THE DESIGN AND CONSTRUCTION OF A LARGE SCALE NOISE BARRIER IN REINFORCED SOIL AT BRUSSELS INTERNATIONAL AIRPORT, BELGIUM.

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ABSTRACT: The village of Steenokkerzeel has suffered for many years from increasing noise from the growth of Brussels International Airport. The village is on the direct line of, and very close to the main runways and so within a relatively narrow area of land, the Belgium International Airport Company decided to construct a 15 m high sound barrier. The concept, prepared by the Company, was an asymmetrical reinforced soil barrier, more than 510 m in length. A particularly interesting feature was that the bund had to be used to dispose of a large quantity of contaminated soil, within the bund, wrapped in a geomembrane. Owing to radar reflection problems from steel inside concrete, the side of the bund facing the airport was to be less steep and vegetated, whilst the side facing the village could be steep and constructed of concrete panels. Aertssen nv obtained the construction contract and retained Prof. Rankilor to design the structure; Frans De Meerleer arranged for the cutting and provision of the geotextiles, as well as the geocell constructions; Dr. Jaecklin designed the facing elements to fit the main design and collaborated with Prof. Rankilor to develop the linking interface between the textiles and the concrete elements; Monika De Vos developed, installed and monitored instrumentation to measure stress and strain on the reinforcing geotextiles; Serge Vandemeulebroecke and Frank De Bossuyt undertook a comparative analysis of the design using the Plaxis finite element program using theoretical and measured data, and Willy Fransen was responsible for the difficult task of constructing a structure which became increasingly narrow with time.

Keywords: airports, barrier, geotextiles, monitoring, performance evaluation.

1 INTRODUCTION

1.1 *Background to the need for a sound barrier*

The village of Steenokkerzeel lies very close to the main runways of Brussels International Zavantem Airport. It also lies more or less on the direct line of the runways. The noise level is very high and has been increasing steadily over the years. International flights leave during both the day and night.

1.2 *Proposed solution*

The Zavantem Airport Authority's engineers drew up a scheme for the construction of a long and high noise barrier to protect the village. In fact, there are two more similar barriers planned in addition to the subject barrier, to protect other parts of the periphery from noise pollution. The airport engineers put together a proposed design outline, involving the use of geosynthetic soil reinforcement and concrete facing elements.

In addition to protecting the village from noise, the barrier was to be used for another purpose. On the airport land there was a large stockpile of soil which had been contaminated with fuel, oil and mostly other hydrocarbons. The engineers decided that this soil should be buried within the bund. The initial scheme involved the construction of a long 'sausage' of high density polyethylene geomembrane with the polluted ground within.

2 DESIGN AND CONSTRUCTION CONSTRAINTS

2.1 *Land area available*

The airport had been constructed very close to the village and so the width of land between the end of the runways and the village was extremely limited. Further, there existed a plan to construct a highway between the village and the airport, which took up a valuable piece of the available land. The design arrived at was that, again to protect the village from noise, the road would run on the airport side of the new barrier. The sequence would thus be airport, road, barrier and village.

2.2 *Radar problems*

The airport uses radar transmissions to track and control the location of aircraft in its vicinity. Erroneous reflections of the radar cannot be tolerated. Therefore, it was specified that the side of the barrier facing the airport should contain no steel. Thus reinforced concrete would not be permissible. To meet this criterion, the airport face had to either be steep reinforced soil restrained by wrap round or a more gentle slope that could be left free standing and vegetated. The scheme envisaged the latter, because of the known difficulties of establishing reliable vegetation cover on steep slopes – especially on isolated elevated structures unable to absorb ground water from natural sources.

On the village side, there were no radar constraints and so a steep slope of approximately 1vertical:4horizontal was proposed, using large scale reinforced concrete facing units. From the start, it was considered that Evergreen facing units would be ideal since they have been used for many similar projects in many different countries.

2.3 *Changing cross-sectional geometry*

The sound barrier, having slopes on both sides, became narrower towards the top, as shown in Figure 1.

Figure 1. Cross sectional sketch of the sound barrier.

It can be seen that the airport slope is more gentle at 1v:2h and the village slope with the concrete elements is at 1v:4h. This asymmetrical geometry causes problems with both the basic design of the reinforced soil and slip circles, and the specification and supply of the geotextiles.

In the first case, the design of the barrier is a non-standard design. There were no published design procedures for such structure. Therefore, the design had to be undertaken in several steps to allow for the unusual geometry.

