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# From false abutment to true abutment using MSEW with polymeric reinforcement: the Lanseria International Airport

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## Abstract

The use of geosynthetics in soil reinforcement is well established, however for critical structures such as bridge abutment there is the tendency of relying on reinforced concrete for the support of the bridge deck, besides soil reinforcement has proven to be able to withstand much stringent design requirements. In 2016 the Lanseria International Airport in South Africa required an underpass for passengers, which at first was designed as with an RCC wall sustaining the wall and an MSEW structure supporting the backfill for the ramp. During the construction phase, it was difficult to build both structures at the same time, as the construction area was very limited allowing only the earthworks contractor. The use of a true bridge abutment, where the girder is supported directly by the reinforced soil mass enabled to stagger the programme of work and reduce the construction time as no RCC wall was required anymore. The design followed the AASHTO guideline as no local standard covered such structure, leading to several changes in the girder design to consider the new span as well as to limit the bearing pressure on the MSEW. The paper aims to showcase this project from the initial phase through the engineering process that brought to the choice of a true bridge abutment, to then explaining the principles of design for both the wall and the bridge, concluding with construction of the system.

**Keywords:** *true bridge abutment, polymeric reinforcement, MSEW*

## 1 Introduction

The use of soil reinforcement technology is proven, and it does not require any further explanation or comparison as we are reaching 50 years since its beginning as it is known in modern technology. Yet, the confidence of using of soil reinforcement stumbles when facing with critical structures, such as vertical walls and even worse, bridge abutments. One of the most critical design aspect, if not the most important, is the relationship between different disciplines of engineering such as the design of a building which requires a geotechnical engineer for the design of the foundation, while a structural engineer for the design of the building. The two designs shall be complementing each other and the forces resulting from one design become the design input for the other one. Bridge abutments are usually designed by structural engineers where the piers of the bridge carry the load of the girder and the superstructure, while the embankment is designed to only carry the traffic load and the pavement infrastructure. False abutments are the most common solutions when the embankment requires to have a narrow footprint as soil reinforcement is used to steepen the sides and a facing is used to ensure an aesthetically pleasing finish and at the same time erosion protection. One of the issues of false bridge abutments is the construction as the bridge piers are often very close to the facing if not within the structural fill, requiring a staged construction between earthworks and formworks. Both operation cannot be executed simultaneously, which can influence the time of construction, due to the special but closed construction methods (Figure 1).

Furthermore, the cost of multiple structures and foundations can be reduced, providing a time and cost saving. Recently the confidence in soil reinforcement has proven to be successful in true bridge abutments walls where the soil reinforcement structures carries the load of the bridge, removing bridge piers and replacing with a foundation pad where the girder sits (Figure 2). The design of the girder needs modification as it gets longer and the foundation pad requires to be designed to transmit an allowable loading to the wall. The result is a cost-effective structure which enable to address typical issues such as foundation as well as interaction between bridge and embankment transition, further discussed in depth.

Figure 1. MSEW with bridge piers – issues during construction

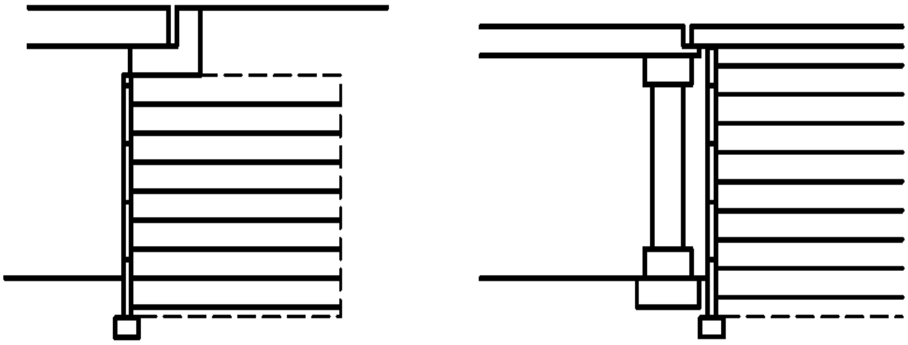

Figure 2. RIGHT: False abutment – LEFT True abutment (BS 8006,2010)

