Figure 1: Aerial view of project; Hoy Street is the near side and Price Street the far side

Concor Civils completes innovative
Newclare road-under-rail underpass

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BACKGROUND

The City of Johannesburg has adopted an urban development policy which focuses on the need to create compact cities and limit urban sprawl in order to use urban infrastructure effectively. The primary measure to support this policy is the Rea Vaya Bus Rapid Transit (BRT) system.

The BRT route chosen through Coronationville and Newclare passes along the route of Commando – Fuel Roads. The BRT route absorbs some of the roadway capacity at this busy area, necessitating additional rail crossing points. The road-under-rail crossing discussed in this article links Price and Hoy Streets, which run parallel to the railway at the Newclare railway station, so assisting with traffic flows in this area.

The solution chosen was 'design and construct', primarily because so much of the technology and methodology is construction related.

CONSTRUCTION TECHNOLOGY INNOVATION

The elements of the construction process have been done before on other projects executed by Murray & Roberts Construction and Concor Civils. However, the combination of construction technologies chosen for this project is unique.

The structure in its final form is an underpass having a total length of 52.5 m. The width is 12.0 m, sufficient for two road lanes of 3.7 m and two sidewalks of 2.3 m. The structure was constructed in two halves – one 28.0 m in length and the other 24.5 m. The difference was necessitated by the 2% site slope and the requirement that the two structures meet on the centre line of the railway. The Price Street side is the longer of the two. Figure 1 shows an aerial view of the project.

The first site construction activity was the construction of the lateral support which was made in two box cuts, one on either side of the embankment. This was constructed as close to the railway platforms as possible in order to reduce the jacking length of the structures. Vertical micro-piles were placed on the line of the excavation to keep the vertical displacement of the railway lines to a minimum. The lateral support was constructed from the top down in the normal manner, with soil nails being placed to provide the required lateral support. This work was undertaken by Esorfranki Geotechnical.

Within the box cut formed by the lateral support, the reinforced concrete strip foundations were cast. These foundations had a steel sliding surface on top and steel side guides to keep the structure on track during the jacking operation. The top surface of the steel sliding surfaces was placed within ± 0.5 mm by using a specially designed adjustable support and grouting system. These foundations formed a portion of the permanent works and had the necessary cover and strength required of the permanent works.

The vertical side walls were constructed next. These side walls have a corresponding sliding steel shoe on the bottom edge. This makes the wall, once the formwork is removed, unstable under lateral loading. A novel method, using welded steel angle sections at the base of the wall, was employed to keep the wall stable while the reinforced concrete deck was constructed. AfriSam supplied all the concrete for the project, as well as technical advice for the more difficult concreting operations.

Figure 2: The Hoy Street side during jacking; the jacks and spacer blocks can be seen in the foreground

The drum-deck was constructed next. This activity used high-load capacity frames supplied by Doka. The top surface was power-floated in order to make the top surface as smooth as possible, and bentonite and HDPE sheets were used to keep the jacking friction coefficient as low as possible.

A special requirement of this project was the reported nature of the embankment material. The material was thought to be mine sand from the nearby mines. This necessitated special cutting edges which would keep the excavation beneath the railway lines stable at all times. As it turned out, the embankment material was found to be well compacted fill with a large clay content and rocks up to 500 mm in size. However, the cutting edges were strong enough to support this material and to keep the embankment stable. Figure 3 shows the top cutting edge on the Hoy Street side.

Jacking commenced on the Hoy Street side. Esorfranki Geotechnical undertook the jacking operation, as well as the removal of material during the jacking operation. The Hoy Street structure weighed 1 100 tons and required a jacking force of 1 200 tons compared with a theoretical jacking force of 1 080 tons.

The Price Street side weighed 1 140 tons and required a jacking force in excess of 1 000 tons. The jacking arrangement is best seen in Figure 2. Both walls were jacked simultaneously, often with differing pressures in an effort to maintain the desired directional heading.