Secondly, every layer of geotextile was a different length from every other. This means that particularly careful drawings had to be created showing each layer in accurate dimensions so that a detailed quantity list could be made up. The contractor asked the geotextile supplier to provide the rolls each pre-cut to the required length so that there would be no site cutting and no onsite wastage.

Drawings were converted into large spreadsheets and the calculation of quantities made accordingly.

2.4 *The unavailability of high quality construction materials*

There were limitations on the availability of good quality sand for the construction of the embankment. Further, the contaminated soil which had to be enclosed within the bund was of a very poor physical quality also. This made the design of the contaminated 'sausage' more than usually difficult.

2.5 *The incorporation of the contaminated 'sausage'*

The particular problem here was connected with the fact that the 'sausage' was to occupy such a large part of the interior that it interfered with the standard or required design lengths of the geotextiles. Also, there was the potential problem of the 'sausage' creating preferential slip surfaces within the barrier, thus causing instability of a non-standard kind.

2.6 *The incorporation of a structural barrier on top*

It was specified by the Authority that there would be a 2 m high light structural barrier on the top of the crest, to act as an additional visibility warning device for aircraft, but to have minimal resistance in the event of impact. This conflicted with the wind resistance requirements which were quite arduous, since the bund formed a substantial wind barrier.

2.7 *The presence of a high water table*

Across the site the water table level is just below the surface during normal weather conditions. During periods of high rainfall, it is possible that this will rise to the ground surface. This leads to potential problems of water rising into the structure and necessitates extra caution in the design of the slip circle and wedge analysis.

2.8 *Changes in direction of the plan line of the barrier.*

Because the barrier has a sloping face, problems arise at each of the points where the barrier changes direction. At a 'concave' bend in direction, the facing units become closer together with height and therefore each individual pair of concrete elements has to be designed and constructed shorter than the pair beneath. Similarly, where a 'convex' bend occurs, the concrete elements have to be individually designed and constructed longer as the slope is constructed higher. This raises the cost of the project, but is essential to cater for this geometrical problem.

3. DESIGN OF THE BARRIER

3.1 The original concept

The original concept was prepared by the Belgium International Airport Company. It was issued as a set of conceptual drawings and minimum specifications for contractors to prepare tender bids. This can be seen in Figure 1.

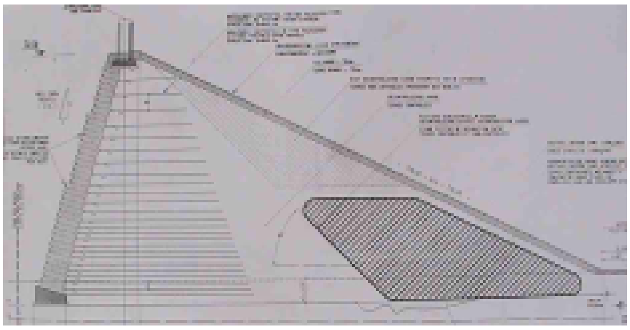

Figure 1. Original conceptual scheme from BIAC

The following were some of the features of the original concept that needed attention by the design consultant. The original concept drawings showed a non-standard geotextile reinforcement pattern; the foundation structure for the concrete facing elements needed revising; the foundation structure for the surmounted fence needed analysis; the contaminated soil 'sausage' needed careful analysis with alternative locations; there was no basal reinforcement to tie the whole structure together, and there were some potential slip surfaces generated by the geometry of the HDPE contaminated soil liner and the proposed soil block construction on the airport side slope.

3.2 *Alternative design options*

In the initial stages, a number of alternative design features were looked at. At all times the essential cross section and safety factor requirements of the Authority were maintained, but variations on the original theme were adopted where necessary to improve economics, constructability and stability.

At one time, replacing all of the concrete facing elements with plastic geocell constructions was considered. This was eventually not adopted, but at various locations on the airport side, where concrete elements had originally been needed, the Authority decided to use VOLTA geocells. These steep slopes were only localised and relatively low, but they formed a useful modification to the original design because they completely removed any steelwork from the airport side of the barrier.

The position of the contaminated soil 'sausage' was changed several times before finally deciding to place it above the basal reinforcement layers. The most logical position considered was below the basal reinforcement beneath the original ground level. However, this was abandoned because of the need to lower the water table temporarily during excavation. The foundations of nearby buildings would be threatened by potential settlement. Finally, tests were undertaken to show that if the contaminated soil was mixed with and stabilized by cement, then the contaminants were adequately sealed and the need for the HDPE wrap was dispensed with. This construction would also be easier to build and the client accepted that removal of the polyethylene wrap would remove the risk of slip surfaces over its upper surface.

