Cost comparison of geosynthetics versus conventional construction materials, a study on behalf of the EAGM, CASE 4: Soil retaining wall

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ABSTRACT: The European Association for Geosynthetic Products Manufacturers (EAGM) commissioned GEOscope GmbH to quantify the economic performance of commonly applied construction materials (such as gravel, concrete, cement or lime) versus geosynthetics. Geosynthetic materials are used in many different applications in civil engineering and mining. In most cases, the use of a geosynthetic beneficially replaces the use of other construction materials. For the quantification, a set of cost studies was carried out concentrating on various functions or application cases. The economic performance of geosynthetics was compared to the performance of competing construction materials used.

Keywords: geosynthetics, costs, drainage, retaining wall, EAGM

1 INTRODUCTION

Geosynthetic materials are used in many different applications in civil engineering and mining. In most cases, the use of a geosynthetic replaces the use of other materials. The European Association of Geosynthetic product Manufacturers (EAGM) commissioned GEOscope GmbH to quantify the economic performance of commonly applied construction materials (such as gravel, concrete, cement or lime) versus geosynthetics. To this end a set of cost studies was carried out concentrating on various application cases, namely filtration, road foundation stabilisation, landfill construction and slope retention. The economic performance of geosynthetics was compared to the performance of competing construction materials used. The specifications of four construction systems were established by the EAGM members as being representative of a significant majority of the European market of geosynthetic materials.

1. Filtration
2. Foundation stabilisation
3. Landfill construction drainage layer
4. Soil retaining wall

For the cost comparisons, the same application cases were used as those detailed in the comparative Life Cycle Assessments of geosynthetics versus conventional construction materials listed in the references. The factor cost is thus added to the ecological assessments carried out there. In this paper, the results for CASE 4 Reinforced retaining wall are reported.

2 CASE 4: SOIL RETAINING WALL

The following description of the structures compared was provided by Fraser I.; Elsing A. (2012). In certain cases, especially in the construction of traffic infrastructure, it may be necessary to build very steep batters or walls. For such walls, supporting structures are necessary. The retaining walls need to meet defined tensile and shear strengths. Retaining walls reinforced with concrete (CASE 4A) are compared to soil slopes reinforced with geosynthetics (CASE 4B). In Figure 1 the retaining wall is 50 metres long and 3 metres high with a slope of 5:1. An average geogrid is used to provide the required performance.

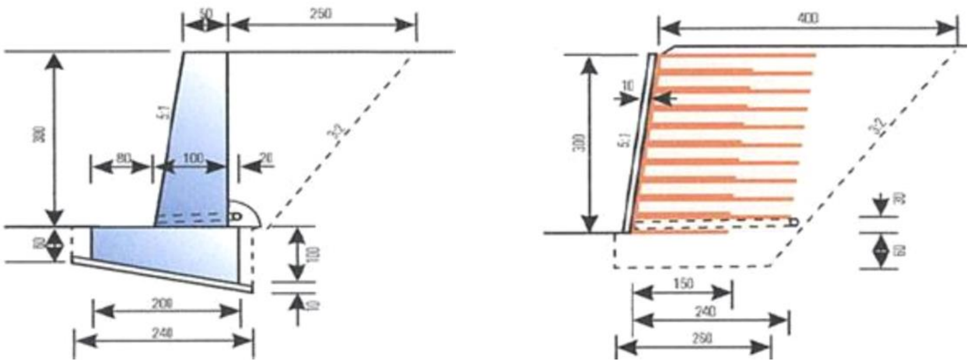

Figure 1 Schematic cross-section of retaining walls: the reinforced concrete wall (CASE 4A, left) versus the geosynthetic reinforced wall (CASE 4B, right)

Polyethylene and polyester are used as the raw material in CASE 4B. In this case a long-term tensile strength of 14 kN/m must be achieved. Typical reduction factors need to be applied to the ultimate tensile strength for that.

The concrete used in CASE 4A is specified as strength class B300.

