Gautrain Station Extension at OR Tambo International Airport

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BACKGROUND

The Gautrain Rapid Rail Link (GRRL) is a transit system designed for the rapid movement of commuters between Johannesburg, Pretoria and the OR Tambo International Airport (ORTIA) in Gauteng. The GRRL was developed as a public-private-partnership concession and includes a 15-year maintenance and operation period after completion of construction. This concession was awarded to the Bombela Concession Company (BCC). As part of the maintenance and operation of the Gautrain system, the BCC recognised the need to extend the station at ORTIA in order to allow for better commuter access at this location. The design-and-construct station extension contract for ORTIA was awarded to Stefanutti Stocks in April 2015 after the tender for the works had been put out. Stefanutti Stocks employed SMEC South Africa as their design consultant for the works.

The ORTIA Station extension project's scope of works included the detailed design and construction of a length of approximately 55 m of extended station platform. The extension now allows passengers access to four train carriages instead of the previous two.

Viaduct 15 is the viaduct that provides access between Marlboro and the ORTIA Station, and begins at Rhodesfield Station and ends at ORTIA. Viaduct No 15.3 provides the third and final part of the access – it begins at Pier 37 and ends at Pier 41

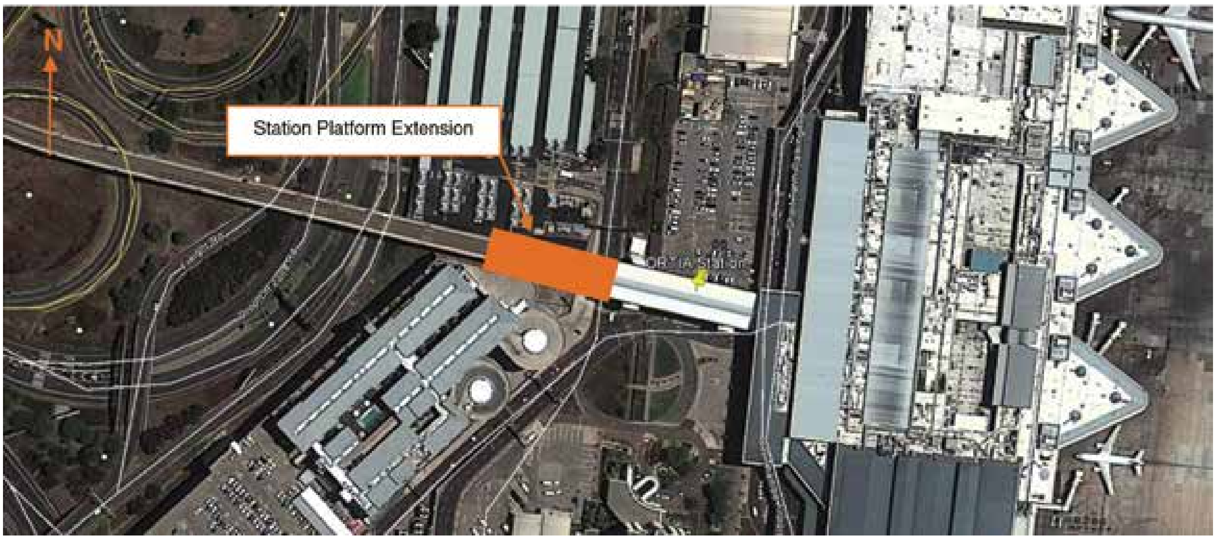


Figure 1: Satellite imagery of the extension to the OR Tambo International Airport Station

within the ACSA (Airports Company South Africa) property boundary. This section comprises four spans with a span configuration of 3 x 40 m, 1 x 48 m, and a cantilever of 2.978 m from Pier 41 connecting to the ORTIA concourse (these spans being measured as centre to centre of the piers). The existing piers are all supported on large-diameter piles.

The existing ORTIA Station platform is supported by the section of viaduct that begins at the ORTIA Departure Building (which is the tip of the viaduct cantilever) and ends halfway between Piers 39 and 40. The station is built on the last 48 m long viaduct span, the cantilever portion of 2.978 m, and half of one 40 m long viaduct span (see Figure 1). The station extension began where the existing station ended (halfway between Piers 39 and 40) and extended to Pier 38. This total extension equates to one and a half spans of the typical 40 m long precast segment viaduct spans. These 'station deck' spans are consequently designed differently to the majority of the viaduct deck spans.