Several different configurations of textiles in relation to the large concrete facing units were considered before adopting a final solution.

3.3 *Soil reinforcement design*

Because of the unusual cross sectional shape, it was evident that a standard solution would tend to be over-conservative. However, the Authority had specified high safety factors and some over-conservatism was to be expected.

The design was split into two phases. Firstly, a design of the geotextile strengths and spacings, was undertaken in isolation as a theoretical study of soil reinforcement and based upon a conventional 'edge of embankment' scenario. Two computer programs were used for this purpose – 'ReSlope' and 'Geosynth'. The first had been written by Dov Leshchinsky and the second by Peter Rankilor.

The two programs were run separately and their outputs compared. Safety factors specified by the Authority were built in and the following was the general design recommendation for the geotextiles.

The reinforcement would be two polyester woven geotextiles with ultimate failure strengths of 100 and 200 kN/m width. These would have an extension at failure of around 12%. A Belgian made woven geotextile called Terralys by Lys-Fabrics was successful in being selected for the works.

One of the more interesting aspects of the design was the design of the spacing of the geotextiles. Since the high strength polyester textiles were to be used as direct links to the concrete facing units, they had to be spaced at precise pre-specified spacings based upon the in-situ height of the concrete elements. The concrete elements were 750 mm high when vertical, but were to be constructed at an angle of 1h:4v. Thus the repeat height of the geotextile was pre-fixed at 750 x Cos 14 deg. = 728 mm.

With the vertical spacing of the geotextile fixed at either 728 mm or a half of this, the ReSlope and Geosynth programs were run looking for suitable geotextile strengths.

The final design for the internal reinforced soil block comprised 16 layers of 200 kN/m polyester woven geotextile at 364 mm centres in the 'lower half' of the structure, followed by 5 layers of 200 kN/m polyester at 728 mm centers and finally by 6 layers of 100 kN/m polyester geotextile at 728 mm centers. This arrangement can be seen in Figure 2.

The internal design of the reinforcement was thus specified in simplified form to make the cutting and placement as easy as possible.

Having assessed the required geotextile configuration, the Slope-W stability computer program was used to calculate the overall stability of the barrier in relation to its real geometry (Figure 2).

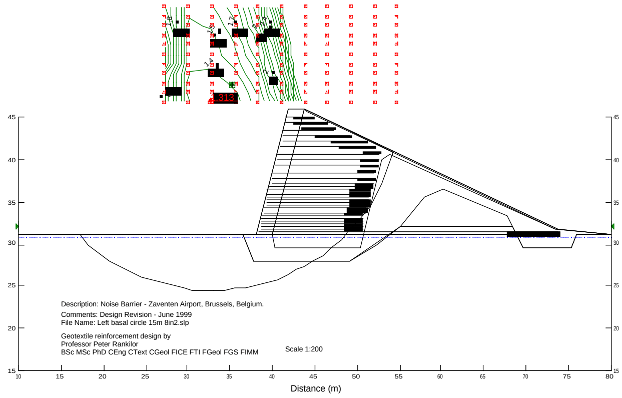

Figure 2. Design cross section similar to final construction.

Neither the ReSlope nor the Geosynth programs permit this. Both of these represent conventional 'edge of bank' slopes.

Figure 2 shows the Slope-W design finally specified to overcome the potential for slip circle and wedge failure.

The underlying foundation material was deep sand, with failure surfaces predicted within it and requiring long basal reinforcing layers. The final configuration was 4 layers of 200 kN/m woven geotextile contained in a granular drainage blanket.

The Slope-W program permitted both the analysis of the failure by Bishops and Morgenstern Price methods, as well as the detailed examination of potential wedge failures with surfaces running between the basal geotextile layers.

In the designer's view, it is critically important to conduct such wedge analyses even though they are very time consuming. Layers of the multiple wedges analysed should each lie between each of the multiple basal layers and particularly between the basal layers and the lowest layer of the internal reinforced soil block. Experience shows that this detailed analysis can produce some very low safety factors for sliding when slip circles are giving acceptable safety factors.

Further, the program was used to provide Monte Carlo statistical analysis of the probabilistic failure of the slopes so that a realistic engineering judgment could be made as to the strength of geotextiles required.

Also, the designer considered that there was a possibility of the structure developing structural cracking at the rear of the large reinforced soil block, so the use of a continuous reinforced soil mattress beneath the entire base of the structure was adopted.

