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A2/M2 Widening : The use of geosynthetics for reinforced slopes

S. P. CORBET, Maunsell Ltd.
J RIGBY-JONES & M NAYLOR, W.S.Atkins Ltd
D.PATTERSON, Highways Agency
P BOULTON, CSM JV.

ABSTRACT: The widening of the A2/M2 trunk road/motorway in north Kent runs from Cobham at the west end across the River Medway on a new bridge to junction 4 of the M2 south of Chatham. The work involved constructing a new 4 lane carriageway alongside the existing 2 lane dual carriage way, the new carriage way carries the west bound traffic. The space available for construction was restricted in a narrow corridor in which the new high speed Channel Tunnel Rail Link (CTRL) has also been constructed. The new works included nine geogrid reinforced soil slopes with wrap around green face slopes with finished heights up to 16m. This paper describes the selection of materials, the design and construction of these reinforced slopes

1. INTRODUCTION

The route of the A2/M2 Widening is shown on Figure 2 along with map of the UK to locate the project, Figure 1. The scheme, which is described as running from west to east (London to Dover), starts about 7 km west of the River Medway, crosses the Medway Valley on a new bridge and follows the route of the existing M2 motorway for another 9 km. Due to constraints imposed by the presence of the existing A2 Trunk Road, the existing M2 Motorway and the new high-speed railway linking the Channel Tunnel with London (CTRL), which is runs just to the south of the widened motorway before the CRTL turns south under the North Downs in a tunnel about 3 km east of the Medway.

The new works were constrained by these features which in many areas made it impossible to construct conventional earthworks with stable slopes. The project was further constrained by a core environmental requirement in the specification that as much of the finished work should be vegetated to give a green appearance in order to avoid vertical concrete surfaces and stark bare white chalk faces in the cuttings.

Figure 1. Map of UK the Site Location

This combination of constraints made the use of steep geosynthetic reinforced soil slopes an economical solution at a number of locations. The underlying strata for much of the route is Chalk, therefore much of the fill won from excavations on the site are Chalk.

The basis for the project is as a Design and Build contract, with a requirement that all parties involved in the contract work as ‘partners’. The concept of ‘partnering’ being intended to avoid some of the normal conflicts which can develop in conventional contracts, to also allow ideas which will benefit the project to be considered. The parties involved in the project are listed in the acknowledgements at the end of the paper

2. THE REINFORCED FILLS

Nine sections of reinforced fill have been constructed using the wrap around face method of construction

Table 1. Description of the Reinforced Fills

Structure Ref	Description & Purpose	Height (m)	Fill Type
S64 Knights Place	Toe of Embankment –to avoid diversion of watermain	6.2	Chalk, Thanet Sand
S52(on) Merrals Shaw	Support to new M2 above slip road, part soil nailed	10.0	Sand & Gravel sea dredged
S52(off) Merrals Shaw	Support to new M2 above slip road, part soil nailed	10.0	Chalk
S62 Shakehole	Support to M2, between rail bridge and new Medway Bridge	6.9	Sand & Gravel sea dredged
SFF Factory Farm	Support to M2, adjacent to waste filled quarry and CTRL	15.9	Chalk
S63 Wouldham	Support to M2 to minimize land take	2.8	Chalk
S16 Borstal Court	Support to M2 to allow const. of new local access road	13.75	Chalk, Thanet Sand
S18 Stoney Lane	Safety Bund to prevent vehicles leaving the road	3.0	Sand & Gravel sea dedged
S46 Lord Lees	Along side A229, to allow access at crest to be maintained, part soil nailed	7.0	Sand & Gravel Crushed Conc

