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Advice on the pricing and planning of earthworks involving the use of geosynthetic reinforcement

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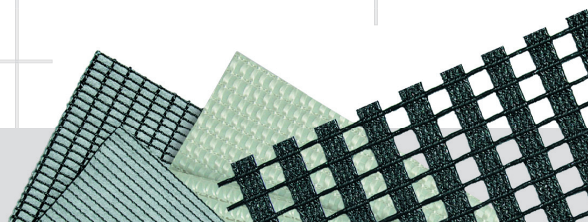
Engineering with Geosynthetics



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Abstract:
In addition to the supply and disposal of quantities of soil, the pricing of earthworks projects is particularly influenced by the output and operating costs of construction plant. The methods and tools for the precise calculation of these costs are widely available and in common use. However, potential cost savings are frequently overlooked in the planning and pricing of construction operations in which the material costs and above all the placement costs of geosynthetics have to be calculated. This article seeks to demonstrate these potential savings and provide suggestions for more effective pricing and planning.

1. Introduction

In addition to the supply and disposal of quantities of soil, the accuracy of pricing of earthworks construction projects is particularly influenced by the output and operating costs of construction plant. Procedures for the collection of precise information as the basis for successful pricing are well known and adequately documented, see e.g. Duic/Trapp [1], Meier [2], Keil/Martinsen [3], Kühn [4], Pietzsch/Rosenheinrich [5]. Estimators and site managers find themselves increasingly faced with the pricing and use of geosynthetics. Although geosynthetics have been widely and very successfully used for several decades now, see e.g. [6], extensive literature with recommendations and guidelines for the design, specification and quality assurance is available, see e.g. [7] to [13], unfortunately adequate knowledge about this material and its versatility of application cannot be taken for granted.

Fig. 1. Geosynthetic installation at Rüstersieler Watt

Consequently geosynthetics are often not given the status they deserve as an element of the pricing of a construction project; they may be ignored or even improperly used as a speculative item. This situation is particularly difficult when pricing projects in which geosynthetics form structural elements and could lead to a failure of the structure, e.g. sinkhole protection, supporting earthworks, etc.
Without claiming to be a complete comprehensive representation of all the aspects involved, this paper is intended firstly to stimulate an open discussion of the subject and secondly to provide general advice and tips on effective pricing.

2. Cost mix

An estimator sees the differences between geosynthetics with comparable technical properties in terms of their prices and conditions of supply. Furthermore, in the regulations relating to construction contracts, e.g. M Geok E [8] and TL Geok E-StB 05 [12], other differentiating characteristics, not mentioned in the above documents, such as roll weight or the work involved in handling the materials, are often underestimated because of lack of experience in this field.