3.4 *The facing elements.*

The facing elements were the 'Evergreen' concrete pre-formed type, as shown in Fig.3. There were a number of different sized standard modules used. The lower layers of the sloping face were larger than the upper layers. In general, the elements were about 2000 mm wide and about 750 mm high. They stacked to produce a face with a slope of 4 vertical to 1 horizontal (4v:1h). Where bends in the barrier occurred, every pair of concrete elements had to be designed and constructed individually to fill the changing gap correctly. The concrete elements were pre-cast offsite in Belgium and imported to the site after curing. They were handled and placed by means of a tall crane. The particular features of these facing elements were that they were noise absorbing and that they could support vegetation, thus producing a 'green' effect.

3.5 *Supply of the geotextile reinforcement layers*

The reinforcement of the noise barrier required the use of high modulus polyester geotextiles with particularly high strength in the lower zones of the wall. The required upward decrease in strength was catered for by adopting variable spacing as well as variable geotextile strength. Consequently, only two strengths of geotextile were utilised this minimised production costs and reduced the chance of any on-site construction error: TerraLys LF 200/50 PES and TerraLys LF 100/50 LF. The first had an ultimate tensile strength of 200 kN/m width and the second, an ultimate tensile strength of 100/kN/m width in the machine direction.

Confirmatory testing of the friction angle between the textile and the construction sand was undertaken to ensure that the design lay within the limits specified by BIAC.

Weather conditions in a western European country can be very variable and it was anticipated that during the construction period, storms and rain would make it difficult to handle and manipulate big textile rolls. The variable cross section of the design meant that every layer of geotextile would have to be cut to a different length from every other layer. The contractor therefore specified that the supplier would have to pre-cut all lengths at the factory prior to delivery on site.

The following parameters influenced the length of geotextiles: a) Different barrier heights varying in three main sections from 15m to 8 m to 4 m high, b) areas of gradual variation between the fixed height sections, c) variation in the angle profile of the barrier along its length, d) the presence of corners where the direction of the wall changed, e) three different style of concrete facing elements, f) some layers were linked to the concrete elements by wrap-round and some were not, g) variation in design length of geotextiles for anchorage purposes.

These complex variables were solved using a spreadsheet into which were entered the parameters and the outcome was calculated. Cross section drawings were produced as part of the computer design procedure, showing the exact positioning of each layer. The spreadsheet calculations resulted in the need for 2044 rolls of different lengths. Theoretical lengths were rounded up to the nearest 0.5 m and put into groups. As a result of this, only ten standard lengths of LF100/50 and 13 standard lengths of LF200/50 were needed. This was an acceptable compromise between wasted material, cost and site usefulness. In the factory, the PES geotextile was cut from long mother rolls using a 600 watt hot electric cutting blade. Careful labelling at the time of cutting identified each roll and its grouping. Subsequently, on site no problems were experienced with installing the right roll at the right place, thanks to the intensive preparation work.

On site, where the geotextile had to be wrapped around the concrete element's cross-beams, the standard width of 5.05 m meant that the geotextiles had to be folded or cut to pass between the concrete legs of the elements. In future projects, it would involve reduced site labour to produce the reinforcement width to match the gap between the legs. This would leave a strip of soil unreinforced, but this can be catered for in the slip circle calculations. Such a feature would involve no extra cost to the project, but requires an ordering time of several weeks so that machines can be set up to make the geotextile narrower than normal.

The quality of geotextile was checked by intensive internal ISO 9001 Quality Assurance systems and later certified by COPRO through independent checking. They checked tensile strength, elongation, pore size and water permeability.

3.6 *Linking of the geotextile with the concrete facing elements.*

Consideration of the original concept led to the conclusion that it was preferable to link the concrete facing elements to the reinforced soil block of the noise barrier. The initial design involved geogrids and interlaid reinforcing textiles, but ultimately a more simple solution was adopted. The contractor decided that the polyester geotextile should be taken horizontally into each concrete element and wrapped around the concrete beam of the element without actually touching it. The polyester is always separated from the concrete by a minimum 200 mm of sand.

The following photographs show the sequence of laying of the geotextile within the facing elements.

Figure 3. An empty concrete facing element viewed from inside the noise barrier. Note textiles at the base which have been wrapped round the element beneath.

Figure 4. Geotextile being pulled up to the concrete facing element prior to placing beneath the concrete cross beam.