## 2 The Lanseria International Airport

In 2016, the Lanseria International Airport, situated in the Gauteng region of South Africa saw the commencement of construction, upgrading of the terminal facility to keep up with the increasing demand of Johannesburg passengers. Part of the upgrade will provide a multi store parking facility across the main access road. Currently to access the parking area from the terminal building it required to cross the road, whilst with this new plan the passenger will walk underneath the road and access the parking building (Figure 3).

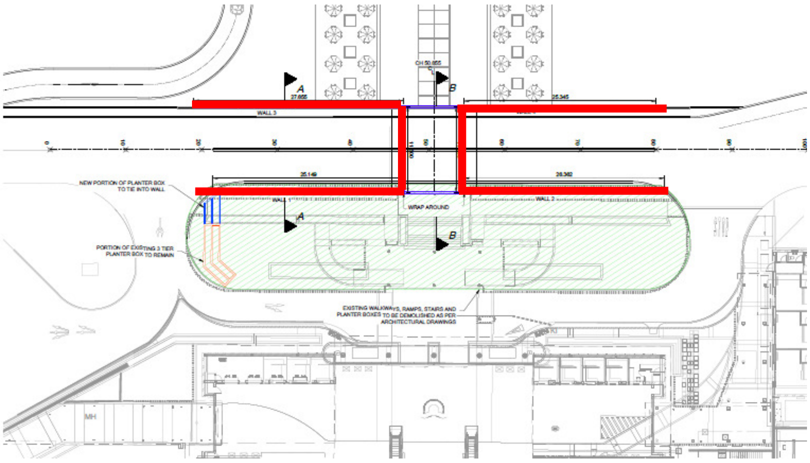

Figure 3. Lanseria International Airport – new access ramp (in red the abutments)

It was required to build an underpass, maintaining the same road level, dropping the ground to a quote of -3.5m. The bridge had to provide a safe underpass for the pedestrians. The first proposal was to provide a cast in-situ reinforced concrete box culvert that would create a tunnel below the road (Figure 4). The box culvert had column supports in the centre to reduce the span requirements of the top slab (bridge). The vertical walls of the box culvert would then serve as the abutment and retaining wall supporting the slab and backfill material behind the wall.