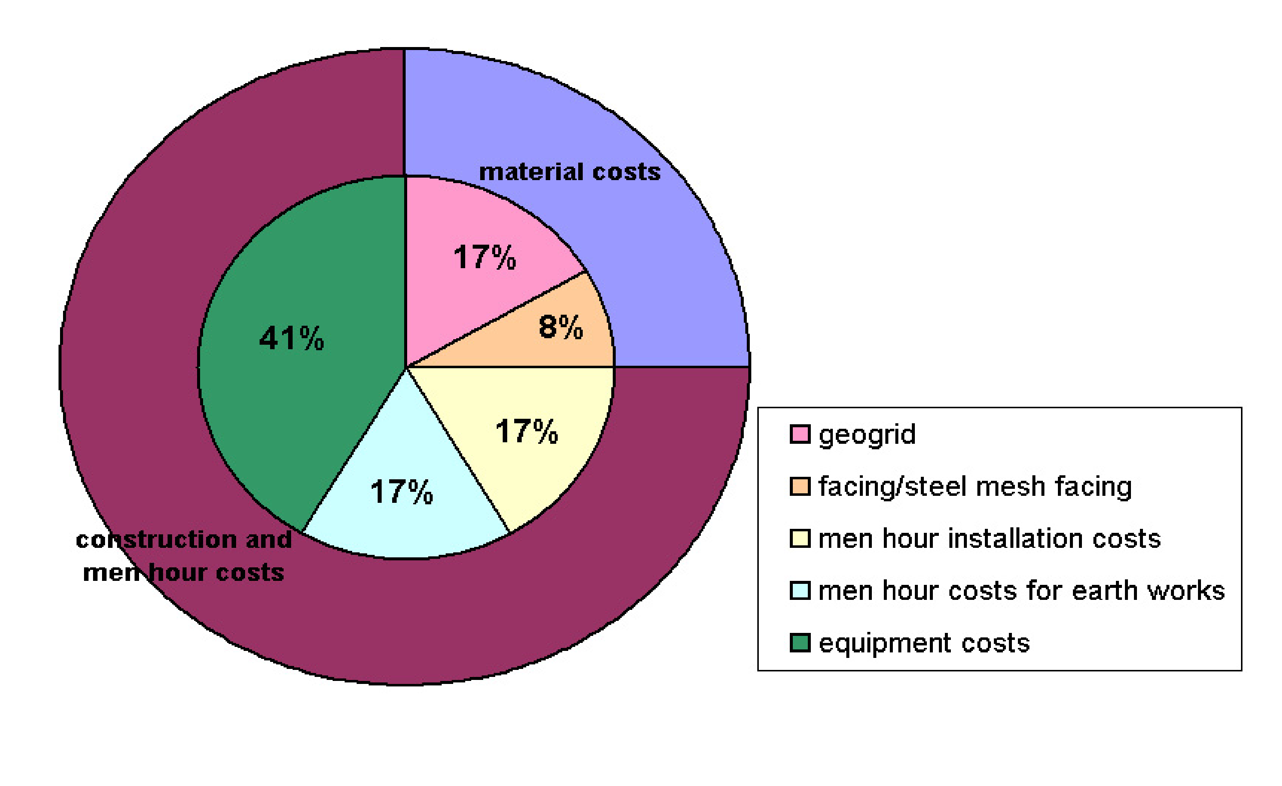

Fig. 2. Cost mix of a completed geosynthetic-reinforced earth structure

Figure 2 shows an example of a typical cost mix of a geosynthetic-reinforced soil structure (GRS). The diagram shows the pure material costs and the costs of labour and plant. If it is assumed that the fill is placed by the client, the analysis clearly shows that the costs of placing the geosynthetic are very significant compared with the pure material costs. In addition, any delays or difficulties in placing the geosynthetic can effect subsequent activities, in particular the supply, deposition and compaction of the fill. Depending on the scope and form of a construction project, there may be further implications for plant costs or standing time.

Figure 3 shows the influence of a low cost of installation on the total cost of a GRS structure. Column 1 is the standardised distribution of total costs per m^2 of face area. Column 2 demonstrates that with only 20 % less daily output the total cost increases by approximately 16 %. Column 3 illustrates that a 20 % reduction in geogrid material cost does not even come close to compensating for the additional total costs (column 2). It is clear that a reduction in installation output cannot be compensated for by a reduction in geogrid costs. A more exact investigation of the factors influencing placing costs in general and in the form of a comparison of products from different manufacturers would be well worthwhile.