Firstly, the correct roll of geotextile is selected and pulled up to the rear of the given facing element. It is then laid beneath the concrete cross beam, between the legs supporting the beam. It is then dropped out over the face of the slope, whilst sand filling takes place on top of it. The sand is placed and compacted up to and over the concrete beam and the geotextile is then pulled back into the body of the reinforced soil block. It is not placed in direct contact with the concrete element.

Figure 5. Reinforcing geotextile is pulled out to the precise pre-measured length as supplied to site from the factory.

Figure 6. Reinforcing geotextile is hung out over the face of the slope whilst sand is built up within and behind the element.

Finally, the reinforcing textile is pulled over the sand and buried within it to form the wrap-round anchor. The procedure is then repeated for each individual facing element within the structure.

4. EXTERNAL COMPARATIVE ANALYSIS

4.1 On-site measurement of stresses and strains.

It was considered desirable to make some attempt to measure the in situ stresses being developed in the reinforcing geotextiles, to verify that safety factors were within the limits specified in the conceptual tender documents. To this end, the Belgian Building Research Institute (BBRI) was retained to devise some method of measuring stresses and to develop and install measuring devices.

Two aspects were studied in particular: the displacements of the concrete facing elements and stresses within the polyester reinforcing geotextile.

As the barrier was already under construction when the monitoring was commissioned, the optimum way to monitor displacements was by optical observation. A site specific set of x,y,z coordinates was established and two lines of fixed micro reflectors down the face were set up and measured. At the time of writing, 120 days of observations have been recorded and the horizontal displacements on the face were a maximum of 16 mm. When measuring started, the face was already about 6 m high and the maximum reading of 16 mm was obtained when the wall was a further 3.5 m high – about 9.50. Effectively, this lateral movement was generated by the 3.5 m of further fill added subsequent to the start of measurement. Vertical movement during the same period was limited to 20 mm.

Measurement of stresses within in situ geotextiles is known to be difficult. Measuring instruments were developed and placed approximately 6 m above ground level (9.0 m below the ultimate crest height of 15 m). At the measuring location the selected piece of geotextile was cut across in two places. The first cut was about 2 m in from the concrete facing unit and the second cut was about 3.5 m in from the facing unit. These are referred to as Sections 1 and 2 respectively.

The cut sections of the geotextiles were now bonded to strips of aluminium which effectively rejoined the textile into a single long strip. Each cut section was bonded to ten pieces of aluminium of 0.5 m width and on each piece of aluminium were mounted electronic strain gauges. See Figure 7.

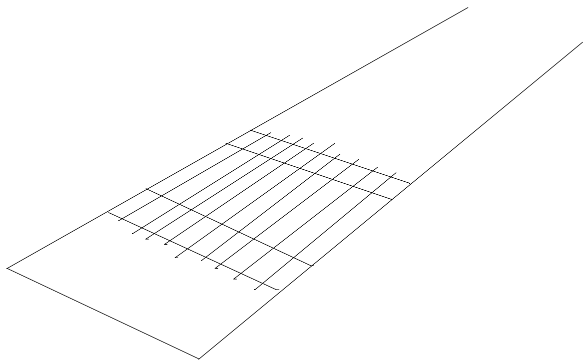

Figure 7. Distribution of aluminium plates in Sections 1 and 2.

This method of working was chosen because it is difficult, if not impossible, to fix strain gauges on geotextiles without changing their stiffness characteristics. Even the solution adopted of replacing the geotextile by aluminium is not an ideal solution because the stress distribution details within the textile and aluminium are not known. However, it was thought useful to place ten separate aluminium panels, so that variations in measured strains could be observed and isolated. This was found to be true as shown below. The numerical method of assessing the stress in the geotextile was as below:

$F_{alu} = \varepsilon_{alu}$ (measured) x E_{alu} (known) x A_{alu} (known)
$F_{gtx} \approx F_{alu}$
$\sigma_{gtx} = F_{gtx} / B_{gtx}$

F (kN)	force
ε (-)	strain
E (kN/m_)	modulus of elasticity
A (m_)	section
σ (kN/m)	stress
B (m)	width

64 strain gages were installed, 48 in Section 1 and 16 in section 2. The results of the measurements at Section 1 are given in Figure 8. Instead of using 1 strip of aluminium of 5 m width, 10 pieces were used, each of 0.5 m width, numbered from 1 to 10 (x-axis). The development of the average stress at Section 1 is given in Figure 9, together with the vertical overburden stress on the geotextile (1 layer of sand ≈ 0.75 m ≈ 13 kN/m_). Section 2 produced about the same values as Section 1 (max. 5 % difference). The measured values are considered to be rather low, but it is expected that ultimate stresses will be greater because stresses are still increasing as the structure continues to be built. Furthermore, it is quite possible that the two test sections are not at the point of maximum stress. Also, stress levels increase downwards and at the time of measurement, total overburden was only about 3.5 m. Finally, there would be a small but significant stress imposed between the placing of the geotextile and the taking of the first stress measurement. This stress would not be recorded and is thus not included in the charts below.