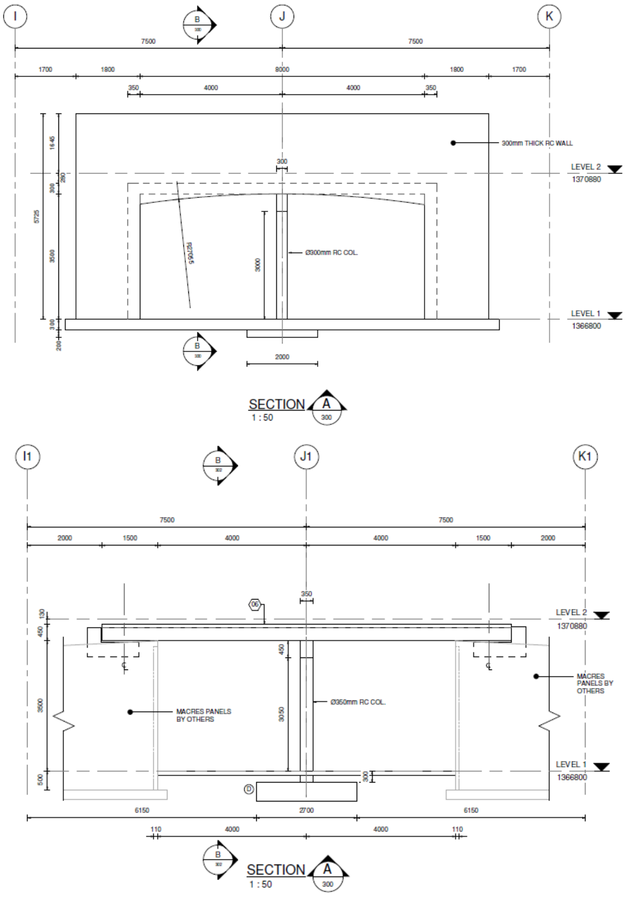

Figure 4 (TOP). First proposal with false bridge abutment – typical section (BOTTOM). True bridge abutment proposal – typical section

Due to time constraints and the construction time required for the box culvert, a second proposal was made to support the edges of the slab by the mechanically stabilized earth wall. The edges of the slab would be supported on bearing pads, which would be cast on the reinforced backfill material. The reinforced soil mass would serve as the “true bridge abutment” (Figure 4). The bridge slab was a continuous one-way spanning slab consisting of two spans. The centre of the bridge slab is supported with a downstand reinforced concrete beam on top of three columns. The columns then transfer the loads through pad footings into the in-situ material. The analysis, design detailing of the bridge slab and components was performed according to TMH7 Code of Practice for the Design of Highway Bridges and Culverts in South Africa.

## 2.1 First proposal – false bridge abutment

The first proposal was to have independent structures, a false abutment with a maximum height of 3.2m above ground level to carry the embankment and piers on shallow foundation to carry the bridge. The type of wall by the client was a concrete panel face wall with polymeric reinforcement straps. For such small structures, the concrete faced panel is usually not recommended as most panels needed to be casted to fit the geometry, however both a concrete block retaining wall and a gabion wall facing were proposed as possible alter-native but rejected. Although the size of the wall was of only 400m$^2$ in 6 walls with a moderate height, the constructability of such solution become the critical issue as the site is within a fully functional airport and a road. There was no much space; many services (among which the main communication cable with the airplane) required to be maintained until the wall was completed.  The other major concern was a tight time schedule as the wall was on the critical path of the contractor to then move on to the parking building. The programme of having two contractors working in such scenario brought the project team to look at the possibility of using a true abutment solution.

## 2.2 Second proposal – True bridge abutment

The redesign of the wall as a true bridge abutment generated a lengthening of the top reinforcement and an increase of the tensile strength of the bottom reinforcement to cater for 1.4m wide bridge pad exercising a dead load of 144 kN/m and a vertical live load of 195 kN/m plus a horizontal load of 18 kN/m (Figure 6).

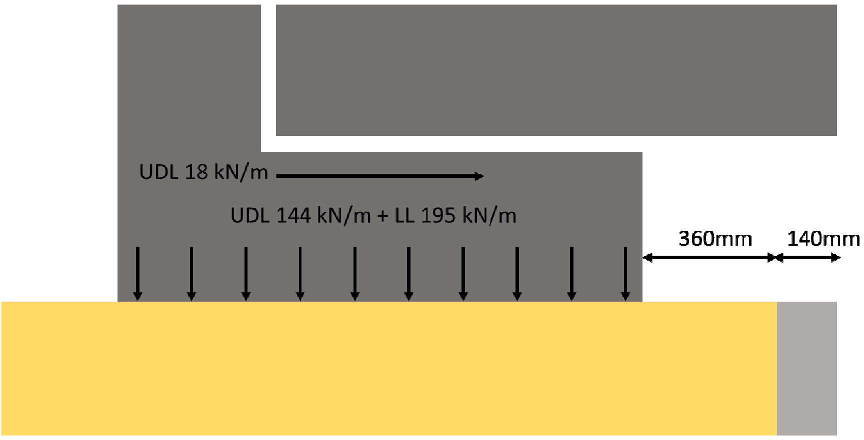

Figure 6. design loading of the bridge on the bridge abutment

In the next paragraphs, the design and the construction will be discussed in detail.