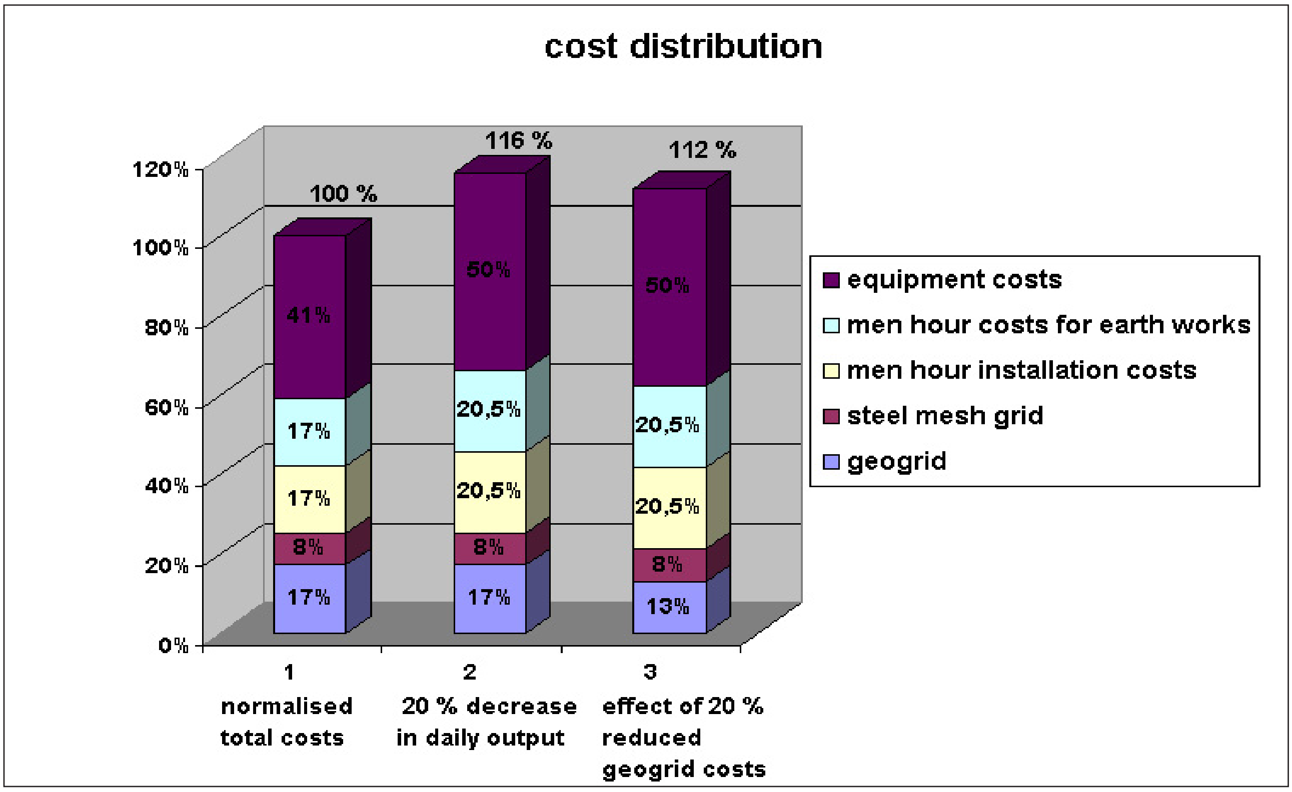

Fig. 3. Standardised total costs of a geosynthetic reinforced soil structure per m² of face area

3. Investigations of the site handling characteristics of geosynthetics

As was shown in Section 2, small differences in the placing costs of geosynthetics can have direct cost advantages or disadvantages. Unlike determining the performance figures of construction plant, putting numbers to placing geosynthetics is difficult. The assessment of the suitability of a geosynthetic, its so-called buildability, and the associated work involved in its placement cannot be adequately demonstrated by theoretical calculations nor by small-scale manual trials. The behaviour of a material has to be investigated under real conditions in order to be able to make authoritative statements, for example about the handling characteristics of different products. Using methods similar to those accepted for the calculation of output indicators for pricing construction projects, the handing of two typical geogrids was observed, recorded and evaluated in field tests during the construction of a retaining wall and a site access road. The planning, execution and evaluation of these field tests were carried out by Prof. Dr. Biedermann of the Geotechnische Institut, Würzburg [14].

3.1 Design of the field tests

With reference to the principles for carrying out work studies according to REFA, Hoffmann/Kremer [15], the field tests were designed with the emphasis on data collection. Various methods of time recording were used in collecting the data from which the insights into the operational processes were gained. The collected information was then analysed in order to be able to make any improvements to the working processes and establish standard work outputs.
Within the scope of the field test, the emphasis was placed less on a comprehensive time and motion study of all the processes involved but rather more on investigating the peculiarities arising from the use of geosynthetics. A complete analysis of the whole work process would require considerably more resources than was possible for an initial field test.