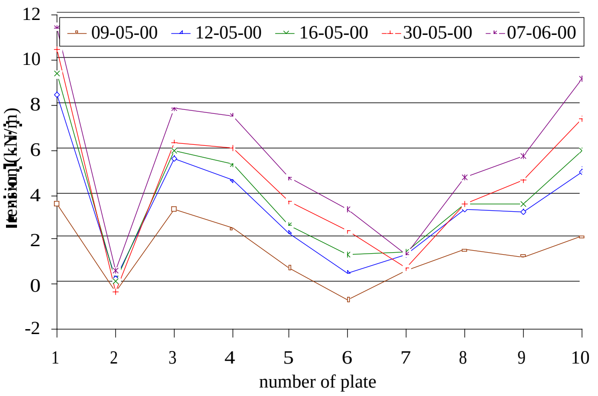

Figure 8. Stresses recorded in Section 1.

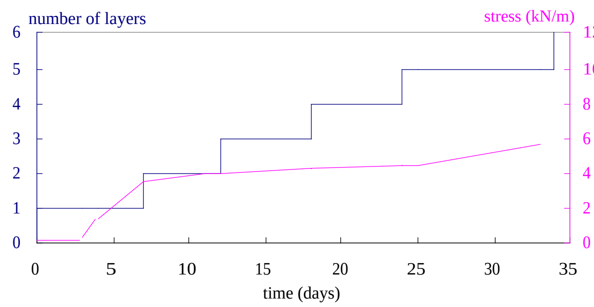

Figure 9. Development of the average stress in Section 1 in relationship to the increased overburden placed during construction works.

In true terms, the stress on the geotextile was not actually measured. A substitute material was placed at the given horizon and attached to the textile. Stresses within that substitute material were measured but it is not known whether these were imparted into the aluminium as a result of the geotextile becoming stressed, or whether they were imposed directly on the stiff aluminium by the overburden in the same way as it imposed stresses on the adjacent textile. It is likely that it is a combination of the two, but that does not necessarily invalidate the results, since this is what happens to the textile in any event. Any given sector of textile is both stressed by its adjacent textile and by the overburden immediately above. Note that the stress is given as kN/m width. The experiment was set up to have a full scale 1.0 m of sand above and below the measuring horizon, so the units are also effectively kN/m2 of lateral pressure.

It is interesting to compare the measured final average stress of 6 kN/m width with the figures expected from the initial design assessment. In the classical design analysis, the lateral force at any point can be taken to be approximately the density of the soil multiplied by its height above the given horizon and multiplied again by the assessed coefficient of earth pressure. If the density of the soil is say 18 kN/m3, the depth is 3.5 m and the coefficient of earth pressure is 0.35, then a peak lateral pressure of 22 kN/m will result. The measured value was 6 kN/m. However, in reality, the stress measured at any given horizon in reinforced soil is not the same as that in design calculations because lateral stresses are absorbed and shared with layers of geotextile above the horizon. It is more important to compare the result with the expected reinforced soil strains. In this case, the total lateral stresses in the block of sand above are being absorbed by 5 layers of 200 kN/m textile. The real stress being imposed on the measuring horizon is thus that from the immediately free 0.75 m of sand above plus a notional small additional stress imposed during the placing of the upper layers. If it is considered that the effective lateral stresses are imposed from a notional 1 m of sand above the measuring horizon, then 1 x 18 x 0.35 results in a lateral stress of 6 kN/m which is the same as that measured.

Analysis of the design using Plaxis.

The advantage of using a finite element model is that it can take into account the difference in stiffness of the interacting materials – providing these can be meaningfully input.

For the analysis we used the robust Mohr-Coulomb model. This model is less accurate when it comes to predictions of deformations, but it has the advantage that it can give a good result without the need for additional tests to characterise the soil.

For interpretation of safety the φ - c reduction method provided by Plaxis was used, which is supported by the Eurocode EC 7.

	Action	Action	Action	Ground Properties Tan φ	C'
Case	Permanent Unfavourable	Favourable	Variable Unfavourable		
Case C	1	1	c1.3	1.25	1.6

Figure 10. Partial factors – Ultimate limit states in persistent and transient situations.

