The National Trust
Battlement walls
Wentworth Castle Gardens
Barnsley

Structural options **Job Ref 20340-Y-RP-005-R0**

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Conservation Approach

The adopted conservation approach aimed at minimising the harm to the architectural and historical significance of the collapsed section of the Battlement walls while addressing issues of long-term stability, drainage, sustainability, and public safety.

The materials and techniques chosen should attempt at minimum disturbance of the site, be compatible with the original fabric, require minimum maintenance in the future, and not compromise the historical character of the walls.

While respecting these guiding principles, the proposed solution should ensure structural and geotechnical stability and effective drainage of rainwater. In addition, continuity between the new retaining wall and the existing one should be maintained.

It is also important to emphasise the recommendation for monitoring and maintenance after the completion of works to address emerging issues promptly and prevent further deterioration.

Proposed solution

The proposed solution consists of soil nails for soil stabilization and to restrain the newly rebuilt dry-stone masonry wall on top of the existing bedrock. This is similar to the solution adopted previously on an adjacent section of the wall.

The stone wall debris will have to be carefully removed prior to works commencing which will allow us to determine the exact profile of the bedrock where the wall will be sitting. The ground behind the wall will be battered back to allow safe working and to provide a 70° slope to the soil. The zone of impact will extend up to 2m behind the wall.

Specialist soil design has been carried out by Byland Engineering. The soil nails will be driven into the ground in sequence to anchor the wall and provide lateral restraint. They consist of 32mm diameter hollow reinforcement bars drilled into the soil which are then injected with grout. Ground anchorage is reliant on the grout penetrating the surrounding strata. They extend

up to 5m from the facing and are inclined to minimise disturbance to the upper layers. The head of the soil nails is anchored to the soil facing through a stainless steel mesh and anchor plates.

In this case, the vertical and horizontal spacings are respectively 1.0m and 1.5m to provide the anchorage necessary to restrain the wall. If the spacing was increased and the total number reduced the potential load imposed on the soil nail would exceed its anchorage capability and cause instability to the soil and wall.

After the completion of the soil nails, the rebuilding of the dry-stone wall can be carried out in stages using the original stone blocks. As the wall is raised, a stainless steel mesh will be placed on the back of the wall which will be connected to the wall using stainless steel bent straps and fixed to the soil nails through clamped stainless steel bars. To ensure a good bond between the newly built wall and the existing one, alternate courses should overlap.

To address drainage issues, the wedge between the soil facing and the dry-stone wall will be filled with Type 3 aggregate surrounded with a Terram geotextile or similar, which will enable the water to percolate and reach the gravel fill with a perforated drain and the weep holes at the base of the wall.

Although the soil nails are a difficult solution to reverse, they will enable minimum disturbance to the site and excavation and are compatible with other solutions for the retaining wall. The combined solution of a dry-stone wall with a permeable backfill is fully reversible, if necessary.

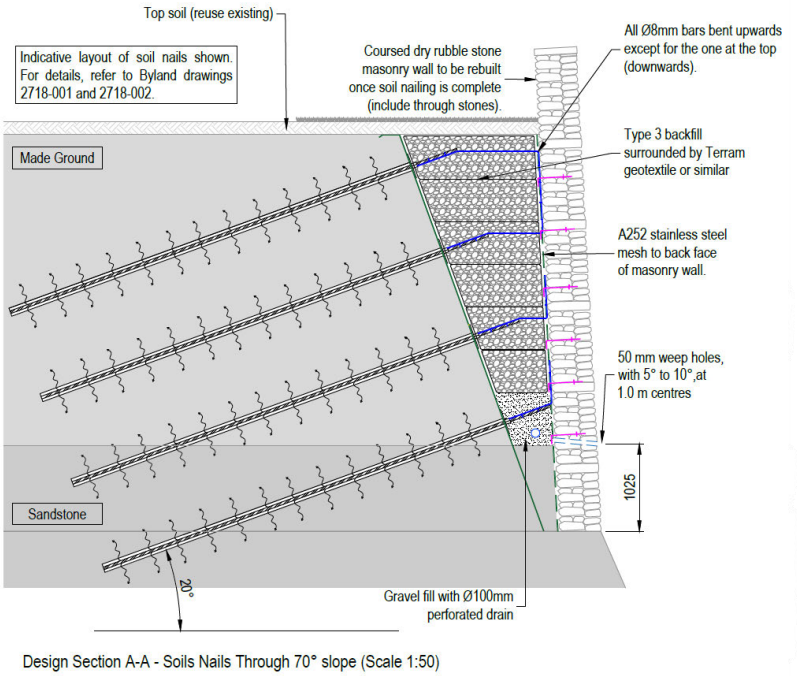

Fig. 1 Proposed solution with a combination of soil nails and dry-stone wall.

