# Design of an SMSE Retaining Wall on a Sidelong Slope in North Queensland

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ABSTRACT: Reinforced Soil Walls (commonly referred to as RSWs) can be an economical way of facilitating new road construction or widening of existing roads. For widening of existing roads on steep terrain, however, the design of an RSW becomes more problematic as the slope below the toe of the RSW gives rise to a bearing capacity reduction. This requires a wider reinforced block to distribute the pressures from the wall, which in turn can have an impact on the existing road as there are typically space constraints when excavating on steep terrain. One method of overcoming this is by designing a Shored Mechanically Stabilised Earth (SMSE) Wall. An SMSE wall consists of two parts; a soil nail wall/slope (shored section) and an RSW (mechanically stabilised section). The function of the soil nail wall/slope is to reduce/eliminate lateral pressures on the RSW block by stabilising what would normally be the retained ground or excavated and replaced with an RSW. The soil nails also contribute to the global stability of the SMSE wall system solution. A primary advantage of this method is that excavation into the existing slope is reduced due to the lower base width requirement for an SMSE. This paper discusses the permanent design and construction of an SMSE wall with a mechanical connection between the two parts for a project in North Queensland and the advantages of adopting the design.

## 1 INTRODUCTION

The subject of this paper is the design of a Shored Mechanically Stabilised Earth (SMSE) wall with 100 year design life as part of an upgrade to a highway in North Queensland, Australia. The project included the widening of the existing highway from 2 lanes to 4 lanes, construction of four bridges, numerous retaining walls, reinforced earth embankments and a large cutting. Due to the lack of alternative routes the highway was to remain operational at all times.

The proposed widening of the existing highway involved the construction of reinforced earth embankments and retaining walls on sidelong slopes of the Cardwell Range. The presence of a steep down slope at the toe of the retaining wall gives rise to a bearing capacity reduction, requiring a wider reinforced block to distribute the pressures from the wall. The impact on existing road users was a major driver in proposing an SMSE wall. A typical cross section of an SMSE wall is provided in Fig. 1.

The project required that design of RSW be carried out in accordance with Queensland Department of Transport MRTS06 and NSW Roads and Traffic Authority R57 (RTA R57). This requires that an external stability analysis be carried out with respect to, sliding, bearing capacity and global slope stability. Soil nail design was to be assessed in accordance with BS8006.

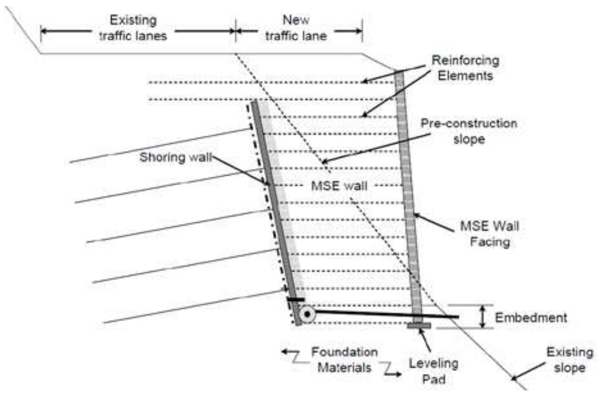


Fig. 1 Generic cross section of an SMSE wall. Drains outlet at the base of the wall (FHWA, 2006).

## 2 SITE DESCRIPTION

### 2.1 *Geological setting*

The site crosses the Cardwell Range and the location of the SMSE wall is on a steeply sloping side slope. The Cardwell Range is predominately composed of Carboniferous to Permian age igneous intrusions of hornblende-biotite adamellite, biotite granite, with subsequent deposition of the Upper Carboniferous Glen Gordon Volcanics described as massive rhyolitic to dacitic volcanic deposits with some andesite (hereby collectively referred to as rhyolite). These latter extrusive deposits have commonly been eroded away leaving intrusive rocks at the surface. The site is shown on Fig. 2.

Fig. 2 Setting of SMSE Wall (photograph taken near end of construction)

### 2.2 *Ground profile*

The geological model was based on the available geotechnical investigations as well as field mapping. The main components of the subsurface profile were considered to be:

- Existing Embankment Fill associated with the existing highway – up to 3m thickness.
- Colluvium and residual soil overlying extremely weathered material.
- Weathered Rock, anticipated along the entire proposed alignment underlying the fill and soil deposits.

There was little information available on the existing fill embankments and was typically described as dry to moist clays, sands and gravels at depths of between 0.1m and 3m with the occurrence of weathered granite cobbles and boulders. Such descriptions suggest that a cut and fill method may have been used to construct the fill with the fill being placed I a side cast manner.

These fill materials were overlying natural deposits of residual soil and extremely weathered material.

Residual soil forms the uppermost layer (beneath topsoil) across the vast majority of the site. It is typically underlain by extremely weathered material although the transition from residual soil to extremely weathered material is interchangeable over a thickness of approximately 5m.