The required safety level was always obtained.
During calculation the following important influences on deformation results were noted (influencing also safety) :

- Density of the mesh of the model
- Soil parameters (φ and E)
- Interface between soil and geotextile (estimated 0.45)

- E modulus of geotextile (tangent – secant)
- Bearing capacity of the soil in front and underneath of the concrete wall since the zone of potential slippage passed through it.

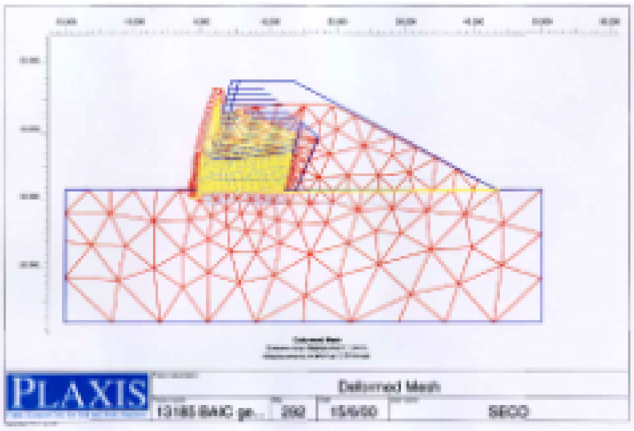

Figure 11. General view of the Plaxis finite element mesh used for calculation purposes.

EA	E soil	Maximum deformation of front
kN /m	kN/m_	mm
1700	1.0 e 5	109
10000	1.0 e 5	65
30000	1.0 e 5	56
30000	2.0 e 5	33

Figure 12. Influence of geotextile and soil stiffnesses on calculated lateral deformation of the slope face.

As deformation measurement becomes more and more important in the future, in situ measuring programs become increasingly necessary. Field measurements on real projects will provide new insights on the mass behaviour of reinforced soil and will enable researchers to adapt soil models, soil properties and other parameters usually derived from laboratory tests. Back calculations and instrumentation need to be done for the future benefit of cost reductions in large designs such as this one.

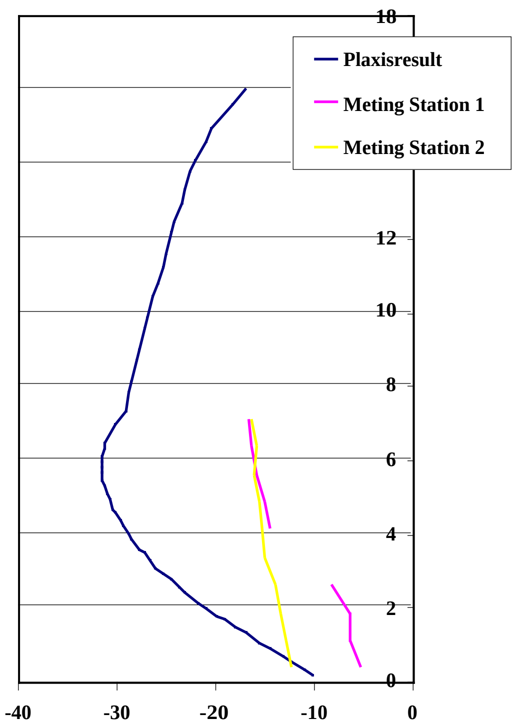

Figure 13. Comparison of the Plaxis calculated stresses with those measured by strain gauges.

5. CONSTRUCTION OF THE NOISE BARRIER

5.1 *Initial site preparation work.*

The first operation was to remove some well established woodland situated within the future construction area. Then the topsoil had to be removed to a depth of about 0.5 m. This was dumped adjacent to the works for subsequent reuse.

Site investigation works were undertaken using cone penetrometers and standard laboratory testing for grading, density, and others. After testing was complete, in October 1999, the foundation slab for the steep concrete faced slope was placed. It was made from reinforced concrete. A slip form paver was used such that the whole 510 m length of foundation was laid in two days. The inclination of this concrete had to be highly accurate since any small variation would have serious consequences on the position of the crest of the wall 15 metres above. Next, the basal reinforcing layers had to be placed across the full width of the noise barrier. Observational tests showed that the permeability of the placed sand was sufficient to provide rapid drainage of water at the foundation horizon and therefore a special drainage layer was not needed. The four layers of 200 kN/m polyester woven textile were placed with intervening layers of 0.25 m of well compacted sand.