Table 1 shows specification values of the retaining walls for both alternatives. The on-site material is used as fill material, wall embankments and cover material in CASE 4B. A gravel drainage layer with a thickness of at least 30 cm is required behind the concrete lining. To be consistent with CASE 4A, a drainage layer of rounded gravel with a thickness of 80 cm is assumed in both cases.

Table 1 Specification of soil retaining wall

Parameter	Unit	CASE 4A - conventional -	CASE 2B - geosynthetics -
wall length	m	50	
wall height	m	3	
excavation foundation	m^3	109	-
base compaction	m^2	121	262
formwork foundation	m^2	83	-
blinding layer	m^2	120	-
concrete foundation	m^3	80	-
foundation reinforcement	kg	2.400	-

Parameter	Unit	CASE 4A - conventional -	CASE 2B - geosynthetics -
formwork wall face	m²	153	-
formwork wall coarse	m²	150	-
concrete wall	m³	105	-
wall reinforcement	kg	5.250	-
building gaps	m²	21	-
drainage	m	62	72
filter gravel	m³	10	11
frost wall backfilling	m³	219	-
backfill compaction	m²	500	-
sub-base excavation	m³	-	79
sub-base fill material	m³	-	79
formwork support	m²	-	153
geosynthetics delivery and laying	m²	-	1960
wall embankment	m³	-	480
layer compaction	m²	-	1.550
shotcrete lining	m²	-	155
cover material	m³	-	45

The typical working life for both cases is estimated to be 100 years. This is in line with EBGEO (Deutsche Gesellschaft für Geotechnik 2010) and the British Standard "Code of practice for strengthened/reinforced soils and other fills" (British Standard 1995).

3 COST ESTIMATION

3.1 *PRINCIPLES*

The depth of detail on which a calculation is based determines the accuracy of the result. This ranges from a rough cost estimate based on a plan in which only rough elements of the construction task are described to a cost calculation taking into account the items of a bill of quantities. Until construction is complete, however, cost calculations are always an uncertain forecast which includes the cost risk of the client until the tender stage and the entrepreneurial risk of the bidder after submission of the tender until completion. In that respect, the calculation presented here is a detailed cost estimate in which essential work items are taken into account and which highlights the economic limits. The estimates are based on costs from the third quarter of 2021.

In earthworks and road construction, three main forms of costing have become established. These are

- Costing with predetermined surcharges
- Final total costing with discounts
- Dynamic calculation of the contribution margins

For bid calculations on bills of quantities, statistical guideline prices provided by service providers or public portals are usually used and given predetermined surcharges. Each construction company sets these surcharges for itself and thus also weights its services and entrepreneurial risk. The company's surcharges consist of site overheads, general business expenses as well as risk and profit. This calculation method is also used for the explanations in this paper.

The individual costs of the partial services are calculated according to building materials, wages and use of machinery. For the project described here, it was assumed that no subcontractor services would be required and that only a minimal quantity of auxiliary construction materials would be required.

3.2 *CALCULATION*

Based on Berthold, C.; Drees, G.; Krauss, S. (2019), a simplified approach was chosen for the compilation of the costs incurred for the construction project.

3.2.1 *WAGES AND SALARIES*

Wage costs are the product of the required hours worked and the associated average wage for a service. A split of wages into individual wage groups and thus also into qualifications is, according to Kuhne, V.; Kattenbusch, M. (2017) not usual.

The working times are assigned to the various services as individual calculations. As a guide to the working time required, these calculations are based on the performance of the equipment used and subordinate all other factors to this approach. This means that the construction machine is manned during this time and that the construction equipment with the lowest output for the implementation of a partial service determines the total time requirement of all equipment and labour used. This approach also allows operational and site-specific additions and deductions to be taken into account. The calculation was based on the assumption that the operator of the construction equipment also carries out work directly in the working area of his equipment, so that an assistant was not always provided for calculation purposes. Where additional auxiliary staff appeared to be necessary, these were explicitly shown in the calculation.

