ABSTRACT

Port Adelaide is an important trade gateway for South Australia, especially for exports of such commodities as grain, livestock, wine, citrus products, and motor vehicles. The Port River Expressway Design-Build Project will add a new four-lane expressway link and a new rail freight line to better access this port facility. The project features highway and railway moveable bridges crossing the Port River.

Hardesty & Hanover, as Movable Bridge Designer for the river crossings, is providing designs for a new 58m/190ft, four-lane, single-leaf highway bascule bridge and a new 61m/200ft, single-track dual-gauge, single-leaf rail bascule bridge. Both bascule bridges will provide a 30m/98ft navigation channel in the Port River. The estimated construction cost for both movable bridges is $30 Million U.S. Dollars.

Keywords: Rail Bridge, Bascule Bridge, Design Build, and South Australia

INTRODUCTION

The Port River Expressway is delivering new road and rail infrastructure with new bridges across the Port River to provide improved access through the Port Adelaide area and between the Lefevre Peninsula and national freight routes.
The Port River Expressway will contribute to South Australia's economic development by providing new road, rail and bridge connections across the Port River; linking South Australia's export enterprises and industrial areas with key transport routes and facilities. The Port River Expressway project is one of the key elements in the Strategic Infrastructure Plan for South Australia, which sets out more than $1 billion in projects to improve South Australia's port and industry-related infrastructure to support the future growth in exports.

The project is being developed in three stages. Stage 1 (5.5km/3.4mile 4-lane expressway) of the project has recently been completed and was opened to traffic in July 2005. More than 18,000 vehicles are using the expressway each day. The construction cost for Stage 1 was approximately $91 Million.

Stage 2 involves the design and construction of a road extension to the west of Stage 1, a road bridge over the Port River and associated works. Stage 3 involves the design and construction of rail works and a rail bridge over the Port River.

Stages 2 and 3 of this Design-Build effort of The Port River Expressway project were awarded to Abigroup Contractors Pty Ltd as the successful design and construct tenderer. The lead engineering design consultant for Stage 2 is Dare Sutton Clarke Pty Ltd and for Stage 3 is Maunsell Australia Pty Ltd. The engineering design consultant for the bascule spans of the road and rail bridges is Hardesty & Hanover (H&H). This project was awarded in July 2005. The estimated construction cost of Stages 2 and 3 is $178 Million, and the project is to be completed in late 2007.

Hardesty & Hanover is responsible for the complete design of the bascule bridges (Structural, Mechanical, Electrical, and Architectural) including the bascule pier and rest piers of both movable bridges.

This paper will focus on Stage 3 of the Port River Expressway project, highlighting the design and construction of a single-leaf single-track rail bascule bridge.
PROJECT REQUIREMENTS

We proposed a single-leaf bascule bridge at the channel crossing for the new railway alignment. A single-leaf bascule bridge was specified to provide the optimal solution to meet all key project requirements set forth by the Owner, Transport Services Division of the Government of South Australia (TSD), and to provide the Port Adelaide community with a lasting and beautiful structure.

Key project requirements included:

- 100-Year Design Life for Bridges
- Single-Leaf Bascule Bridges for Movable Spans
- Sealed Decks To Prevent Runoff From Entering River
- Remote Operation From TSD Traffic Control Center
- Provide 30 Meter /98 Foot Navigation Channel
- Maintain Structures for 10-Year Period

The railway bridge has been designed in accordance to the current Australian (AS5100) Bridge Design Code. The AS5100 code is a limit state design code. The railway structure has also been sized in accordance to the current American Railway Engineering Association Manual (AREMA-1997) for movable bridge specific requirements. Machinery and electrical systems have been designed in accordance to the current AASHTO LRFD Standards for Movable Bridges.

ARCHITECTURAL DESIGN CONSIDERATIONS

Special attention was given to the aesthetic design of the bascule piers and leaves of both highway and rail bridges. The bridges close proximity required that elements of each structure compliment one another. Both bridges were designed with similar architectural elements to meet this goal.
The bascule piers, which normally dominate the appearance of a single-leaf bascule bridges, are open concrete “V” shaped post-tensioned members. The rest pier compliments the bascule pier. The bascule and rest piers geometry features angles balanced to the span-open angle. A glass curtain wall enclosure is utilized for electrical and machinery rooms.

Since the bridges will be operated from a remote location, control houses are not required.

Box girders were utilized to minimize structure depths and to provide a sleek appearance.

**STRUCTURAL DESIGN CONSIDERATIONS**

Both highway and railway bascule bridges will have simple-trunnion style framing. This type of bascule is defined by the support mechanism for the trunnion shafts. The trunnion shafts (one per bascule girder) transfer weight of the leaf and counterweight to the pier while allowing the operation of the bridge. Each trunnion is supported symmetrically, with two, plain-sleeve bronze bearings spaced equally and positioned immediately adjacent to the bascule girders. The trunnion bearings are supported directly by steel towers founded on the bascule piers.