Figure 3: The top cutting edge on the Hoy Street side prior to bolting to the deck; the vertical lateral support wall can be seen on the left

Figure 4: A closer look at the structure during the jacking operation

A large volume of very hard quartzite was encountered in the embankment – an unexpected occurrence at a critical time during the construction. This delayed the jacking by close to six months. Drilling and blasting were required to remove the rock, as can be seen in Figure 6.

The two structures met exactly as expected on the centre line of the project (see Figure 5). This short-lived relief was, however, totally eclipsed by the unexpected additional volume of quartzite to be blasted and removed for the construction of the triangular in-fill walls – clearly shown in Figure 6. The excavation process for these walls involved working from the top, shotcreting and anchoring the gunited surface to form a stable surface against which the in-fill walls were cast.

The in-fill walls were then constructed. This was done using a single-sided shuttering system, as well as employing rock anchor ties to restrain the formwork.


Figure 5: Light at the end of the tunnel; the two structures met exactly at the centre line

The structure was completed by the addition of the galvanised steel gutter placed under the junction of the two structures and linked to a drainage system within the walls to take any leakage to the road level below.

The construction of the road works and drainage completed the project.

CORPORATE SOCIAL INVESTMENT

During the 18-month contract period, 30 local labourers were employed and trained in basic construction activities. Small to medium enterprises were employed for managing the traffic on the roads adjacent to the site, as well as the paving of the sidewalks. Special training was conducted for the workforce who had to work close to the existing railway. Railway flagmen and scaffolding erectors were also trained.

DESIGN INNOVATION

The new Newclare underpass was designed in such a way that the Newclare to Westbury rail traffic remained operational at all times. The Murray & Roberts Construction/Concor Civils solution was chosen as the most cost-effective and reliable solution for this difficult crossing.

The adoption of two semi-complete structures for the crossing is considered innovative. Originally it was intended that both structures would be jacked simultaneously in order to maintain a stable embankment. But after the installation of the lateral


Figure 6: The walls of the two separate structures and the excavation for the triangular in-fill section; the lateral support for the in-fill walls has been completed

support it was clear that the embankment was sufficiently stable to have the jacking operations undertaken sequentially.

While the soffits for both structures line up, as well as the inside surfaces of the walls, the design required the Hoy Street structure to have a deck of 100 mm thicker than the Price Street structure, and to have walls that are 100 mm thicker as well. This was required to ensure that the Hoy Street deck cutting edges overlapped the Price Street cutting edges as the two structures met in the centre. Figure 3 shows the Hoy Street cutting edge.

As the structures closed, the pipe sections were cut away to allow the Price Street cutting edge to pass below the inverted channel sections. This supported the railway embankment for the last 1 500 mm of the closure. The Price Street cutting edge was of a different design and was unbolted and removed in sections as the two structures closed. The final gap of 150 mm was partially sealed using gunite.

The side cutting edges were bolted in place using threaded bar cast into the concrete. Once the cutting edges were removed, reinforcing couplers were screwed over the stubs and continuity rebar screwed to the couplers to be part of the wall rebar. The stubs are just visible in Figure 6.

About 5.0 m from the final jacked position, both structures are unstable due to the large soil and rail loading. In order to maintain stability over this crucial construction stage, it was necessary to anchor the back of the structures. The installation of one set of anchors can be seen in Figure 2.

The last 5.0 m of all four walls were constructed parallel with the sliding surfaces. This can also be seen in Figure 2. The concept was to anchor the back of the structures during the last 5.0 m of jacking by placing rock anchors on either side of all four walls and constructing a steel cross-head over the top of each wall, and anchoring the structure down. Double steel sliding plates were built into the top of each wing wall, as can be seen in the photographs.

