-mounted Bridge Inspection platform (MBIP), with the truck set up in the outer lane, provided a more economic whole of life solution than to install new gantries and monorails. The improvement to the appearance of the bridge resulting from the removal of the gantries was a bonus.

The MBIP, the largest of its kind in Australia, is used for bridge inspection and light maintenance work with the expectation that any major work such as repainting the bridge would be performed from purpose-made platforms suspended from under the bridge. It is serving the bridge management team well and when the current programme of bridge inspections is complete offers the potential for a return to the owner of the MBIP by making it available to others for bridge inspection for a part of the year.

AUTHOR BIOGRAPHIES

Dimi Polymenakos is the Manager of the West Gate Bridge Management Team with over 26 years working with VicRoads on major Projects. Dimi was part of the recently strengthening works of the West Gate Bridge managing a wide range of construction activities.

Javier Silla-Sanchez bridge team leader with the VicRoads West Gate Bridge Management Team has international experience in steel bridge maintenance and design. He has been involved for some five years in the strengthening and maintenance of the West Gate Bridge and was responsible for the development of manuals for the operation of the MBIP.

John Noonan currently structural consultant with the VicRoads West Gate Bridge Management Team has had over 45 years experience with the design, construction and maintenance of bridges. He was the design manager for the recent West Gate Bridge strengthening project and was involved with the loading and geometric assessment of West Gate Bridge for its suitability for the MBIP.