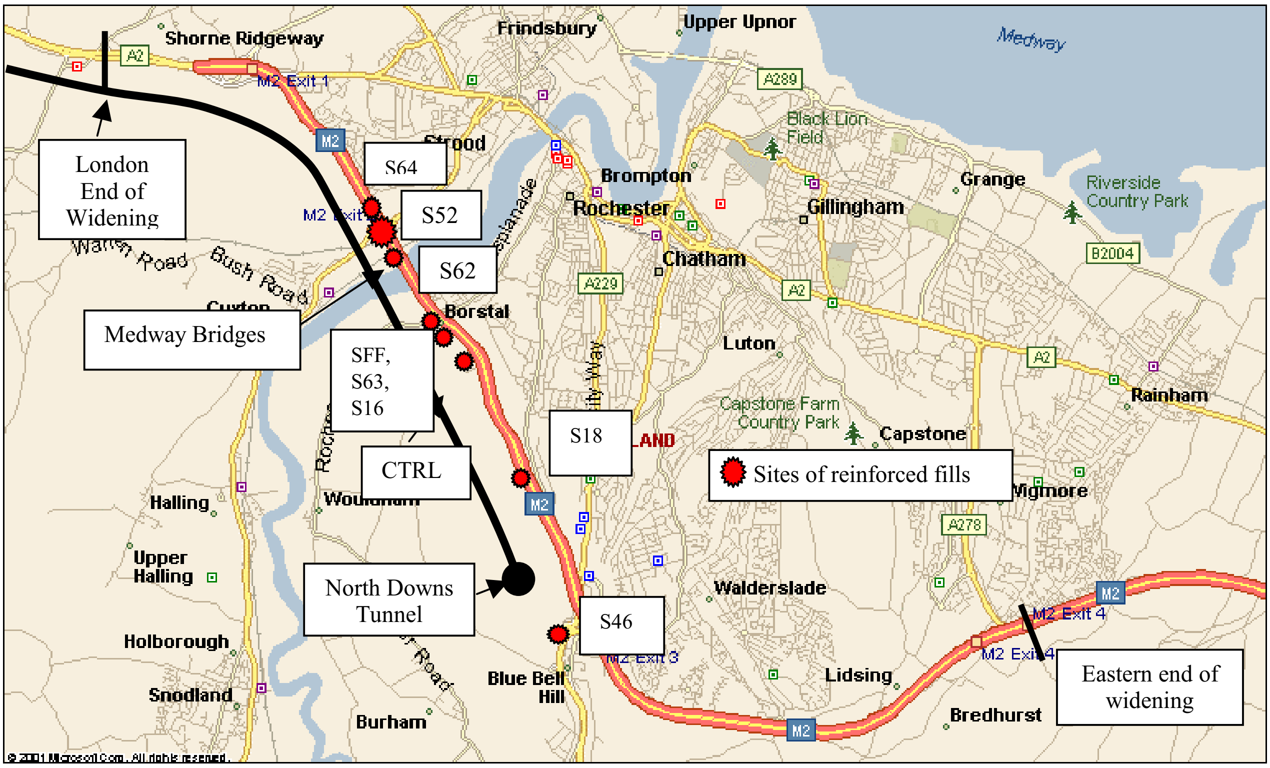

Figure 2 Site Plan

All reinforced fills have been constructed using PVC coated polyester knitted geogrids, with a variety of fills which have been tested for compliance with the Specification for Highway Works (SHW), Class 6I and Class 7C

The reinforced embankments, the fill materials used and the geogrids are described in Table 1. The principle dimensions, height, length and the length of the geogrid layers are described in Table 2.

Table 2. Soil Reinforcement Details (all 0.5m vertical spacing)

Structure Ref	Characteristic Strength (kN/m)	No of Layers (No)	Length of Layers (m)
S64	80	3	15 to 8
	55	4	
	35	6	
S52 (on)	110	2	10.5 to 4.5
	80	5	
	55	5	
	35	4	
S52(off)	110	2	10.5 to 4.5
	80	5	
	55	5	
	35	4	
S62	80	7	8.7
	55	4	
	35	4	
SFF	80	9	16
	55	15	
	35	8	
S63	55	3	3.75
	35	4	
S16	80	9	19
	55	15	
	35	8	
S18	35	5	Twosided
S46	80	3	8.5
	55	5	
	35	6	

The fill materials were, when ever possible, soils which had been won from the site or from nearby sources to minimize the amount of material imported to the site. One of the main site won materials was Chalk, a soft calcium carbonate rock, found extensively in South East England. Chalk is very variable and breaks down if handled roughly or if over compacted. The harder Chalks can be considered as frictional fills but the weathered soft Chalks which need extremely careful handling behave more like cohesive soils. The Thanet Sand is a very silty fine sand which is found geologically above the Chalk, provided Thanet Sand is kept dry it can be placed successfully in most reinforced structures.