Teflon pads were placed below the steel cross-heads. As the structures were jacked forward, the initially vertical tendons simply displaced to an angle of 2.3 degrees, representing the friction angle of Teflon to steel. This was a pleasant surprise, since we anticipated jacking the cross-head backwards as the structures moved forward.

Figure 6 shows an overlap of the sliding structure over the cast foundation of about 1.0 m. Since it was not advisable to construct sliding foundations for the structures once they were moving, an angle of the front cutting edge was chosen as 37 degrees (flatter than the normal 45 degrees), and a 1.0 m overlap over the end of the cast sliding foundation was allowed. This allowed the two structures to meet without having to construct additional sliding surfaces beyond the extent of the lateral support.

Figure 7: The in-fill walls have been completed and the finishing surface treatment is in progress

ENVIRONMENT IMPACT CONSIDERATIONS

The project was constructed in a built-up environment, so due care and attention had to be given to construction noise levels. Compressors were specially silenced, and noise and vibration from blasting was managed by using small-charge-delayed blasting.

The material excavated from the underpass was placed and compacted to reinforce the toe of the adjacent railway embankment, thereby obviating the necessity for hauling this material over the already busy streets. This was seen as a safety consideration, since the local community use the streets for recreation activities.

HEALTH AND SAFETY

The normal health and safety standards applicable to all Murray & Roberts Construction/Concor Civils projects were applied to this project. All persons required to work close to the operating railway were given special training to ensure knowledge of the specific and invisible hazards. All sub-contractors were inducted into the Murray & Roberts Construction/Concor Civils safety standards and were expected to conform to the requirements, as well as to produce Risk Assessments and Method Statements for all activities.

QUANTIFIABLE TIME, COST AND QUALITY

The project took 18 months to complete with a final completion value of R29.5 m. The quality was managed according to the Murray & Roberts Construction Quality System. Special attention was paid to the accuracy of the sliding surfaces to ensure the lowest possible friction force, as well as the accuracy of the final junction between the two precast structures.

RISK MANAGEMENT

There were numerous risks associated with this project.

The major risk was the interruption of the PRASA (Passenger Rail Agency of South Africa) rail service. This was mitigated by the strapping of the rail tracks by driving mini-piles as vertical support behind the gunited lateral support and by bracing the embankment using a lateral tie system through the embankment from one face to the other, as can be seen on the right in Figure 3. The vertical and horizontal movements of the track were monitored on a regular basis during jacking to ensure that the track alignment was not compromised. The railway lines nevertheless needed to be realigned and packed out a few times during the jacking. An interesting aspect was that the rail displacements did not always follow a predictable pattern, and various complex theories were proposed to account for the various movements.

The actual jacking force applied to the structures was a risk. The jacking force depended on numerous factors, such as the friction between the two steel sliding surfaces at the base of the walls, the friction of the side walls and the actual lateral pressures, the friction of the top deck and the friction between the foundation directional guide system. The final jacking forces were significantly more than calculated, probably due to the variation in the embankment material.

The two structures had to line up in the lateral direction. This risk was mitigated by placing up-stands on either side of the sliding foundations to steer the vertical walls. The out-of-position was then limited to 50 mm.

The stability of the jacked structures was a significant risk. This was obviated by the tie-down system, 600 ton on the Hoy Street side and 400 ton on the Price Street side. While the tie-down force was constant, the lever arm changed as the structure was jacked forward, thereby increasing the restraining moment as the structure was jacked forward to counteract the increasing over-turning moment. ◻

PROJECT TEAM

Client Johannesburg Development Agency
Consulting engineer Vela VKE
Structural design Murray & Roberts Construction/Concor Civils
Lateral support design Jones & Wagener
Lateral support construction Esorfranki Geotechnical
Concrete construction Concor Civils
Jacking of structures Esorfranki Pipejacking
Concrete supply AfriSam

Figure 8: The completed underpass

Source:
http://www.saice.org.za/downloads/monthly_publications/2012/2012-Civil-Engineering-September/#/0