3.2.2 *MATERIALS*

The actual costs were used for the materials. This assumes that the price for the geosynthetics or granular materials is already included in the delivered price. Interim storage of the granular materials on the construction site is not planned. Just-in-time deliveries were assumed.

Although this approach involves a slight increases in planning work on the construction site, it has become accepted for construction sites in earthworks and road construction.

3.2.3 *EQUIPMENT COSTS*

The aim of this cost estimate is to compare different solutions for a construction task. Since the result depends to a large extent on individual service items, the equipment costs were not determined for their being held on site but were allocated to the individual items of the implementation of the selected example depending on the service being carried out.

The equipment costs are calculated on the basis of the construction equipment list (CEL). The equipment costs themselves were calculated and taken into account according to the method described in Kuhne, V.; Kattenbusch, M. (2017).

3.2.4 *TRANSPORT*

The costs for transport include the driving distance, the driving time and the additional time required for loading and unloading as well as securing the load. The example chosen takes into account the transport of construction equipment to the site at a distance of 120 km at a speed of 50 km/h and with a time buffer of 2 hours for loading and unloading as well as possible waiting time. In addition, the calculation includes the transport of soil on the construction site within a radius of 2 km at an average speed of 25 km/h and associated loading and unloading times of 0.1 hours in each case.

The building materials are priced in such a way that they are delivered by the supplier to the construction site and no further transport costs are incurred in addition to their purchase price.

3.2.5 *UNIT PRICE*

The final unit price of each service item takes into account the aforementioned costs as well as a factorised surcharge for risk and profit, which is quantified by the respective company taking technology-and site-specific aspects into account. Typical values for this are between 1.03 and 1.25, but can also deviate considerably from this.

3.3 *DESCRIPTION OF THE CALCULATION SITUATIONS*

The computational examples were carried out using the specifications mentioned previously. The planning and technical aspects will not be discussed here. They are the result of a discussion process within the EAGM and have been chosen in such a way that they can actually be applied throughout Europe in this or a slightly modified form.

The calculations do not reflect any technical considerations. It has been assumed that the situations that have found their way into the comparison will only ever be implemented if they are suitable and technically equivalent.

3.4 *RESULTS OF THE COST CALCULATION – SOIL RETAINING WALL*

The following table shows the cost results of the individual titles for the installation of a filter layer. The sum of all costs is related to one metre of a finished 12 m-wide road.

Table 2 Results of the cost calculation for retaining structures (cost basis third quarter 2021).

		CASE 3A - conventional -			CASE 3B - geosynthetics -		
	Unit	Unit	Unit price	Costs	Unit	Price per unit	Costs
Site preparation	Pcs.	1.0	€ 4,692.00	€ 4,692.00	1.0	€ 4,692.00	€ 4,692.00
Excavate soil for foundation and store temporarily in construction site area	m³	109	€ 4.49	€ 489.59	79	€ 4.49	€ 354.84
Construct and compact foundation base	m²	121	€ 1.51	€ 182.41	-	-	-
Supply, install and compact soil replacement for foundation	m³	-	-	-	79	€ 15.35	€ 1,212.62
Supply and install blinding layer	m²	120	€ 12.86	€ 1,542.84	-	-	-
Supply and install foundation formwork	m²	83	€ 33.55	€ 2,784.28	-	-	-
Supply and lay steel reinforcing mesh cut and bent for foundation	t	2.4	€ 1,933.92	€ 4,641.40			
Supply and install foundation concrete	m³	80	€ 220.11	€ 17,608.80			
Supply and install large-area formwork for outer face of retaining wall	m²	153	€ 17.03	€ 2,604.94			
Supply and install large-area formwork for inner face of retaining wall	m²	150	€ 17.03	€ 2,553.86			
Supply and install steel reinforcing mesh cut and bent for foundation	t	05:25	€ 1,945.42	€10,213.44			
Supply and install geogrid	m²				1.960	€ 4.83	€ 9,459.29
Supply and install concrete for retaining wall	m³	105	228.97	€ 24,041.33			
Close sound holes	Pcs.	21	€ 183.85	€ 3,860.78			
Supply and apply bitumen sealing	m²	154	14.55	€ 2,240.32			
Supply and install drainage pipe	m	62	€ 17.50	€ 1,084.85	72	€ 17.50	€ 1,259.82
Supply and install granular filter	m³	10	€ 24.00	€ 240.03	11	€ 24.00	€ 264.04
Supply and place backfill	m³	219	€ 10.38	€ 2,272.78	480	€ 11.80	€ 5,665.99
Supply and place cover soil	m³				45	€ 98.11	€ 4,414.94
Supply and apply shotcrete for front face	m²				155	€ 26.02	€ 4,032.79