The simple-trunnion arrangement with steel trunnion towers was chosen because it has proven to be one of the most reliable bascule bridge designs. The use of steel towers allows for one of the most precise erection procedures available, and provides the required stiffness to support the large moving weight of the span, thus ensuring dependable operation of the span.

**RAILWAY BASCULE SUPERSTRUCTURE**

The railway bascule bridge is a single-leaf bascule bridge that spans 47.25m (155ft) trunnion-to-toe, and weighs 11,340-KN (2,550-Kips). It carries a single-track. The track is configured for dual-gage operation (1.6m broad gage and 1.435m standard gage). Three rails are utilized: Two closely spaced rails one side of centerline track and a single rail on the other side.
The span possesses a floor-break between the trunnion and toe, which decreases the live load span length. A fixed span (deck-over-counterweight) 15.9m/52.2ft long is situated between the floor-break and fixed approach spans. The deck-over-counterweight span is founded on the bascule pier.

The railway bascule superstructure consists of a through steel box-girder superstructure. A through structure is required because of the limited envelope between the top of rail and clearance envelope of the channel (1.2m/3.9ft maximum).

The leaf has two bascule girders. The bascule girders are welded steel box girders. The bascule girders are the most visible element of the structure. As with the highway bascule girders, special care was given to the design and detailing of the railway bascule girders to once again assure a sleek and continuous look to the structure.

Box girders were utilized, as opposed to I-girders, without the use of external stiffeners or flanges to assure this sleek appearance. Care was taken to ensure that the sections would perform most efficiently considering the size of the plates and the economy of large weldments of this type. The girders are positioned as to minimize the transversely cantilevered live loads on the span. The bascule girders are a non-redundant system. To mitigate fatigue issues, all weld details are limited to high fatigue resistance types.

The railway bascule span is fully counterweighted.

The floor-break forward of the trunnion acts to decrease the loaded length of the span. This span is supported by two points acting as a simple beam under live load, supported at the rest pier and the trunnion bearing itself. Dead load is taken through the trunnion bearings.

The floorsystem of the railway bascule is a conventional stringer and floorbeam system supporting timber ties.

To minimize noise and vibration, the Pandrol Vipa fastening system is employed between the rails and ties.
Special techniques were required for the design of miter rail assemblies that join track at the ends of the bascule leaf. The miter rail assemblies allow for the required break in rail necessary for bridge openings. To our knowledge, there has never been a miter rail assembly designed for a dual gage track system. CMI-Promex developed a custom design for the miter rail assemblies. Their Ridex® system is manufactured from precision-machined elements that are adaptable to the dual gage layout. Traditional cast-manganese miter assemblies were deemed unsuitable for this application.

The entire floorsystem is sealed to prevent storm water from draining to the river. Drainage troughs channel runoff to the rest pier and bascule pier where it will be collected, pumped off the bridge, and treated with appropriate measures at the approaches.

**RAILWAY BASCULE SUBSTRUCTURE**

The piers are cast-in-place reinforced concrete. The bascule pier is founded on a cast-in-place concrete pile cap placed just below the tidal zone supported by 900mm/36in driven steel piles. The railway bascule pier is supported by 36 piles. The piles are filled with reinforced concrete from their top to below the river bottom to compensate for anticipated corrosion of the steel shell.

The bascule pier is constructed utilizing a cofferdam. The cofferdam does not require complete dewatering since the pile cap is well above the river bottom. This minimizes the required depth of the tremie pour.

The bascule pier forms a pit to allow the rear end of the bascule span to open below the water line. Above the water line, the piers are opened with a V-shape.
The V-shape of the bascule pier is made possible by utilizing post-tensioned pre-stressed reinforcing strands in the top tie beam. The V-shape allowed for a smaller pile cap. Voids in the pier reduce the weight of the pier, thus simplifying seismic design considerations. The voids are located as to not decrease pier rigidity.

The rest pier is founded on a cast-in-place concrete pile cap placed in the tidal zone supported by 900mm/36in driven steel piles. The railway rest pier is supported on 8 piles. The piles are filled with reinforced concrete from their top to below the river bottom to compensate for anticipated corrosion of the steel shell.

Removable forms are utilized to cast the pile cap for the rest pier. Cofferdam construction is not required.

RAILWAY BASCULE BRIDGE MACHINERY

The single leaf bascule for railway bridge, rotates about, and is supported by two trunnion shaft assemblies, one mounted at each bascule girder. The trunnion shafts are at the rotational center of each span during operation. Each trunnion shaft will be simply supported between two sleeve bearings.

The railway bascule leaf is operated as well by span drive machinery located beneath the roadway level. A 75 KW (100 hp) span motor has been sized to operate the span under normal operation. The machinery is also equipped with a 18 KW (25 hp) auxiliary motor to be operated by an independent electrical drive system for complete redundancy.

In the event of an electrical utility and back-up generator failure, the machinery for the bascule bridge will be equipped with a manual drive speed reducer for manually lowering each span in accordance with the given design criteria.
The railway bascule leaf primary reducer will be equipped with an internal differential gearset in order to equalize the torque between the output shafts. The mechanical differential system ensures correct indexing contact in the gearing and equal load distribution.