# 3 Design

The design of soil reinforcement structures in South Africa is governed by the SANS 207 – "The design and construction of reinforced soils and fills" which is an amended version of the BS 8006:1995. The design of the true bridge abutments is not included in the SANS 207, therefore the design was based on the Federal Highway Administration (FHWA)  National Highway Institute (NHI) 10-024 "Design and construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes" based on Load and Resistance Factor Design (LRFD) method which considers design of true bridge abutment. The main concern was the distance between the bridge pad and the back of the panel as if it was too little, once the girder would be placed over the vertical pressure would have create a horizontal trust at the back of the panel which would have cause a movement due to the straining of soil and reinforcement. The structural engineer requested 50mm at first to maintain the girder design. However, the National Cooperative Highway Research Program, NCHRP Report 556 recommended at least 150mm distance between the bridge bank and the back seat of the panel for such typology of structure. All the loadings considered are reported in Table 1 indicating the worst-case reaction forces which were used in the design of the MSEW.

Table 1. Loading configuration and factors at ULS

| Load Combination | Load Type (TMH7) | | | | | |
|---|---|---|---|---|---|---|
| | G | $Q_{NA}$ | $F_{LNA}$ (Hor. Force) | $Q_{NB}$ | $F_{LNB}$ (Hor. Force) | $Q_{NC}$ |
| 1 | 1.5 | | | | | |
| 2* | 1.2 | 1.5 | | | | |
| 3* | 1.2 | | | 1.2 | | |
| 4* | 1.2 | | | | | 1.2 |
| 5* | 1.2 | 1.3 | 1.25 | | | |
| 6* | 1.2 | | | 1.1 | 1.1 | |

* Variations of the live loads were imposed on the bridge slab. These combinations are indicating the factors used for the Ultimate Limit State.

As the design anticipated the test on the proposed backfill, conservative values were used with $\phi$=30° and 20 kN/m$^3$ cohesionless as the material suggested was a blend of the excavation material and the pavement layerworks removed. Triaxial testing consolidated undrained confirmed the soil properties exceeded the values assumed with $\phi$=33° and 20.07 kN/m$^3$. Table 2 is a summary of the fill properties.

Table 2. Soil properties

| | Mixed G1 |
|---|---|
| Unit Weight | 20.07 kN/m$^3$ |
| Friction angle | 33° |
| Cohesion | 0 kPa |
| Passing 0.075 | 8% |
| OMC | 7.2% |

### 3.1 MSEW Components

As mentioned it was a request from the client to have a concrete finish of the wall, therefore square precast panels were used. The components of the MSEW were a 1.5m x 1.5m panel, 140mm thick made with 35MPa concrete which was reinforced according to the connection force required. The connection used was a polymeric loop cast in the concrete with a saddle to allow the reinforcement strap to rest on. The reinforcement was a geosynthetic strap (Figure 7) comprising polyester fibres encased in a polyethylene sheath (BBA, 2012) with properties reported in Table 3.

Table 3. Reinforcement strap properties

| | | Paraweb 2D |
|---|---|---|
| Ultimate tensile strength | | 75kN |
| Strain at UTS | | 12% |
| Creep 120 yrs @ 20° | $RF_{CR}$ | 1.38 |
| Installation damage Passing 0.075 ($d_{50}$ >15mm) | $RF_{ID}$ | 1.05 |
| Chemical/ environmental (pH 4.0 – 9.5) | $RF_{CH}$ | 1.08 |

Figure 7: Paraweb reinforcement installed

As the structure is a bridge abutment, the design strength used was based on the serviceability criteria rather than failure criteria. The reduction factor for creep was increased to 2.0 in order to meet the requirements of the BS 8006:2010 of 0.5% allowable creep strain post-construction. In the design process both tie back wedge method and coherent gravity method were analyzed as the polymeric reinforcement during working conditions has been proven to work at strain much lower than 0.5% thus behaving as an inextensible reinforcement both in short and long term as it does not exceed a strain of more than 1%. The final configuration for the highest section is reported in Figure 8.