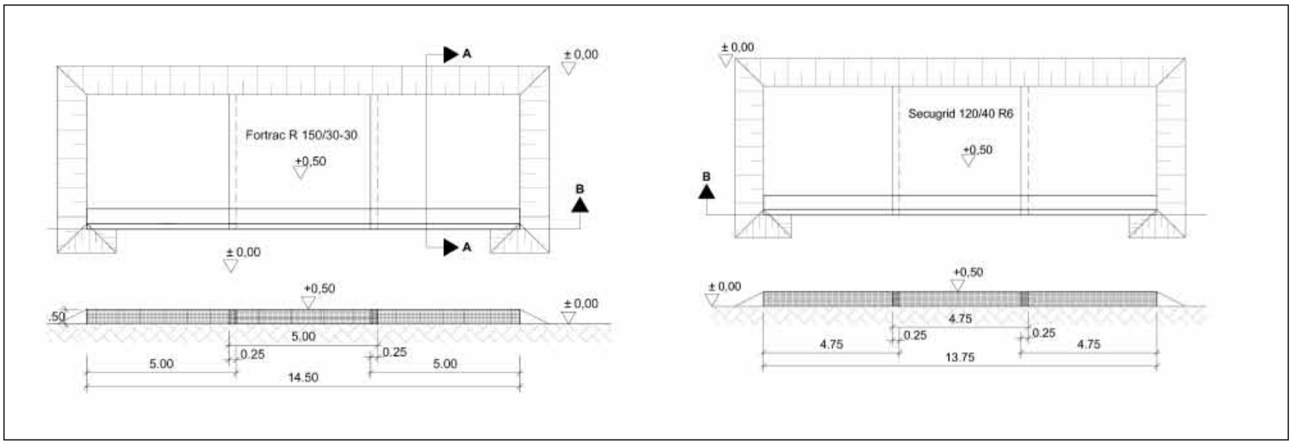

Fig. 4. Plan and longitudinal section of the trial earthworks for the "Steep reinforced soil slope" field test, left: Area 1 with flexible geogrid type 1, right: Area 2 with interlaced geogrid type 2.

3.1.1 Field test "Steep reinforced soil slope"

The earthworks for the "Steep reinforced soil slope" field test incorporated a flexible, high-modulus (resistant to extension) knitted geogrid, the second area incorporated an interlaced geogrid. The raw material for both geogrids is polyester (PET) and they have comparable strength properties, see Table 1.

Table 1. Properties of the geogrids used for the "Steep reinforced soil slope" field test earthworks

Parameter	Standard	Units	Flexible tensile-resistant geogrid / type 1 Fortrac R 150/30-30	Interlaced geogrid / type 2[1] Secugrid 120/40 R6
Polymer	-		PET	PET
Short-term strength	DIN EN 10319	kN/m	150	120
Short-term ext.	DIN EN 10319	%	< 12.5	< 10
Width		M	5	4,75
Weight	DIN EN 965	g/m²	600	568
Mesh size	-	mm x mm	30 x 30	72 x 28

[1]: from manufacturer's data

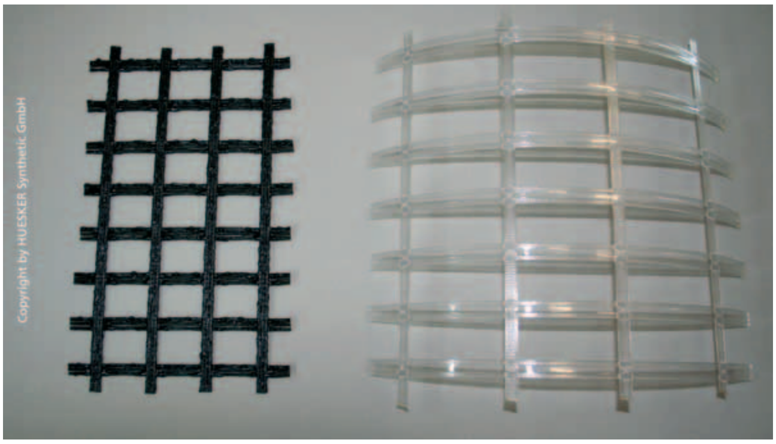

Fig. 5. Geogrids used in the "Steep reinforced soil slope" field test earthworks, left: Flexible high-modulus geogrid (type 1) right: interlaced, spot-bonded geogrid (type 2)

The dimensions of the field test were selected to enable at least three lengths of the standard production widths of geogrid to be placed alongside one another. Including the overlaps required to transfer stresses between adjacent widths in practice, the total width of the trial earthworks was approximately 30 m. The geogrid anchorage length had to be ≥4.0 m. As the steep slope was to be designed as a wraparound wall with the geogrid in the front face zone taken up 0.50 m, and returned 1.50 m to form each lift, the overall length of geogrid was approximately 6.0 m. The field test earthworks was representative of a base layer for a retaining earth wall some 6 m high. Corrosion-protected steel mesh, type DeltaGreen, was used as permanent formwork in the outer facing system.

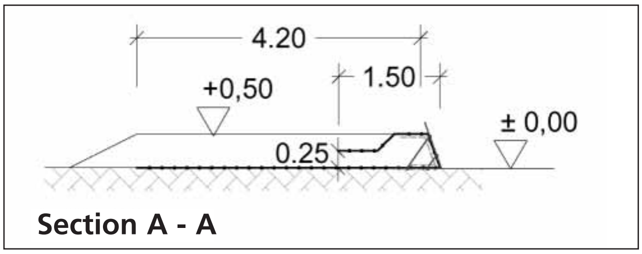

Fig. 6. Cross-section A-A through the "Steep reinforced soil slope" field test earthworks

3.1.2 Field test "Reinforced sub-base"

The design of the second field test earthworks took the form of a single-lane carriageway, the width of the field test area being approximately 5 m. The length was made up out of a total of 4 different products. Each product was laid transversely to the carriageway. The reinforcement was not returned at the sides of the earthworks. The length of the test embankment was approximately 20 m. After placing, the geosynthetic was covered with a minimum 0.10 m thick layer of crushed stone (0/56) mm. So as not to adversely affect the behaviour of the system, this operation was carried out using an excavator from the sides and ends.