Alternative solutions

The solutions considered have to suit the specific project requirements and the conservation strategy. Common solutions such as reinforced concrete walls, concrete block walls or reinforced soil can be combined with stone-facing to ensure continuity with the original retaining wall. These would, however, have increased site impact with less respect for the original fabric and techniques, and be less sustainable.

A. Reinforced concrete retaining wall option

A common engineering solution to a new retaining wall would be a cantilever reinforced concrete wall. For a 5m height wall, reinforced concrete would be the most economical option, with an estimated stem thickness of 500mm at most. A non-structural facing of stone would then be provided to match the remaining intact wall.

The heel typically projects up to 2.0/2.5m for a 5m high wall. Allowing for 600mm of working space and a 60° batter to the soil behind, the overall construction extends up to 5.5m behind the wall.

This is clearly a high-impact solution in terms of site disturbance, significant excavation, and sustainability, and was rejected.

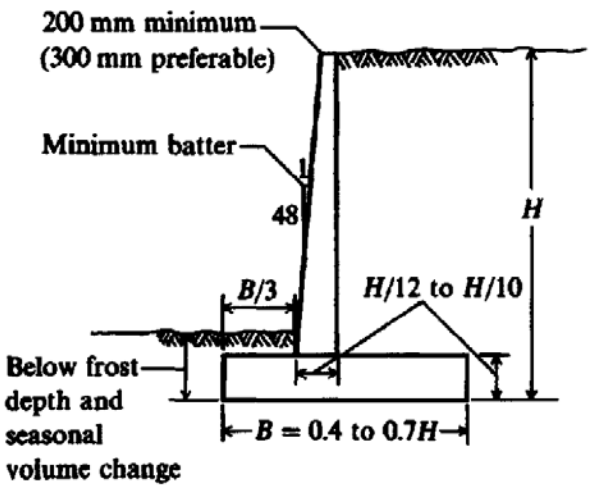

Fig. 2 Typical reinforced concrete retaining wall (Source: Joseph E. Bowles, Foundation Analysis and Design, 1996).

B. Reinforced soil with stone-facing option

A second option would be to reinstate the soil with geotextile reinforcement layers to allow the backfill material to act as a mass retaining wall. This would also then receive a non-structural stone facing.

For a 5m high wall, the reinforced "block" would need to extend a minimum of 2.5 to 3m. Allowing for a batter to the soil behind, the overall construction extends up to 5m behind the wall.

This option was also rejected due to the high impact in terms of site disturbance and significant excavation.

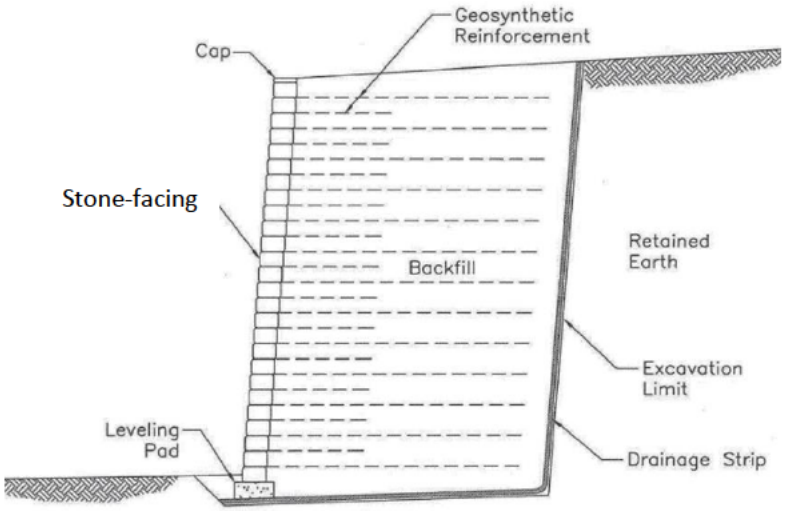

Fig. 3 Typical cross-section of a geosynthetic reinforced soil with facing (Source: https://www.fhwa.dot.gov/publications/research/infrastructure/10077/001.cfm)

Conclusions

We consider that the proposed solution of soil nailing, in combination with rebuilding the dry-stone wall will allow the new section to blend harmoniously with its surroundings, maintaining the visual integrity and continuity of the site while decreasing the risk of further collapse.

The proposed solution finds a good balance between geotechnical and structural stability, feasibility and the wall's significance, causing less site disturbance, ensuring continuity with the existing wall, and promoting the use of traditional techniques and materials.

The inclusion of permeable backfill, a perforated drain, and weep holes promotes a drainage system that will require less maintenance.

Alternative solutions would be more intrusive to the site, cause greater public disturbance, and be less sustainable in terms of excavation, material reutilization, and use of concrete.

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