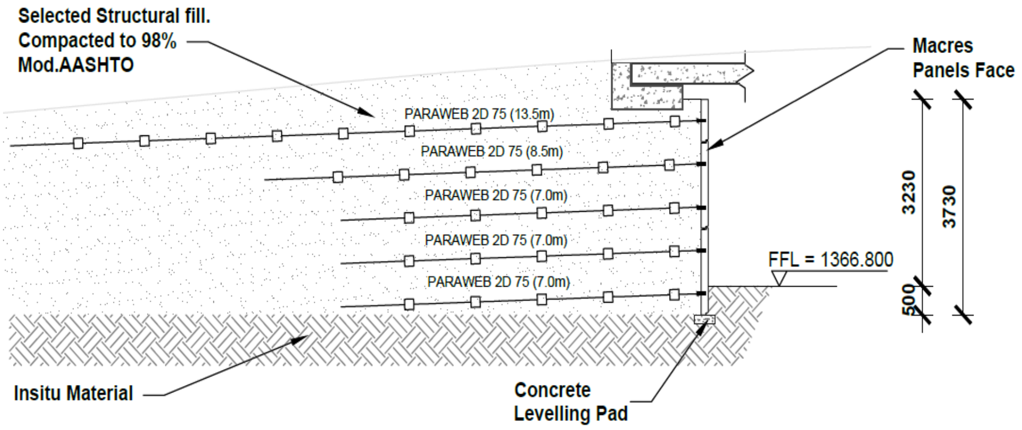

Figure 8. Typical section

### 3.1 Girder design

The analysis began with the bridge slab. The imposed vehicle loads were applied in accordance with the requirements and specifications of TMH7, Parts 1 & 2 of 1981. These included the vertical forces, the horizontal forces from braking vehicles, and horizontal accidental forces which could be applied in any direction in the plane of the slab surface. The three types of imposed loadings that was considered included the following:

1. Type NA – Normal traffic loading
2. Type NB – Single abnormally heavy vehicle loading
3. Type NC – Multi wheeled trailer for very heavy applications

These imposed loads were analysed in various combinations with the permanent loads acting on the bridge deck. The combinations were applied to provide the worst possible loading scenario to obtain the ultimate forces required for the design of the concrete components. The permanent loads included the self-weight of the concrete, the barriers along the edges of the deck with base supports, walkway kerbing and paving blocks, road layer works and asphalt covering.

The total span of the bridge deck had to increase with the change in the edge supports. Due to the requirements of the MSEW, the span increase by 1.5m. The slab was designed to satisfy both ultimate and serviceability limit state design requirements, in accordance with THM7. SANS 10100 Part 1, The structural use of concrete served as the minimum requirements for the design and detailing. Some constraints were placed on the thick-ness of the slab. The final slab thickness was 350mm, using Grade 30 concrete with a compressive cube strength of 30 MPa @ 28 days in conjunction with high yield steel reinforcement with a yield stress of 450 MPa.

The bridge slab was supported by concrete bearing pads along the edges and concrete columns in the centre. The reaction forces from the bridge slab was used to calculate the requirements of the bearing pads and columns. One of the requirements of the concrete bearing pad was to keep the bearing pressure below the allowable bearing pressure of 250 kPa at the top of the MSEW abutment support. The thickness of the concrete bearing pad was determined from the ultimate forces. The column and downstand beam in the centre of the slab was designed to resist the various vertical forces acting in them.