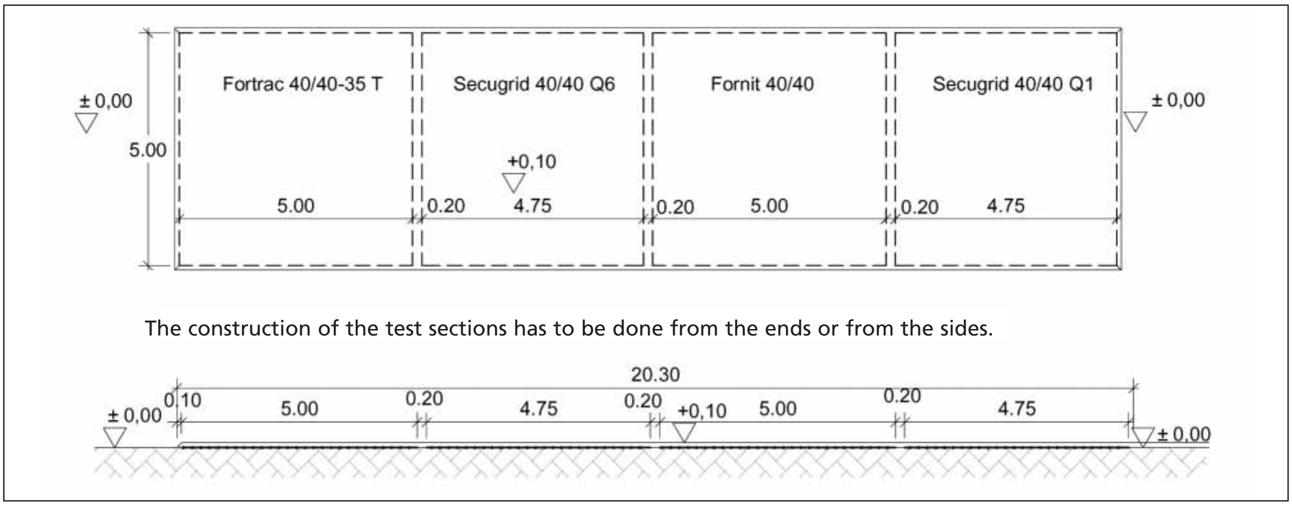

Figure7. Plan and longitudinal section of the trial earthworks for the "Reinforced sub-base" field test.

3.2 Carrying out the field test

Following the methods for data determination the construction of the field test earthworks was observed using a grouped activity time study. Without taking into account all the purely earthworks-related processes the flow of work was generally divided into the following:

- Placing and aligning the formwork elements ("Steep reinforced soil slope")
- Cut to length, transport and roll out the reinforcement
- Roll out and fix the GRK 4 non-woven filter and separation layer ("Steep reinforced soil slope")
- Supply, deposit and compact fill, 0.25 m crushed stone (0/56) mm

• Supply, deposit and compact the second layer of fill in the front face zone
approx. d = 0.25 m, b = 0.50 m, crushed stone (0/56) mm ("Steep reinforced soil slope")
• Return the ends, tension and fix the geosynthetic ("Steep reinforced soil slope")
• Supply, deposit and compact the remaining layers of fill ("Steep reinforced soil slope")

The approach adopted in the field tests was to concentrate on the special aspects arising from the use of geosynthetics. In addition to the recording of overall times, the following sub-processes were observed and recorded photographically, reference may also be made to Biedermann [14]:

• Storage
• Transport
• Cutting
• Laying

The work was carried out by a team of three operatives. Two operatives were specialists and were also qualified to drive the excavator and compaction equipment, the third was a foreman and instructs the others. The fill was deposited in heaps and then moved and spread by an excavator.