The residual soil varies from a medium dense to dense sand, typically medium to coarse grained subangular to angular, orange to red, with some fine to medium grained subangular to angular gravel, and some medium plasticity clay. It is moist. The material is fairly uniform with no signs of reworking.

Due to the widening of the road to the east (downslope), fill, colluvium, residual soil and extremely weathered rock were all anticipated.

### 2.3 *Other considerations*

This site was also surrounded by National Park and the road corridor was consequently very narrow. This also made the SMSE wall a preferable option.

## 3 DESIGN METHODOLOGY

The geotechnical design consisted of the external and global stability of the wall. Internal stability was assessed by the RSW contractor (VSL) in consultation with Coffey. Design was required to be in accordance with the Geotechnical Design Standard for the project, MRTS06 and RTA R57. The Federal Highways Administration SMSE Wall Design Guidelines (FHWA-CFL/TD-06-001) and AS4678:2002 Earth Retaining Structures were used also. The wall was 160m long and between 7.9m and 12.2m in height. It was assessed at five chainages to cover the range of heights and ground conditions. The assessment was carried out under effective stress conditions for long term stability.

### 3.1 *External Stability*

External stability was assessed as per AS4678 (2002) Earth Retaining Structures. In accordance with the FHWA-CFL/TD-06-001 approach, sliding and overturning do not need to be assessed for SMSE walls and, provided the soil nail wall is appropriately designed, the effects of the earth pressure forces on the rear of the RSW walls for the bearing capacity check do not need to be considered. Settlement criteria were not stipulated in the Geotechnical Design Standard so an acceptable value of 15mm was adopted.

### 3.2 *Global Stability*

Geo Science's Slope/W 2007 with a Morgenstern Price Limit Equilibrium method and a circular failure mechanism was used and a target factor of safety (FoS) of ≤1.6 was stipulated. Soil nails were designed in accordance with BS8006. For the analyses, the global factor of safety has been calculated using the slip surfaces that pass through the heel of the RSW wall and into the underlying foundation, through the soil nails and using slip surfaces that pass behind the soil nails.

RTA R57 states that groundwater should be assessed at ground level in the design but this was considered over-conservative and, after consultation with the client, groundwater was assessed 1m below the interface of the colluvium and residual soil based on the actual conditions. Drainage was modeled almost full height at the back of the wall and outletting underneath the front face of the wall (see Fig. 1).

A crash barrier was located at the top of the wall and the impact load (500kN over a 12m length) and a 20kPa live surcharge load was designed for.

## 4 GEOTECHNICAL ASSESSMENT

The external stability was used to indicate the minimum RSW wall width, provided it exceeded the minimum recommended width of 0.6H as per RTA R57 (where H is the total height of the wall including embedment) and also the embedment. The global stability was used to determine the required soil nail support.

Initial assessment indicated external stability was not critical to the design. For global stability a FoS less than 1.6 occurred for a circular slip starting at the road surface, extending through the heel of the wall between the soil nailed section and the RSW steel straps and daylighting in the slope face beneath he embedment. Due to the loads and the size of the wall it was considered that the soil nails would have to be connected to the internal wall reinforcement to achieve the necessary global FoS.

To confirm this, support was then modeled as anchors with a free length from the back of the RSW part of the wall to the front face of the SMSE wall. This effectively modeled the restraining force from the bonded length (soil nailed section) working on the front face of the SMSE wall.

## 5 ENGINEERING A CONNECTION

The geotechnical assessment indicated that a connection between the shored elements (soil nails) and the mechanically stabilised elements (stainless steel RSW straps) was required. After consultation with the client, the RSW contractor and the structural designer a mechanical connection was considered the most appropriate solution considering the use of steel elements.

Several options were discussed with the following design requirements:

- must not have slack or require movement for load to be taken up;
- must meet the durability requirements;
- must have sufficient strength to resist failure.

The primary control was found to be durability due to the 100 year design life. The strength requirement was met as the loads were relatively small (less than that in the individual RSW straps). The only solution that was considered acceptable was complete encasement in concrete. This also removed the issue of load take up.

A design cross section through the connection is shown in Fig. 3.

The design connection consisted of cogged soil nails extended 100mm proud of the excavated face and then two layers of galvanised SL81 mesh with ‘C’ shaped loops connecting the two sheets of mesh at 350mm vertical and lateral centres. The RSW steel straps were extended through both sheets of mesh and bent and tied in place with tie wire. 40MPa concrete was then poured over the entire connection with a minimum 50mm cover of all steel elements.

