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Soil Nailing on the A3 Hindhead Scheme – Meeting the Environmental Expectations

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ABSTRACT

The A3 Hindhead scheme completes the missing dual carriageway link between London and Portsmouth and comprises the construction of 6.7km of dual carriageway trunk road. As part of the 4.9km of surface earthworks over 8,000 soil nails were installed for both temporary and permanent works. Soil nailing was predominantly adopted as a method for steepening cut slopes thereby reducing landtake and reducing the environmental footprint and effects in a highly sensitive protected area. The varied nail location requirements dictated that a range of facings were adopted with slope angles varying from 45° to 90° for heights of up to 21m. This paper presents a case study of soil nailing in which environmental factors were key in both the choice of selecting a soil nail solution and the detailed engineering design of that solution.

Keywords: soil nailing, case study

1 INTRODUCTION

The A3 Hindhead scheme comprised the construction of 6.7km of dual carriageway trunk road which included a 1.8km twin bore tunnel. The 4.9km of surface works included three bridges, five underpasses, and 1Mm3 of earthworks to form cuttings, portals, embankments and reinforced soil embankments.

The Scheme was delivered on time and budget on behalf of the UK Highways Agency under a Design and Build contract by Balfour Beatty, with Mott MacDonald employed as the Designer. The estimated Scheme cost was £371M (~AU$576M) of which the construction cost is estimated as £275M (~AU$427M).

The project completes the missing dual carriageway link between London and the major south coast port of Portsmouth removing a major source of congestion in the centre of Hindhead. The project area is located on the Surrey/Hampshire border in the South East of England as shown in Figure 1. It is an environmentally important area within an Area of Outstanding Natural Beauty (AONB) with Site of Special Scientific Interest (SSSI) status. The area is heavily wooded and home to a number of protected species of flora and fauna. In addition, the area contains the local geographical landmark of the Devil's Punchbowl which the road scheme was designed to avoid impacting. Addressing environmental sensitivities was therefore key to the successful delivery of the Scheme. These environmental issues were at the forefront of concerns expressed during local public consultations and at the formal planning inquiry.

Due to the sensitivity of the local environment extensive use of soil nailing was included to steepen earthworks and thereby limit the amount of landtake and thereby retain existing habitat. Soil nailing was adopted at a number of localities for both permanent and temporary situations resulting in approximately 8000 soil nails being required. The soil nailing was undertaken as a sub contract by System Geotechnique (now part of the Keller Group) between 2007 and 2010.

This paper presents a case study of soil nailing in which environmental factors were key in both determining the strategic use of soil nailing and subsequently the engineering nail design. It is such environmental factors that increasingly impact upon engineering design and construction to provide sympathetic and sustainable solutions. There was concern that whilst attempting to minimise one environmental concern to minimise the construction footprint, the eventual construction could result in a separate environmental aesthetic impact. Significant effort was expended to address both of these concerns.

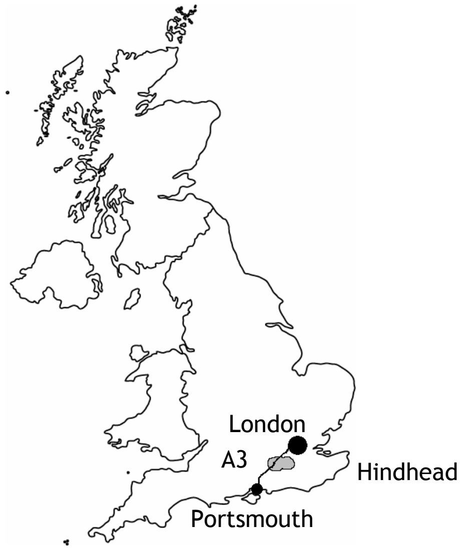


Figure 1 A3 Hindhead Site Location

2 GROUND CONDITIONS

The Hindhead area is situated upon the Hythe Beds which form part of the Lower Greensand Group of the Cretaceous. The strata predominantly comprise of glauconitic medium dense to dense silty sands interbedded with very weak to weak sandstones. At the base of the sequence they become increasingly finer grained with silt and clay interbeds becoming frequent, before passing into the underlying Atherfield Clay. Throughout the succession there are thin beds of strong chert and Fullers Earth of stiff to hard fissured clays. The main environmental influence of these strata was the acidic nature of the quartz sand which restricted the suitability of flora. Other design implications were related to the lack of precedent soil nailing experience in these particular materials, the potential for drill hole instability in granular materials, potential nail misalignment due to extreme strength variations of the interbeds, and the corrosive effect of the acidic conditions.