3.3 Findings / Observations

Within the terms of reference of the field test discussed above the following comments can be made:

3.3.1 Storage

The layout of the site required the materials to be stored approximately 150 m from the installation site on a piece of firm ground with good access for all types of vehicles (even large delivery lorries and semi-trailers). Adequate crossfall provided good drainage of the formation. When larger volumes of material are involved, with many more accesses for transport and the reinforcement is unrolled and cut to length on site (as is normally the case), it is preferable to store the geosynthetics as close to the installation site as possible. This assumes that the materials can be installed soon after they are delivered to site. Longer-term temporary storage areas along the edges of construction sites, e.g. as might happen on roadworks projects, should be avoided. Depending on the calculated daily output, the materials are usually better kept in a central store, where they can be protected from the weather, vandalism or improper handling. With predominantly linear construction sites and relatively high daily outputs, it may be worthwhile delivering materials directly to the installation site itself.

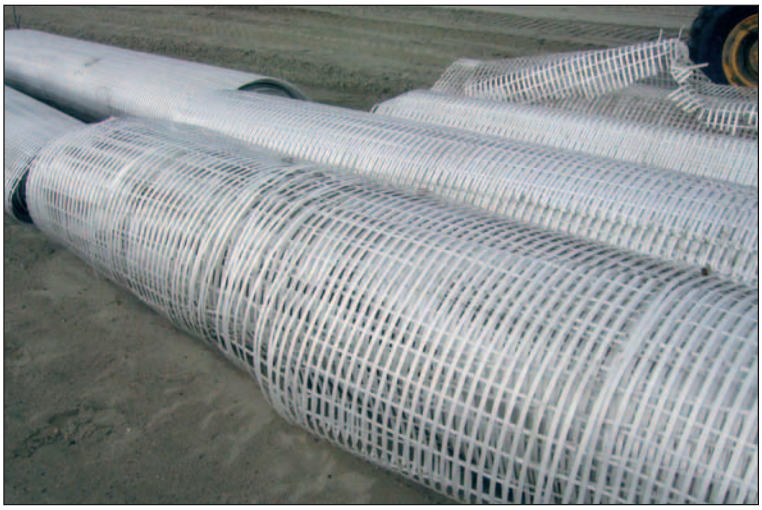

Fig. 8. Improper storage of geosynthetics: The materials should be protected from the effects of weather if stored for extended periods outside

Figure 9. Improper storage / treatment of unrolled geogrids

3.3.2 Transport

As only a small amount of material was used for this field test, it was moved by hand from the storage area to the installation site. In normal circumstances, this is not possible because of the high weight of the rolls. The materials usually have to be manoeuvred with the help of suitable construction plant. The type of plant and equipment shown in the photographs below can be used to transport geosynthetics in an organised manner without damaging the reinforcement. If, as is often the case in constructing steep slopes, many individual short lengths have to be laid, it is more economic to prepare the lengths of geosynthetic at a central cutting yard before they are taken to the installation site. Flexible geogrids (type 1) have the clear advantage here that they can be folded to form more easily handled units. The transport of individual lengths can be undertaken without problem by one person, or several lengths can be placed on a pallet and in brought to the installation site in larger batches. Interlaced or stretched geogrids, often described as "stiff junction", are resistant to bending and have a pronounced tendency to unroll themselves again after being cut and rolled up because of the way they are manufactured. This so-called memory-effect characteristic (Figure 11) makes transport considerably more difficult and the prepared lengths must be moved in their full widths (not folded).

Fig. 10. Equipment for proper unrolling and installation of geosynthetics

Fig. 11. Memory-effect of interlaced geogrid

3.3.3 Cutting

Depending on how much cutting to shape is required, it might be worthwhile to carry out the cutting centrally in a cutting yard. To keep transport routes between the installation site and the cutting yard short, cutting should take place as close to the installation site as possible. The use of clamping devices and stands ease the job of unrolling and rolling out of the rolls. On large construction projects a measuring wheel may also be useful. With relatively long anchorage lengths and especially with high-quality and therefore heavy reinforcement products, it may be worthwhile under certain circumstances to take large rolls to site and there roll shorter rolls on to separate cores. Figure 12 shows the schematic diagram of a device for unrolling, rolling out and winding geogrids. A simple pocket knife or box-cutter is usually adequate for cutting geogrid type 1. With interlaced geogrids like type 2, it is advisable to use electric cutters (Handflex) even with low tensile materials, otherwise the time required to cut interlaced geogrids can be at least 2-3 times that of flexible geogrids. Difficulties in cutting the rolls occur more where there are short lengths to be placed and with narrower rolls. It was also noticed that when the geogrid type 2 was being rolled out, the transverse strands became detached at the junctions. Protective gloves must be worn when cutting and installing geogrid type 2.