MAIN OBJECTIVES

The principal objective of the station extension project was to safely add an additional 55 m length of station platform to the existing ORTIA Station, whilst successfully maintaining the operations of the existing train and its passenger transportation schedule. Furthermore, the construction was to be such that it facilitated safe erection methods, maintained operational safety, ensured economy in materials and construction works, achieved long-term durability with low maintenance requirements, and matched the new structure to the existing one in terms of its aesthetic finish.

PROJECT DESCRIPTION

The project involved the following elements:

- Demolition works to the existing parapets and box girder cantilever tip to allow the installation of the new precast struts and slabs
- Installation of the precast concrete struts
- Construction and installation of the new precast station slabs and parapets
- In-situ grouting of the slab to strut connection stitches
- Fabrication and installation of the structural steel canopy roof
- Fabrication and installation of the structural steel escape stairs

Figure 2: Precast struts attached to the viaduct section

Figure 3: Southern side roof construction during installation of sheeting and services

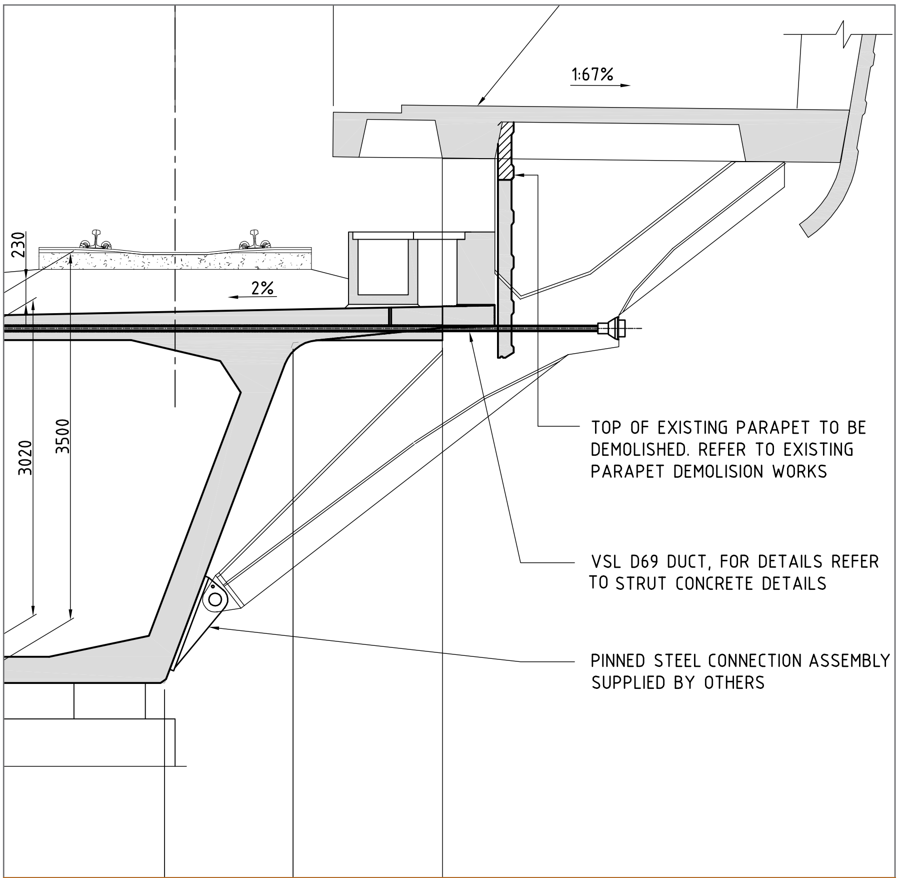


Figure 4: Structural system for strut connections, transverse pre-stressing and slab supports

- Signalling and overhead traction equipment (OHTE) relocation works
- Longitudinal and transverse post-tensioning works inside the viaduct box girder.