3. METHOD OF DESIGN AND DETAILING

The designs were prepared in accordance with the contract requirements, that the design of strengthened earthworks be designed in accordance to the provisions of The Highways Agency's Design Advice Note HA 68/94 (HA 68/94). HA 68/94 was followed to the end of Section 1, where the Designer has a choice of either following the design methods given in the Annexes or 'using any other method with which the Designer is satisfied will give a safe design'. In this case the Designers choose to use Jewell's charts (Jewell) with the partial factors given in Section 6 of BS 8006 (BS 8006) and the partial material factors set out in the BBA certificate applicable to the geogrids selected for the project (BBA).

The basic Jewell's method was considered to be applicable to the design cross sections as in all but one case there is ostensibly flat ground at the crest of the reinforced soil blocks and the use of uniform loads converted to equivalent additional height was not a significant problem. The implementation of the Jewell's charts was through a spreadsheet provided by the geogrid manufacturer, which allows the internal stability to be analyzed and the basic geogrid layout to be determined at constant vertical spacing. The spreadsheet program has been subjected to verification by both W S Atkins and

Maunsell to ensure that the design layouts are correct to the theories being applied.

The external checks on overall rotational stability, sliding and bearing capacity of the foundations were checked outside the spreadsheet using other conventional methods of analysis.

Most of the reinforced slopes have been detailed with the face slope in one single plane from base to crest, but at Factory Farm and Borstal Court, where the slope height is up to 15m, the face is split into a series of 5m high slopes with a 2m wide bench between each. The benches serve two functions : the first is to provide access for maintenance and repairs, the second is to allow these flat areas catch any rainwater which is allowed to soak into the fill to help maintain the vegetation. Figures 3 and 4 show typical cross sections through the two types of reinforced slope used on the project.

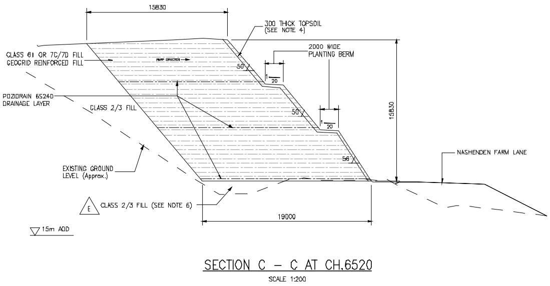

Figure 3 Section of Reinforced Slope S16 – Borstal Court

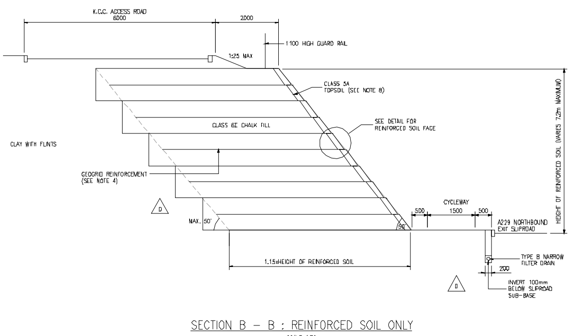

Figure 4 Section of Reinforced Slope : S46 - Lord Lees

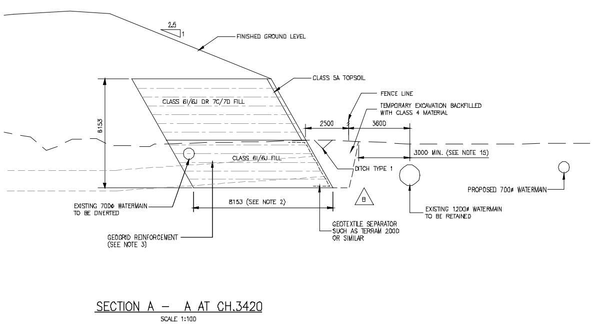

Figure 5 S64 Knights Place Reinforced Slope with Water Main at Toe

4. DESIGN LAYOUTS AND FILL PROPERTIES

The internal design calculations made using the methods described previously were based on the properties of the geogrids provided by the manufactures, the characteristics of the fill soils were based on initial estimates of the properties. During construction samples of the actual soils were tested to confirm or check that the design parameters had been achieved. The results of these tests are presented in Table 3 along with the details of the geogrids used in each slope.