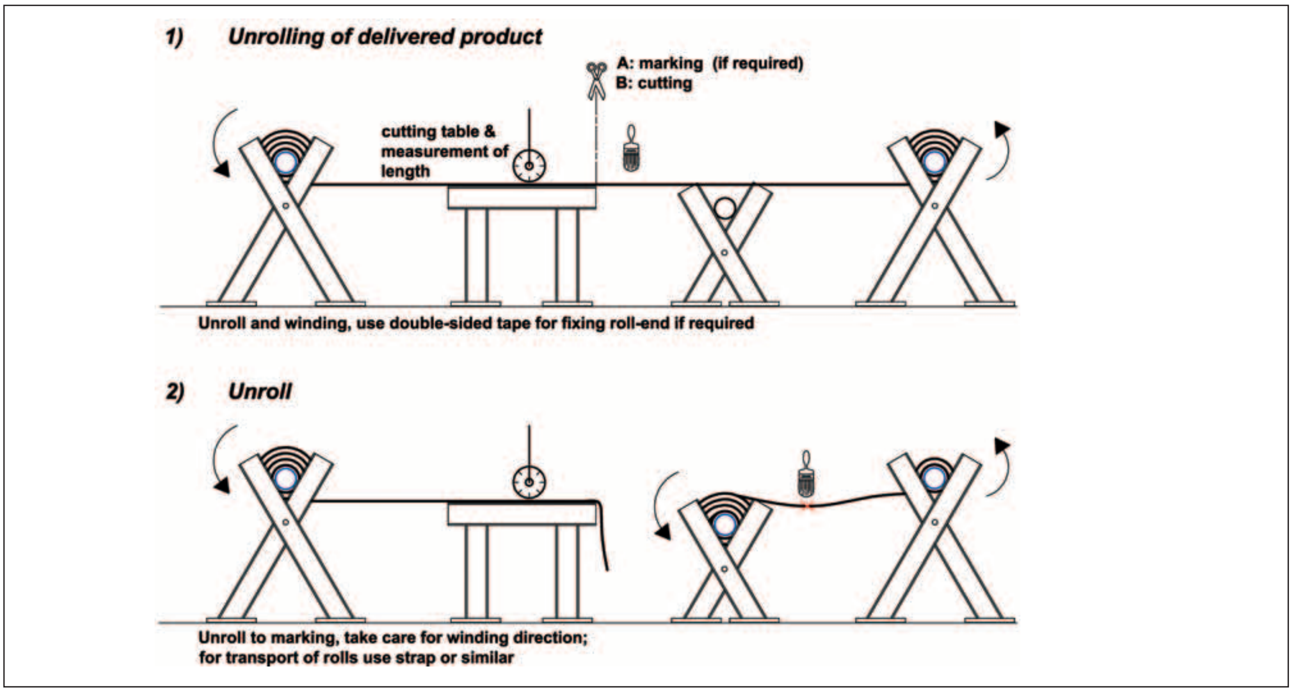

Fig. 12. principle of unrolling and winding station

3.3.4 Laying

Laying geogrid in lengths greater than 15 m is best done with the help of placing equipment, (see Figure 10 above). If individual lengths have to be stretched to bed them down absolutely flat then equipment which can simultaneously transport and tension the geogrid has proved extremely effective. With long lengths of geogrid that have to be wrapped back and with lengths less than 15 m, placement by hand offers considerably more flexibility of operation, especially if space is limited. In the light of these considerations, manual placement was used on the field test. It should be pointed out that the flexible geogrid (type 1) is easier to roll out and put in place. Geogrid type 2 tends to roll itself up and go back its original shape because of the way it is manufactured, (see 3.3.2 and Figure 11). At least two or even three operatives are needed to lay geogrid type 2 precisely in its correct position. The ends of the rolls must be fixed with ground nails or weighed down with a small amount to fill to prevent the geogrid from rolling itself back up again. Alternatively the lengths can be turned over once about their longitudinal axes then placed. However, the material then tends to arch upwards. For the "Steep reinforced soil slope" field test, the geogrid in the front face zone was brought up and returned. The reinforcement must always remain in close contact with the fill to allow plants to establish themselves successfully on the face of the slope. To ensure this is the case, the reinforcement return is held down with steel nails so that the geogrid in the front face zone goes into tension as more fill is deposited and compacted. It should be pointed out here that the transverse strands of the interlaced geogrid (type 2) detaches from the longitudinal strands at the junctions. The geogrid is heat-bonded at these points but despite the low loads involved it obviously proved inadequate. It was only possible to properly and effectively tension the front face zone in the field test using the flexible geogrid (type 1). Apart from the difficulties described above caused by the memory effect, there were no other problems with any of the materials during the installation of the geogrid in the "Reinforced sub-base" field test.