The groundwater table is typically found at significant depth forming an unconfined aquifer of limited thickness overlying the Atherfield Clay aquitard. The aquifer is locally important as it provides potable water for the local community. Given the depth of the aquifer though the main environmental design concern was the potential for desiccation of the soil during summer months and the impact upon the landscape.

3 DESIGN APPROACH

3.1 General

Nail design was undertaken to the requirements of the UK Highways Agency design manual HA68/94 supplemented where required by additional guidance including BS8006, PrEN14490:2002, FHWA & Clouterre. Ultimate limit state analyses were undertaken using the computer program Talren. The required nail design life was typically 60 years for permanent slopes and 5 years for temporary slopes although a section of soil nailing integral to an overbridge structure required a design life of 120 years.

The global stability analyses resulted in a range of nail bar requirements with primary steel nails varying from 6m to 10m in length with diameters from 20mm to 28mm. Vertical spacing was typically 1.5m and horizontal spacing varied from 1m to 2m. Secondary nails, provided only for face support, were smaller at 3m length and 16mm in diameter. Closer nail spacings were required for the steeper slopes and those with extended design life requirements. Face plate sizes varied from 250mm to 400mm square typically increasing with slope height and angle.

3.2 Facing Design

Due to the range of gradients, finish requirements and the temporary or permanent nature of the slopes there were a range of different face support designs. These were adopted as follows:

- Flexible facing comprising of hexagonal plastic coated wire mesh was adopted on permanent slopes with a maximum slope of 45° that required a vegetation finish. A minimum diameter of 2.7mm plastic coated mesh was specified.

- Flexible facing support comprising rigid steel mesh was provided on permanent slopes with a slope steeper than 45° that required vegetation finish. British Standard (BS4483:2005) reinforcing mesh types used depended upon the design requirements at a specific location and included A252 and B1131 mesh types.

- Hard reinforced sprayed concrete was provided on both temporary slopes, and permanent slopes where an aggregate finish was to be adopted, on slope angles from 60° to 90°. Standard mesh types used depended upon the design requirements at a specific location and included British Standard A142, A252 and A393 mesh types. The sprayed concrete varied in thickness from 100mm to 200mm with the reinforcement fixed using spacers approximately at mid layer thickness.

The hard sprayed concrete facing was designed to the methods provided in the FHWA guidance document and face plates designed using HA68/94. There is however no definitive published guidance on appropriate methods for the design of facing support in flexible facings. In order to address that an internal spreadsheet based design methodology was developed to assess potential lateral loads acting between nail heads. In order to provide independent verification of the design approach a three dimensional numerical model using the finite difference program FLAC, was developed to assess the slope deformations and loads associated with the proposed design.

3.3 Permanent Works

The calculated long term design stable slope gradient was 1V:2H (26°) which was corroborated by geomorphological mapping of natural slopes in the area. With a requirement to construct permanent highway cuttings in excess of 20m below existing ground level the adoption of that design gradient would have resulted in an earthwork cutting corridor approximately 100m in width in places. In order to preserve the natural landscape and woodland setting, soil nailing was adopted in order to provide steeper slopes than would otherwise be possible. However, in order that the design did not become overtly engineered a number of compensatory features were included to make the designs aesthetically acceptable within the local rural setting. This was a key issue at the planning inquiry without which permission to proceed could have been delayed.

Wherever possible an overlying unreinforced cut slope, typically of gradient 1V:2H (26°), was included in the cut slope profile in order to provide a composite slope profile to reduce the engineered appearance to the slopes. This profiling approach also had a number of beneficial design advantages. It prevented the need to undertake soil nailing in loose superficial colluvial deposits within which nail bond strengths were expected to be low, and therefore, nail efficiency limited. The adoption of an upper lower gradient slope also creates a greater area for rainfall catchment for runoff to maintain the moisture content in the topsoil in the steeper underlying slope and therefore contribute to a sustainable vegetation cover.