5.2 *Building the reinforced soil block.*

A number of practical problems were experienced in the co n-struction of the sound barrier. Firstly, the placing of the geotextile through each facing element and around the concrete beam was difficult. The textile was wider than the distance between the supporting legs holding the beams. Therefore, the fabric had to be either folded inwards around the concrete or cut to fit. Either solution was time consuming. Secondly, it was impossible for the site workmen to distinguish between the 100/50 and the 200/50 textile on site, because they are both white and seem very similar. This meant that great care had to be taken to identify each customized roll for site use. To cater for this, a detailed identification system was set up with each unique group of textile type and length having a unique letter identifier from A to V (23 groups in all). Then there was a matter of identifying the concrete facing elements which, again, looked very similar to the workmen on site. The three main types were labeled B, C and D. The special length facing units for use at the corners where the barrier changes direction, also had to be individually and uniquely numbered for identification.

The compaction of the sand layers was controlled by on site and laboratory testing (one test per 1000 m3). A compaction value of 17 MN/m2 was required. In good weather it was no problem to attain this value, but during rainfall it was not possible. So progress was necessarily slow since the weather was particularly bad during the construction period.

For the inclusion of contaminated soil within the barrier, firstly the contaminated soil had to be sieved to remove the very large items of timber, concrete and similar objects from within it. Some of these were more than 1 m in size. Using large diameter grill sieves, the maximum size of particles was reduced to about 200 mm. The oversized contaminated material was shipped off site to a specialist firm to be split into three categories of contamination and dealt with accordingly.

The remaining contaminated material was then mixed with cement to stabilize the contaminating chemicals – a technique which had been successfully used with lime previously by the contractor on a Belgian Railway construction project. In this case, however, it was decided to use cement and to mix it into the contaminated soil using a rotor blade. The stabilized material still had to be tested and had to meet criteria pre-set by BIAC.

Possibly the most difficult problem for the construction team is that the higher the barrier was constructed, the narrower became the working platform area and the more difficult it became to transport materials, compact the soil and undertake the actual geotextile installation work. Machines can not pass each other any more; the organisation of construction equipment had to be controlled with continuous observation and care. Placement of the geotextiles, topsoil, sand fill, and concrete blocks became increasingly dangerous.
During upper level construction, workmen spent more time in the bucket of the big crane than they did standing on the barrier. Workmen have to be made safe by means of safety harnesses. They feel more like mountaineers than site workmen. Construction is not complete at the time of writing and so the worst narrow conditions have not yet been experienced. An external safety organisation monitored all aspects of safety including the use and condition of the safety harnesses.

5.2 Construction of geocell walls.

On the airport side of the barrier, the slopes are generally sufficiently flat that they can be topsoiled and grassed without special retaining structures. However, the land space needed for the future road to be constructed at the toe of the barrier, means that at a few locations, the barrier toe has to be steepened and supported by a small retaining wall. Rather than use the concrete facing elements (because of their internal steelwork) the contractor decided to use polyethylene geocells stacked vertically to produce a number of small scale reinforced soil retaining walls. At the time of writing these have not yet been constructed but their appearance will be similar to that shown in Figures 14 and 15 below, which show similar geocell constructions from another site, after construction and showing naturally seeded vegetation.

Figure 14. A 7 m high geocell retaining wall from a highway construction site in the U.K. No vegetation soon after construction.

5.3 *Post-construction activities.*

Construction is expected to be complete by end August 2000. After that, the process of seeding and planting shrubs will take place. These plants will have special properties allowing them to grow successfully under arduous climate conditions. The environment on the barrier will be demanding, including high winds where the wind is forced over the barrier. There will be more extreme frosts during the winter and droughts during the summer. Altogether, the vegetation placed on the barrier must be very hardy and drought resistant. Further, no shrub is allowed on the barrier that can grow to a height greater than 1 m. This is specified so that birds will not nest in them, thus discouraging birds from living in the area, because they can cause 'bird strike' on aeroplanes – a highly dangerous phenomenon.

Post-construction sound testing will also take place to compare the results of constructing the barrier with conditions before its construction.

For this wall, the contractor had to transport, place and compact 130000 m_ of sand, treat 25000 m_ contaminated soil, place 150000 m_ geotextile, 600 m_ geocell, 1300 concrete blocks and 638 noise reducing elements.

Figure 15. The same 7 m high geocell retaining wall a few weeks after construction. Natural vegetation has established itself to achieve the desired natural appearance.

The wall and its two successors will be totally completed by early 2003. They will be environmentally friendly and attractive, being finished with vegetated slopes.

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