Lateral support was provided by the rubber bearing pads at the end of the bridge, and the concrete columns in the middle. To reduce the impact of the horizontal forces acting on the bearing pads, the columns were designed to resist a major portion of it. The column ends were designed to be fully fixed into the bridge slab and pad footings. The differential settlement was also considered when determining the final sizes of the bearing supports and pad footing. Once the final design details were made, the reaction forces from the bearing pads was provided to the Geotechnical engineers for the final MSEW design, in serviceability loads. Coordination between the design engineers took place during the detailed design phase with a few iterations being performed before the structural and geotechnical engineers were satisfied.

## 4 Construction

Construction began in July 2017 with the foundation preparation and the levelling pad for the alignment of the concrete panels (Figure 9). The construction team were trained in the installation of this type of MSEW as their background was concrete block retaining walls which made the QA/QC much easier for the engineers as they had knowledge of facing displacement, compaction and quality of backfill.

The construction was divided in two parts as the approach ramps were independent from each other. Originally the wall on one side was supposed to be longer, however due to the challenge of working in a fully operational airport with passengers and vehicles nearby, it was decided to postpone the construction of one stretch of wall as it would had interfered with the passenger drop and go access ramp. One of the challenges faced was planning the casting of the panels and the installation to complete one wall at the time. Unfortunately, the weather did not assist and a late delivery of panels become a challenge to the site. Further a usual benefit for such MSEW technology of having a big size face compare to the Concrete Block Reinforced Wall (CBRW) became a struggle given the small dimensions of the project, where the backfill could not come up to level as panels were missing. One of the requirements during the design was to ensure that no movement would take place once the bridge is placed as the walls are part of the entrance and the demands for the quality of the finishing was higher than other projects. As the backfill was very good a compaction of 98% mod AASHTO was easily achieved, however to ensure the compaction effort did not misplace the panels, 3 different compactions took place as shown in Figure 10. Near the face a hand compactor for 300mm, then a 1ton roller for 1m and then the normal 12 ton roller.

Figure 8. Foundation and levelling pad with first row of panels

Figure 9. Different compaction techniques used in the backfill

Compaction tests were carried by external laboratory using Troxler machine, confirming the compaction of the backfill at 98% mod AASHTO. Only in one occasion the backfill brought was rejected as the contractor in charge of bringing backfill used the incorrect borrow pit. Fortunately, there was no reinforcement straps beneath and it was removed and replace with approved source.

## 4 Construction

The bridge was officially opened in October 2017 as per programme of work. This wall represents the “bridge” between the traditional and innovative design which is achievable using geosynthetics technology. The benefits acquainted from the use of true bridge abutment were:

Staged construction enables the earthworks contractor to have full access to the site and able to plan his construction without the interference of any structural contractor which would have been challenging given the close interaction and the tight space

The construction time of the MSEW did not vary from the original scope as only the reinforcement got lengthen and stronger, therefore saving the time that the structural contractor would have taken to build the concrete structures.

A saving of 15% was achieved between materials as well as time and project management.

Although the type of MSEW chosen with concrete panels was not suited for such small work, the outcome overcame all the issues during the construction (Figure 11).

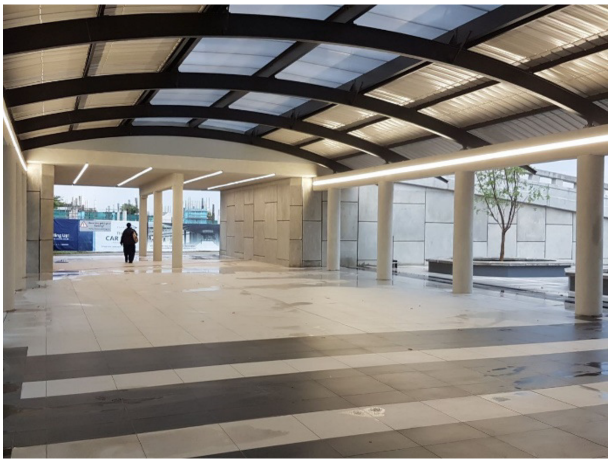

Figure 11. Project completed

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