4. Summary and recommendations

The carrying out and evaluation of large scale field tests provides important information for practical application which cannot be obtained in the laboratory. An assessment and evaluation of different geosynthetics should not therefore be based on the technical properties (laboratory tests) alone. It should also involve information about the handling, labour requirement and sequence of operations from the results of trial earthworks. The practical aspects of construction influence pricing and are crucial to the smooth and efficient flow of operations on site.
In this context a simple cost comparison with a breakdown of the individual cost types has shown just how important construction and labour costs can be compared with the purely material costs of the geogrid.
It was possible using a large scale field test of the construction of a geosynthetic reinforced soil structure (GRS) to look further than the purely engineering properties of a geosynthetic product and highlight and record fundamental differences, above all in the handling characteristics of various products.
The handling of insufficiently flexible reinforcement products such as the type 2 geogrid in the field test was found to be considerably more awkward and time-consuming. Given the same site conditions, an estimator should allow for the installation to be an average of 30 % to 50 % more time-intensive. In addition, the junctions of geogrid type 2 cannot be fixed down with steel nails because they burst apart when the fill is placed and compacted. Loss of contact with the fill encourages local deformations of the reinforcement and frequently leads to problems with the establishment of vegetation on the slope.

In a second field test to simulate a reinforced sub-base layer considerable detachment of the junctions was noted with geogrid type 2. In principle, it can be empirically determined that by incorporating geogrids a 30 cm thick load distributing layer of crushed stone or similar fill is adequate even for very soft substrates . In highway construction the use of a geogrid offers a considerable improvement compared with the conventional solution of excavate and replace.

Bibliography

[1] Duic/Trapp: Handbuch für die Kalkulation von Bauleistungen, Vol. 1, Bauverlag Wiesbaden & Berlin.

[2] Meier: Kalkulation für den Straßen- und Tiefbau anhand von durchgerechneten Beispielen, Bauverlag Wiesbaden & Berlin (1989).

[3] Keil/Martinsen: Einführung in die Kostenrechnung für Bauingenieure, Werner Verlag (1988).

[4] Kühn: Der maschinelle Erdbau, B.G. Teubner Verlag Stuttgart (1984).

[5] Pietzsch/Rosenheinrich: Erdbau, Werner Ingenieur Texte 79, Werner Verlag (1983).

[6] HUESKER Synthetic GmbH: Mehr als 40 Jahre Erfahrung mit Geokunststoffen, Bautechnik 81 (2004), Issue 12

[7] Wilmers: Das neue Regelwerk für Geokunststoffe im Erdbau des Straßenbaus, Straße + Autobahn 7 (2006)

[8] Forschungsgesellschaft für Straßen und- Verkehrswesen, Arbeitsgruppe Erd- und Grundbau: M Geok E – Merkblatt über die Anwendung von Geokunststoffen im Erdbau des Straßenbaues (Edition 2005), FGSV, Cologne

[9] Forschungsgesellschaft für Straßen und- Verkehrswesen, Arbeitsgruppe Erd- und Grundbau: Merkblatt über Stützkonstruktionen aus Betonelementen, Blockschichtungen und Gabionen (Ausgabe 2003), FGSV, Cologne

[10] Deutsche Gesellschaft für Geotechnik e.V. (DGGT): Empfehlungen für Bewehrungen aus Geokunststoffen – EBGEO (1997)

[11] Deutsche Gesellschaft für Geotechnik e.V. (DGGT): GDA-Empfehlungen Geotechnik der Deponien und Altlasten, 3rd Edition (1997)

[12] Forschungsgesellschaft für Straßen und- Verkehrswesen, Arbeitsgruppe Erd- und Grundbau: TL Geok E-StB 05 – Technische Lieferbedingungen für Geokunststoffe im Erdbau des Straßenbaues (Edition 2005), FGSV, Cologne

[13] Deutsches Institut für Bautechnik (DIBt): Bauregellisten A, Bauregelliste B and Liste C (2007), Ernst u. Sohn

[14] Biedermann: Dokumentation und Stellungnahme zu den Ergebnissen eines Feldversuches zur Untersuchung der Einbaubarkeit und Beständigkeit von Geogittern, unpublished (2005)

[15] Hoffmann/Kremer: Zahlentafeln für den Baubetrieb, 5th Edition, B.G. Teubner (2002)

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