DESCRIPTION OF STRUCTURAL ELEMENTS

The existing viaduct is a pre-stressed concrete segmental box girder – 10.1 m wide and 3.5 m deep. The typical box girder is modified at ORTIA Station to be able to support the platform slabs. In the original planning of the viaduct design, allowance was made for the station extension.

Differences between the typical viaduct box girder segments and the station segments include the use of a pinned steel connection assembly, with steel plates cast into the viaduct web (these can be seen in Figures 2 and 4) to support the base of the precast struts, transverse pre-stressing to support the top of the precast struts, and additional longitudinal pre-stressing cables (see Figures 4 and 6) to allow for the additional load on the girder.

The existing station platform slabs are precast concrete elements that are supported on precast concrete struts. The maximum weight of one of these slabs is 20.5 tonnes. The spacing between the pairs of struts is between 7 m and 9 m. The station canopy columns are located between the pairs of struts on the torsionally stiff slab edge beam which is part of a grillage-type slab arrangement (discussed further on in this article).

The struts are designed for combined compression and bending, and the section has been profiled to follow the linear bending moment diagram, and therefore tapers to reduce materials as well as provide additional aesthetic impact. Linearly varying sections were detailed to simplify the strut constructions. The struts are pinned at their base to the box girder and stressed together through the top flange of the existing box girder with transverse pre-stressing. This was possible because corrugated ducts had been cast into the viaduct top flange, in anticipation of the pre-stressing requirements for the station extension. In the temporary condition, however (when only one strut is erected per side of the viaduct), the struts were tied to the existing structure using a tie-bar arrangement.

There are two types of platform slab panels used in the design. Panel type 1 is connected to the struts by a cast in-situ grout pocket and carries the station roof canopy. Panel type 2 is simply-supported between the adjacent type 1 panels via halving joints which are reflected through to the tiling joints. The interfacing of these slab types is visible in Figure 2, where the halving joints can also be seen. During construction, the type 1 panels were temporarily supported on jacks prior to grouting.

The roof is composed of tree-type columns (see Figure 3) with extended arms which carry the roof loading down from the curved rafters. The rafters span over the entire 16.4 m station area, and the roof includes a skylight, profiled sheeting and radiused polycarbonate sheeting. The new station roof had to be modified to avoid clashing with the existing City Lodge building. The loads from the platform roof are applied to the platform slabs via the steel columns in the form of a series of point loads with fixed end moments. Since these roof loads are significant for the platform slabs, the slabs are designed in a grillage-type beam formation which distributes the loading back to the struts and then into the viaduct.

To comply with the National Building Regulations, SANS 10400 Part T, the travel distance to the nearest escape staircase should not be more than 45 m, hence new fire escape staircases were required. The location of these new escape staircases (on the ends of the platform) are such that they avoid the adjacent parking garage and the below-ground tunnel linking the ORTIA Departure Building and parking garage. The foundations to these stairs also avoid any below-ground services.

DESIGN CHALLENGES

The principal difference between the new station installation and the previous installation is that the current