Table 3. Fill Properties

Structure Ref	Fill Type	Design Para (ϕ')(degrees)	Measured Paras (ϕ') (degrees)
S64	Chalk	35	29.4
	Thanet Sand	35	38
S52(on)	Sand & Gravel	30	48
S52(off)	Chalk	28	29.4
SFF	Chalk	30	29.1 (c':4 kPa)
			33.6 (c':11kPa)
S63	Chalk	30	29.1 (c':4kPa)
			33.6 (c':11kPa)
S16	Chalk	30	As S63
	Thanet Sand	30	38
S18	Sand & Gravel	30	48
S46	Sand & Gravel	30	48
	Crushed Conc.	30	45

The results of the site tests on the fill materials generally show that the design criteria were achieved. The reinforced slope S64 Knights Place, was constructed using Chalk fill which has a measured shear strength of only 29.4° while the design requires that the shear strength is 35°. The design of the reinforced slope was reviewed and as the full height of the slope is only exposed in an extreme event, (a wash out of the fill which covers the toe of the reinforced slope if the water main at the toe bursts), reduced factors of safety were accepted for this event. The normally exposed part of the reinforced slope was shown to be stable with the normal partial factors applied to the fill and the geogrid. Figure 5 shows a section through the S64 Knights Place reinforced slope

5. CONSTRUCTION OF THE STRENGTHENED SLOPES

The strengthened slopes were constructed using the conventional procedures with a climbing front face form to maintain a good alignment during construction. At each layer the face was stepped back by 50mm to provide some areas for the retention of rainfall to help irrigated the face vegetation. Behind the face geogrid a layer of hessian was placed to retain the topsoil which was laid and sown with seed as each layer is placed.

The fill is placed in layers over the geogrid with each layer compacted as specified in Table 6/1 and Table 6/3 of the Specification for Highway Works (SHW). The use of Chalk fill in reinforced soil fill is not common in the UK. Chalk can be difficult to manage due to its sensitivity to small changes in moisture content and over compaction. The SHW normally prohibits the use of Chalk which has been previously excavated, from being reused as structural fill, and sets a upper limit on saturated moisture content (SMC) of 20%. However to minimize the disposal of this material either offsite or into landscape areas additional testing was carried out in order to justify relaxations to the SHW. Additional shear box testing of the chalk fill at a range of compacted dry densities demonstrated that acceptable angles of internal friction could be obtained at elevated values of SMC and the SHW limit was relaxed to 29%. Additional quality control testing of the chalk fill during placement was also carried out to ensure that the compacted densities obtained correlated to the required design value of effective angle of friction. Chalk for the reinforced fill came from several sources, some was won as fresh Chalk, material which had been excavated from the CTRL North Downs Tunnel, Chalk previous placed in an access ramp from the M2 to the CTRL site and Chalk from the temporary ramp used to launch the CTRL Medway Bridge. Most of these sources yielded good quality Chalk which when tested showed a good degree of compaction, there were some areas the Chalk fill became very soft when compacted, indicating that the moisture content was too high. In these areas the soft Chalk fill was either removed or left to dry out, (as it drains well and gains strength very quickly if left).

Construction of the Lord Lees (S46) and Merrals Shaw Off Slip (S52) slopes were particularly interesting due to the topography and geology it was advantageous that some parts on the slopes were strengthened with soil nails rather than with geogrids. This minimised the amount of soil to be excavated and fill to be placed, but required some ingenuity to develop facing systems which would allow the two types of strengthening to merge together. Figures 6 and 7 show the Lord Lees slope during construction and just after completion

Figure 6 Lord Lees Reinforced Slope – Showing Construction of Geogrid Layers

Figure 7 Lord Lees Reinforced Slope – Completed face with soil nailed section in centre of picture.

6. CONCLUSIONS

The use of strengthened earthworks have allowed this project to be realised within tight physical and environmental constraints. The principle advantages which all members of the project team have made use of include:

- Quick to construct
- Environmentally effective – green vegetated faces
- Flexible – some complex shapes have been formed, can be partly completed to allow other works to proceed – as at Factory Farm
- Use of a wide range of fills from different sources has allowed the construction team to maximise the use of site won material and other available materials as fills.

The use of the strengthened soil slopes was evaluated through Value Management and Value Engineering process before design and construction, these process confirmed that the use of geogrid reinforced strengthened spoil slopes were the most effective solution in each case.

7. ACKNOWLEDGEMENTS

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