The railway leaf machinery primary reducer is coupled directly to the main pinion shaft. As with the highway leaf machinery, each main pinion shaft will be simply supported between two spherical roller bearings. The main pinions mesh with rack segments (which is the means of span rotation operation) mounted to the bottom flange of the railway bascule girder.

Breaking for the bascule span will be provided by motor drum brakes and machinery disk breaks.

To secure the bascule span in the seated position, lock bars will be driven by machinery mounted at the rest pier to a receiving socket located at the toe of each bascule span. The actuator for each leaf will be remotely operated during normal operation, but will also be equipped with a manual hand crank for emergency operation.

To secure each span in the fully open position, lock bars will be driven from the bascule counterweight pit to a receiving socket located at the tail end of the bascule span. The actuator for the leaf will be remotely operated during normal operation, but will also be equipped with a mechanical system for emergency operation as per the technical criteria.

**RAILWAY BASCULE SPANS ELECTRICAL SYSTEMS**

The new Port River rail bridge electrical systems were designed for high reliable safe operation. The bascule bridge utilizes a PLC control system. The PLC system shall be operated remotely from the Traffic Control Center for the Transport Service Division of South Australia that is located 5 KM from the project site.
The bascule bridge will be equipped with one main span motor and one reduced speed auxiliary span motor. The main span motor will be capable of operating the span at full speed while the auxiliary motor will operate in creep speed, which should only be used if the main span motor fails.

The ancillary equipment will include span locks, span brakes and traffic and barrier gates (for highway bridge only) and will be controlled from the PLC based control system or the back-up relay control system if required. Separate isolated limit switch contacts shall be used for the relay system to complete the redundancy. Manual controls for these devices will be provided, in the event the PLC and relay systems do not function with any of the ancillary device.

The complete electrical system will contain PLC control, Manual hand crank controls, two span motor options (Reduced Speed or Main), and a standby generator to power both bridges in the event the utility feeder fails.

Flux vector variable frequency drives (VFD) were selected based on their superb ability to regulate motor shaft speed and torque.

The Owner (TSD) specified special requirements for redundancy for all systems. These include:

- Electrical System is fully redundant to ensure operation if the primary system fails

- Power System Redundancy
  - Single standby generator set rated to supply back-up power for both bridges
  - Transfer switch system interlocked with controls system for bridge operation

- Control System Redundancy
  - Fully redundant PLC system with “hot” back-up with a 3rd processor monitoring both bridges
  - System tied into a SCADA system for remote operations thru Ethernet fiber optic links
Motor-Drive System Redundancy

- Variable Speed Drive controlled single motor system for full speed span operation
- Soft-starter controlled single gear motor drive system for reduced speed span operation
- Portable generator powered single gear motor drive system for emergency span operation

DESIGN-BUILD ISSUES

Design work has overlapped fabrication and construction on this project. Factors that necessitate this overlap include:

- Tight Construction schedule (20 months for rail and 25 months for highway)
- Long-Lead Times for Fabrication
- Limited availability of Special Construction Equipment

To deal with scheduling constraints, individual elements of the design (piles, substructure, machinery, etc.) have been separated, expedited and submitted prior to completion of other design elements.

CONSTRUCTION

The bridges are currently under construction by Abigroup Contractors Pty Ltd, whose tender won the design-build competition in 2005 for Stages 2 and 3 of this project. All piles for the bascule and rest piers have been driven. Cofferdam construction and pier concrete placement is underway. Construction completion is scheduled for late 2007. In the mid 2007, the Railway Bridge is scheduled for its first freight train crossing, while the Highway Bridge will be opened to vehicular traffic in late 2007. These impressive feats will highlight the completion of a complex, significant, and historic bridge project in South Australia.
ACKNOWLEDGEMENTS

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- Abigroup Contractors Pty Ltd – Contractor
- Hardesty & Hanover – Bascule Bridge Designer (Highway and Railway)
- Dare Sutton Clarke Pty Ltd – Highway Approach Span Designer
- Maunsell Australia Pty Ltd. – Railway Approach Span Designer
- Samaras Group – Steel Fabricator (Steel Fabrication images provided by Samaras Group, utilizing TEKLA Structures)
- Woodhead International – Architect (Renderings)
FIGURE 1
Project Location Map

FIGURE 2
FIGURE 3
Highway and Railway Bascule Bridge Elevation

FIGURE 4
Railway Bascule Bridge Elevation
FIGURE 5

Railway Bascule Bridge

FIGURE 6

Bascule Span Railway Longitudinal Section
FIGURE 7

Bascule Pier

FIGURE 8

Simply Supported Plain-Sleeve Trunnion Bearings
FIGURE 9
Railway Bascule Span Operating Machinery

FIGURE 10
Bascule Pier Pile Driving
FIGURE 11

Installation of Bascule Pier Cofferdam Sheeting