4 COST COMPARISON – SOIL RETAINING WAL

Table 3 Cost comparison for retaining structures (cost basis third quarter 2021)

	CASE 4A - conventional -	CASE 4B - geosynthetics -
Site preparation	€ 4,692.00	€ 4,692.00
Preparatory work	€ 489.59	€ 354.84
Foundation work	€ 26,759.72	€ 1,212.62
Retaining structure	€ 49,112.32	€ 25,096.87
Total costs/m² without site preparation	€ 76,361.62	€ 26,664.32
Cost comparison	286 %	100 %

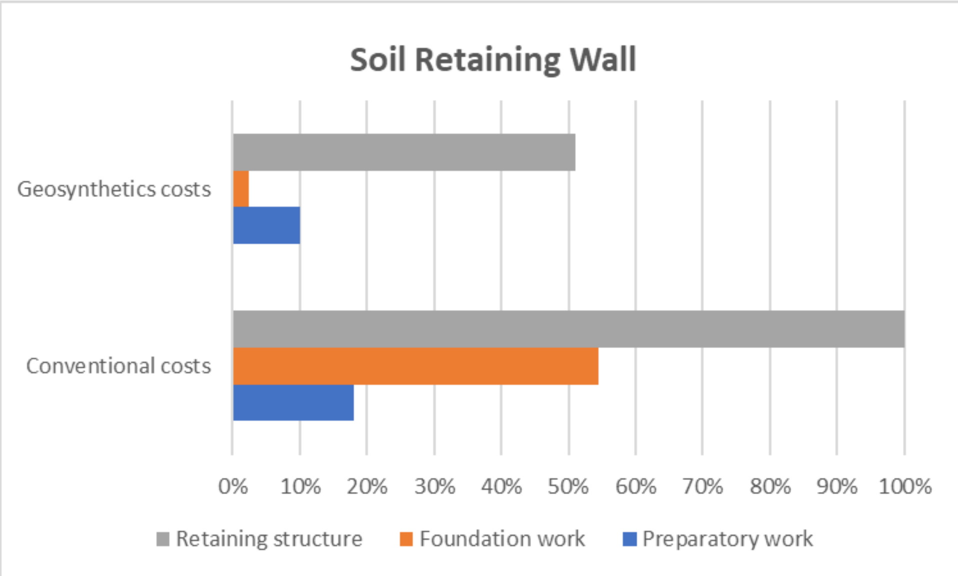

Figure 2: Schematic comparison of geosynthetics versus conventional costs

5 CONCLUSIONS

A cost comparison was made between conventional constructions and solutions with geosynthetics on the basis of significantly more extensive cost calculations than those presented in this paper. In CASE 4 the structural reinforcement of a supporting structure was considered.

In this case, it was shown that whenever the use of geosynthetics can save soil movements on the construction site or reduce required quantities of soil, this leads to significant cost savings. In the direct cost comparison of the retaining structure investigated, it was obvious that the use of concrete and steel is associated with considerable technological outlay, and this is reflected in the costs. In the configurations investigated, the cost savings of the selected solutions with geosynthetics were significantly more than 50 % in each case.

The comparison is based on cost rates for the third quarter of 2021. Since the classic solution always requires more equipment to be used on the construction site and transport to/from the construction site is necessary, the cost advantages of the geosynthetic solution in summer 2022 are estimated to be even higher due to the significant increase in energy and fuel costs compared to summer 2021.

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