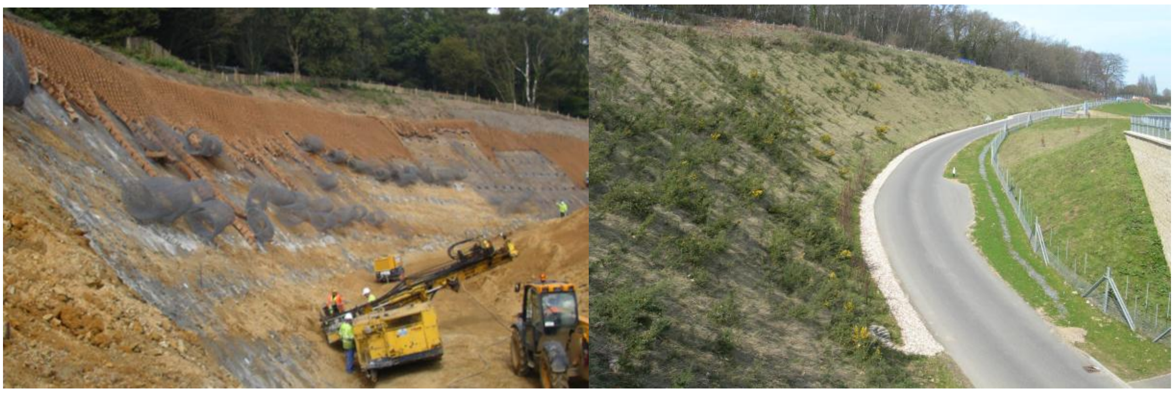
The final designs were also to be aesthetically sympathetic to the local environment and wherever possible a soft landscaped vegetation finish was provided. In order that the eventual vegetation was sympathetic to the local environment a pre-construction seed harvesting programme was undertaken to enable local plant species to be included within the construction seed mixes.

The successful development of a vegetation cover on steep slopes is known to often be problematical. A series of inspections of engineered steep slopes on motorway cuttings using different landscaping systems was undertaken to identify positive and negative factors associated with sustainable vegetation development on steep slopes. Where possible two series of inspections were undertaken in winter and summer to inspect the seasonal variation in vegetation development. The inspection team included both geotechnical engineers and landscape architects to ensure that a wide range of relevant factors were considered.

The inspections, product literature and published guidance suggested that the maximum sensible slope angle at which a long term vegetation cover could be sustained on significant sized slopes was 60°. Evidence of successful steeper slope angles on smaller slopes was observed but the 60° criterion was adopted as a maximum angle for use on the higher slopes for the Hindhead project. Soil nailed slopes steeper than 60° were used on the project but they were constructed with a hard facing where a permanent vegetative finish was not required.

The inspections clearly indicated that vegetation was more healthily established where the slope finish included a layer of topsoil above the cut profile. Examples of cut slopes where hydroseeding applications had been applied directly to a cut slope surface, with or without, a polymeric form of runoff erosion protection, were generally poor. As a result of the study two different types of topsoil retention systems were adopted depending upon the angle of the cut slope.

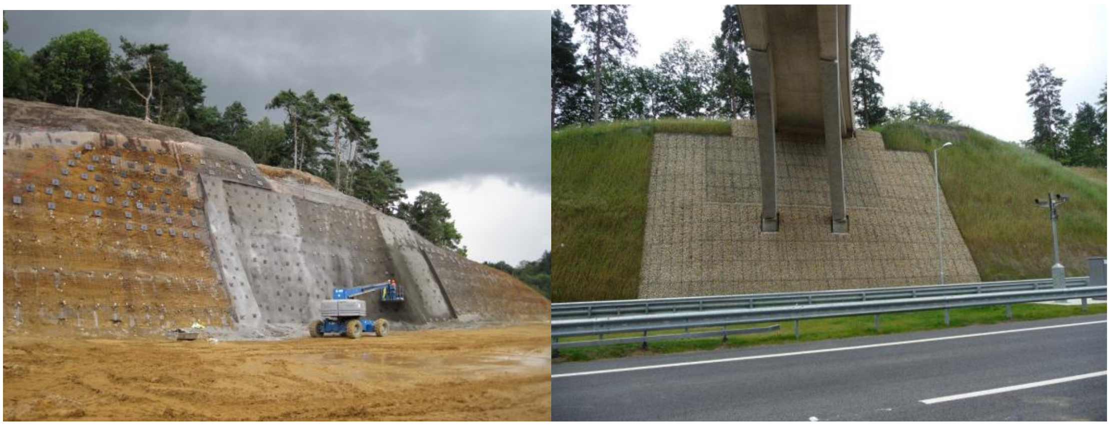
For slope angles up to 45° a topsoil cell retention system was specified. These comprise of connected hexagonal cells of varying depth and size that are pinned to the slope and filled with topsoil. There are a number of these systems available manufactured in different materials, cell sizes, depth and colours. At Hindhead a product was used which was available in a range of depth sizes to suit the range of topsoil thickness's, between 100mm and 300mm, required to support the different landscaping planting requirements. An example showing this solution both during construction and on completion is provided in Figures 2 and 3. This example is a 10m high 45° soil nailed slope.