Figure 5: Structural steel roof segments ready for erection

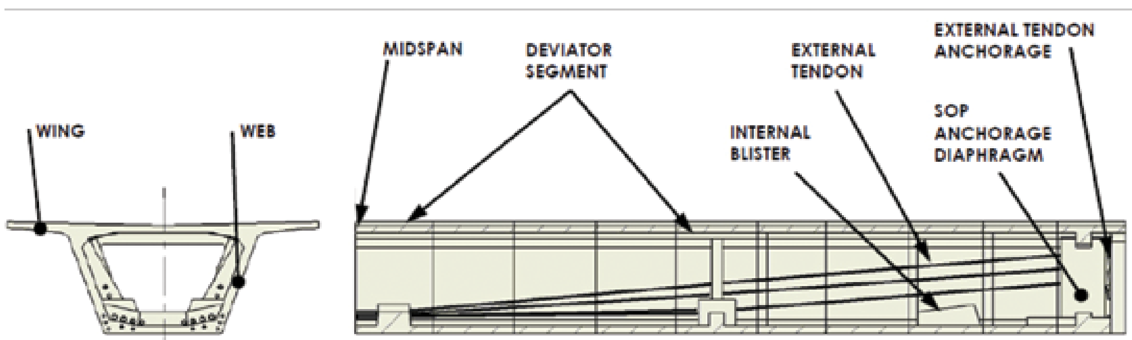
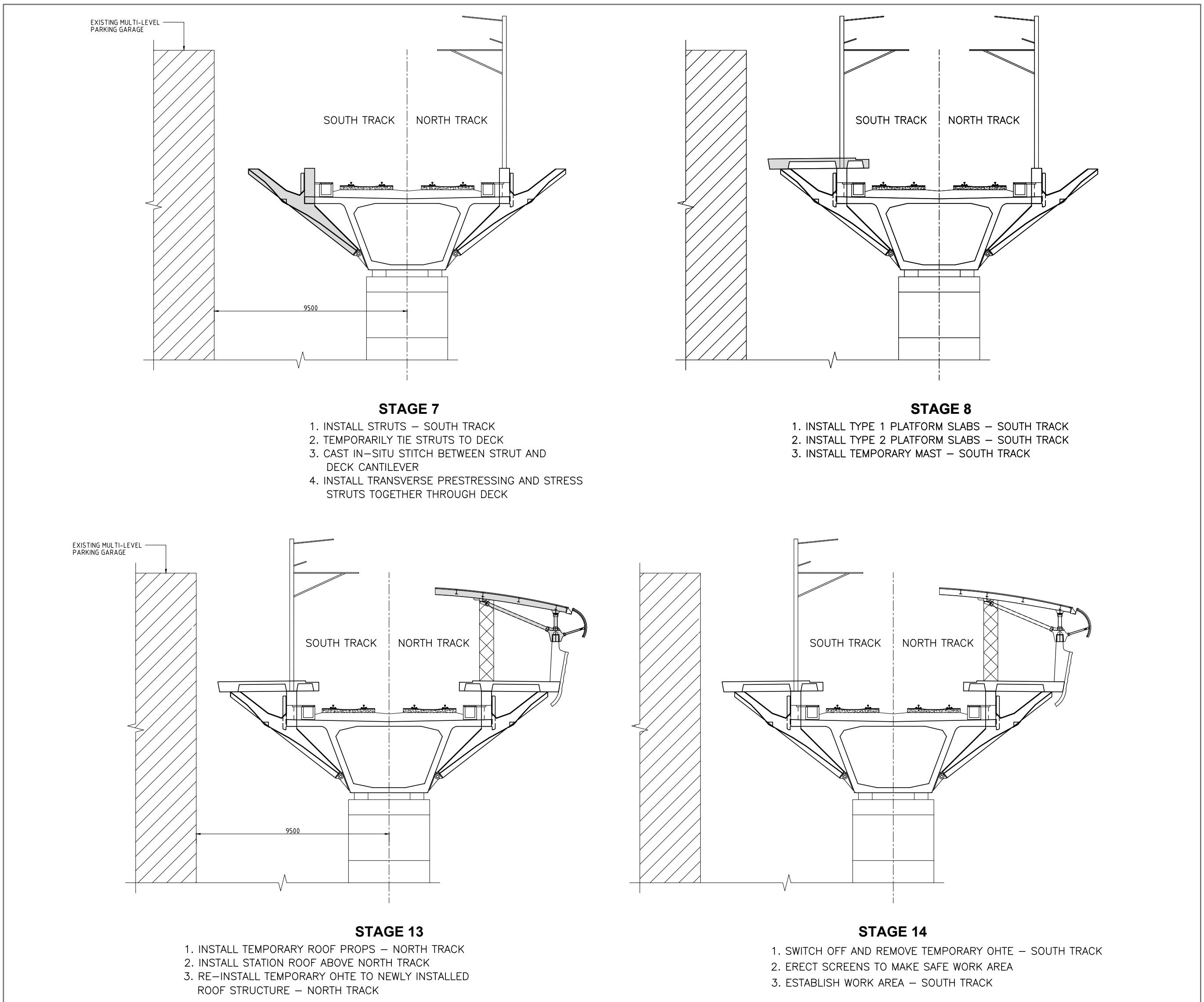