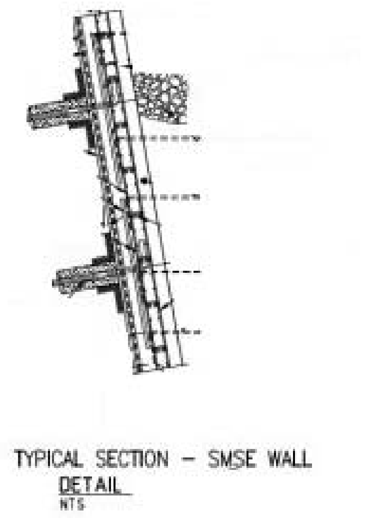


Fig. 3 Typical section of SMSE wall connection

## 6 CONSTRUCTION

Construction of the SMSE wall was undertaken in a ‘top-down’ fashion with soil nails and subhorizontal and strip filter drains installed as the excavation progressed. This reduced the risk associated with temporary works. Survey monitoring was also regularly undertaken to manage the risk of instability with a live highway at the crest of the excavation. A typical 2.0m maximum vertical height was excavated prior to soil nail and drain installation. The face was assessed by the geotechnical engineer for temporary stability and conformance with the design assumptions.

In the temporary case the soil nails were faced with a single layer of galvanised SL81 mesh tied to the nails with steel wire (tie-wire) and covered with a nominal 50-100mm thick layer of shotcrete. The subhorizontal drains and the cogged ends of the nails were extended through the shotcrete and the strip filter drains were extended as the excavation continued. This SL81 and shotcrete layer formed the temporary facing during construction.

Once the excavation reached the target depth the strip filter drains were extended out of the face and into a drainage slot that ran along the base of the excavated face and extended to the front face of the SMSE wall at 20m centres.

A minimum of 6% of the installed soil nails were acceptance tested to 150% of the working load as per MRTS03.

Once excavation was complete the foundation was assessed by the geotechnical engineer for conformance with the bearing capacity requirement.

The second layer of SL81 mesh was then affixed to the cogged nails with tie wire along the base of the excavation. The connection was then formed up to approximately 200mm below the level of the first RSW strap, the strip filter was checked to ensure it extended beneath the formwork and the connection was poured. The basal drainage was constructed as a minimum 300mm by 300mm trench infilled with geofabric wrapped clean single size 20mm aggregate that ran along the base of the excavated facenext to the connection incorporating the strip filter drains. This was extended to the front face of the SMSE wall at 20m centres with 100mm diameter subsoil pipes recessed and graded into the foundation to maintain positive drainage. Washouts were placed for maintenance of the 100mm diameter subsoil drains during the 100 year design life.

Once basal drainage was completed the first lift of RSW material was placed and compacted up to the level of the first straps. The straps were placed extending through the SL81 mesh and bent and tied in place. Formwork was placed and the next section of the connection (up to approximately 200mm below the next RSW strap) was poured. A period of 24 hours was left after pouring before compaction of the next lift of RSW material occurred.

The wall was constructed in 0.5m lifts, concurrent with the vertical strap spacing. With each lift the 300mm wide drain was trenched and extended to form a full height drainage blanket at the back of the wall. Care was taken to maintain the geofabric wrap around the 20mm aggregate. Durability of the stainless steel RSW straps was considered to be sufficient for the 100 year design life.

## 7 ADVANTAGES

Advantages of the SMSE design include:

- Allowed the temporary works to be utilised in the permanent works as the soil nails installed to support the live highway during construction formed the shored part of the SMSE wall (reduced rework increases efficiency and reduces time to complete the job).
- Reduced excavation into the hillside meant that the road could be kept open to traffic during the entire SMSE wall works (reduced traffic interruption on a range job).
- Not extending the footprint down the hillside meant that additional environmental approvals and stakeholder involvement was not required. It also meant that larger volumes of externally sourced RSW material were not required (cost saving for the project).

## 8 LESSONS LEARNED

The minimum RSW width is defined as 0.6H by RTA R57 (the design document specified by the client for this project) which relates to reinforced soil structures. The FHWA SMSE Design Guidelines, specific to SMSE, states 0.3H with the top two rows of RSW reinforcement at least 0.6H as shown in Fig. 4.

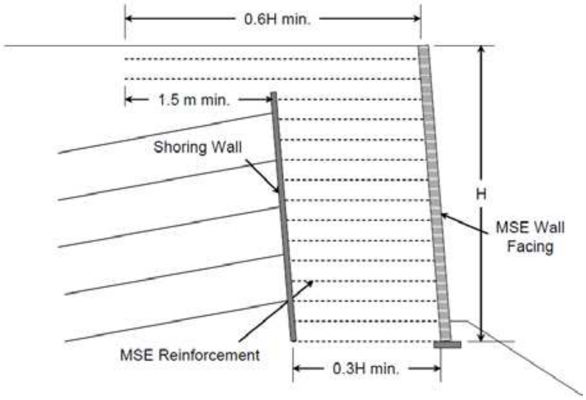


Fig. 4 Proposed geometry of an SMSE wall system (FHWA, 2006)

The RSW strap length was ultimately designed by the RSW contractor and this meant that reducing the wall width beyond the typical 0.6H adopted for an RSW requires detailed consultation.

## REFERENCES

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