Figures 2 & 3 – Blackhanger Cutting 45° flexible facing during construction, and post construction

As the topsoil within each cell tends to a longer term stable angle of repose there is a risk on very steep slopes that the top of the cells may lose their topsoil infill with time. This not only exposes the hexagonal cells but also isolates the topsoil infill between adjacent cells leading to increased desiccation and plant die back. For slopes steeper than 45° therefore a different form of topsoil retention system was adopted comprising of soil panels. That system comprises of steel mesh panel cages that can be supplied to retain different thicknesses of topsoil up to 500mm.

Whilst the soil panel system was adopted primarily for the development of vegetation on steep slopes it can also be backfilled with aggregate. That alternative was adopted at two locations on the project where permanent slopes steeper than 60°, or in rainshadow locations which were not considered conducive to a vegetation finish. The aggregate was a light brown coloured calcareous sandstone which was chosen to be aesthetically sympathetic to the local geology. An example showing this solution both during construction and on completion is provided in Figures 4 and 5. This example is a 18m high 60° soil nailed slope with both vegetation and aggregate as a finish.



Figures 4 & 5 – Miss Jame's Bridge 60° cutting rigid and hard facing during construction and post construction

3.4 Temporary Works

The main temporary works on the project involved the construction of two cut and cover portals for the twin bore tunnels. These required cut depths of up to 30m below existing ground level both within densely wooded hillsides. There was therefore a strong direction to minimise excavations to retain the natural vegetation rather than adopt wider temporary cut and cover works with landscape planting on completion. In these areas the temporary nature of the slopes meant that steeper profiles could be adopted and use made of stiffer sprayed concrete facings. Slope angles were typically set at 70° rising to 90° at the tunnel excavation face to facilitate subsequent cast in-situ portal hood connection. Where the vertical faces were to be excavated for the tunnel construction glass fibre soil nails were adopted to facilitate ease of excavation. The glass fibre nails being weaker than steel required a larger diameter of 31mm, longer length of 10m and a closer spacing at 1.0m horizontally and vertically. Figure 6 shows the temporary north portal.

Figure 6 – North portal temporary soil nailed slopes

3.5 Composite Soil Nail/Reinforced Soil

At the cut and cover portals the subsequent infill of the temporary excavation required the construction of steep reinforced fill slopes to achieve the required final appearance. Given the desire to limit the extent of cutting during the temporary works there was insufficient space to fit the required design lengths of geogrid reinforcement. A composite reinforced slope design was therefore developed that included geogrid reinforcement within the fill connected to the soil nails installed within the temporary cut slopes. A load transfer bar system was provided to the nail heads to which the geogrid could be connected and a uniform load distribution achieved between the two reinforcement systems. The system was designed to be flexible to be able to accommodate variations in nail head locations in the horizontal plane to prevent difficulty during construction.

4 CONSTRUCTION EXPERIENCE

During construction it was found that the junction between the two slope gradients created localised enhanced erosion and a local detail using biodegradable erosion matting was required. Problems were also encountered filling the soil panel system where an irregular cut slope profile created voids behind the attached structural facing mesh. Overfilling of retention cells with topsoil also created the potential for localised shallow slumping of topsoil during wet weather. Whilst these issues were not of a significant stability concern they did affect the visual appearance and potential for increased longer term maintenance. These issues were identified and resolved promptly due to the presence of a site geotechnical engineer who was familiar with both the environmental design philosophy and the structural stability requirements.

5 CONCLUSION

The A3 Hindhead project successfully demonstrated that soil nailing can be used to achieve environmental benefits and deliver a constructible engineering design whilst also addressing aesthetic appearance concerns. A significant effort was expended in assessing environmental options to provide design solutions to meet the project commitments. The inspection of existing constructed cuttings proved invaluable in informing and determining the design approach. Where constraints lead to design requirements that resulted in a reduced level of confidence that a vegetation solution could be provided an alternative aggregate solution was adopted. The successful outcome was also the result of close cooperation throughout from geotechnical designers, landscape architects and the contractor to ensure that the schemes were stable, aesthetic and constructible. At the time of opening the majority of the engineered slopes had developed a significant vegetation cover providing not only a good first impression of the project for the public, but also reducing the immediate potential for slope erosion and degradation.

6 ACKNOWLEDGEMENTS

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