Figure 6: Viaduct section and pre-stressing arrangement

Figure 7: Underside of the viaduct – this photo illustrates the new width of the station extension, as well as the temporary crash deck which is visible behind the mobile crane; the fixed crane is also partially visible to the left of the photo



Figures 8: Typical stages of construction, illustrating the temporary propping and temporary OHTE relocation arrangements

installation has been constructed and erected while the Gautrain remained fully operational. This resulted in numerous challenges for the erection and design team. The main challenge was how to safely lift the 20 tonne platform slabs to a height of 25 m above ground level, over the 25 kV live train line. A number of options were considered by the contractor, including the use of various mobile and fixed crane types, and even a moving vierendeel gantry frame, which would have required a rail to be installed in the adjacent road. The adopted solution was to use a fixed-in-place heavy-lift crane (the largest in Africa) which met the load and lever arm requirements for lifting the heavy slabs into place on the southern side of the viaduct. The crane is visible on the northern side of the viaduct in Figure 7.

Since a portion of the works took place over the well-used ORTIA access road, the contractor had to design and install a temporary crash deck to prevent any construction or demolition debris from falling on the road. This crash deck can also be seen in Figure 7.

In order to mitigate the risks associated with working adjacent to a live rail line, the design of the station roof had to be revised so that it could be installed in three sections. This is because the construction works could only occur over one track at a time after the OHTE had been switched off and removed, and safety hoarding had been erected between the two tracks. This allowed one track to remain operational whilst the overhead traction equipment was transferred from an existing mast support to the future roof support position. Temporary props (see Figure 3) were required to support the cantilever tips of the first two roof sections (northern side and southern side) until the central section was lifted into place and the roof beams were made continuous via bolted splice connections. The temporary props were situated as closely as possible to the train to reduce the cantilever length of the rafters. The splice was positioned such that the installation of services would not be affected during the construction phase. To avoid uplift of the roof structure during construction, the temporary props required holding-down supports.

During construction the section of catenary from the ORTIA Departure Building to the second OHTE mast had to be removed. The horizontal tension force in the catenary after the second mast therefore had to be resisted. On the northern side of the viaduct a tie element existed to resist this horizontal force; however, on the southern side of the viaduct this tie element had to be designed and installed before this section of catenary could be removed. The existing tie was checked to ensure that it was sufficient to adequately restrain the support mast for the horizontal catenary force.

Various challenges were encountered with respect to the torsion load effects from the additional dead load that arises during the construction sequence, and hence several scenarios were investigated in order to find a solution that maintained a suitable set factor of safety for the stability of the viaduct, considering that the existing station remained in use during the construction of the new platform. The final sequence of erection that was adopted was the least onerous to the viaduct stability. The strength of the viaduct box girder in torsion, shear and bending was also checked and was found to be acceptable for the applied loading. Deflections arising from additional dead load and the use of longitudinal pre-stressing were also checked and found to be within acceptable

Figure 9: The completed viaduct structure with fire escape staircases as seen at night

criteria. Deck rotation and deflections were monitored during the construction as a further safety check.

PROGRAMME OF ERECTION SEQUENCE

Twenty individual construction stages were necessary to erect the full station structure to both sides of the viaduct. The construction stages had to account for the temporary hoarding that was erected on the working side of the platform, the OHTE relocation works, the signalling and services installations, the steelwork propping and roof erection, the strut, slab, screeding/tiling and parapet installations, as well as the pre-stressing requirements.

A sample of these stages is shown in Figure 8 and provides an idea of the details pertaining to some of the more complex stages of the installation.

CONCLUSION

The new station platform was successfully handed over to the Bombela Concession Company on 23 May 2016 after a challenging contract period of approximately 12 months. The design-and-build contract approach by Bombela allowed for a team who could provide for design iteration and problem solving during the course of the project. Consequently there were no disruptions caused to the airport operations, despite the detailed and complex nature of the work required for the extension construction. A total additional dead load of 150 kN/m was added to the viaduct bridge structure over the station extension area. The project highlighted that careful planning and sequencing are required when dealing with works in close proximity to an existing live train line. The project also highlighted the positive impact of the detailed foresight shown in the original Gautrain viaduct construction. The completed structure is shown in Figure 9.

ACKNOWLEDGEMENTS

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