Cost comparison of geosynthetics versus conventional construction materials, a study on behalf of the EAGM, CASE 3: Landfill construction drainage layer

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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

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

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 3 Drainage layer in landfill construction are reported.

2 CASE 3: LANDFILL CONSTRUCTION DRAINAGE LAYER

The following description of the structures compared was provided by Werth K.; Höhny S. (2012). The European Regulation specifies the thickness of gravel for a drainage system in a cap of a hazardous/non-hazardous waste landfill site. The particle size is not exactly defined.

A geosynthetic on top of the drainage aggregate is often used to prevent movement of fines from the topsoil into the drainage layer, and a second geosynthetic is used below the drainage as a protection layer to ensure that the sealing element is not damaged by the drainage aggregate. Instead of the conventional gravel drainage layer a geosynthetic drainage layer is used. In practice both solutions use geosynthetics - on top of and below the drainage layer. The other layers in a landfill site change neither in thickness nor in material requirements. The cross-sections of the conventional and geosynthetic alternatives are shown in Figure 1. The average values of two different types of geosynthetics are used to represent their performance, namely

- drainage nets and
- 3D drainage filaments.

Polypropylene or polyethylene are the basic materials used in CASE 3B. The average weight of the drainage core is 500 g/m² (excluding two geosynthetic filters). Gravel with a fairly uniform particle size of 16 to 32 mm and a layer thickness of 50 cm is used in CASE 3A.

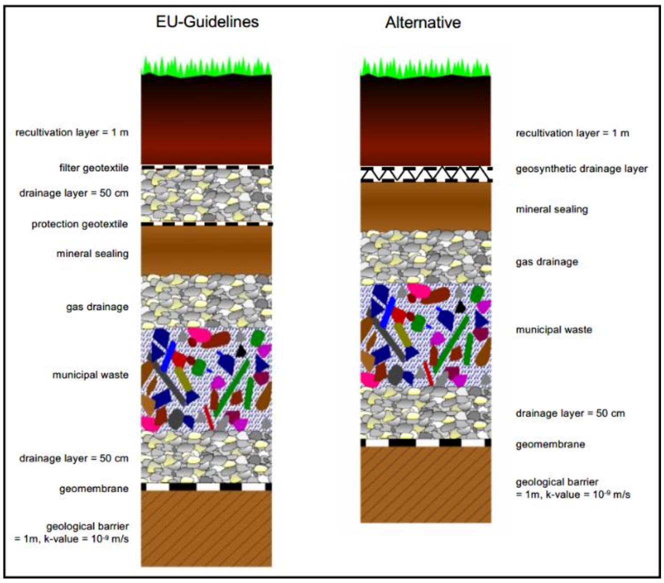


Figure 1: Schematic drawing of the cross-section of waste landfill site class 2 according to EU guidelines (CASE 3A, left) and with a geosynthetic as an alternative drainage layer in the cap (CASE 3B, right)

According to the European Council Directive 1999/31/EC, granular drainage layerr with a thickness of 0.50 m is required. The hydraulic conductivity of the drainage layer (its k-value) has not been defined according to the European Council Directive 1999/31/EC (European Comission 1999). All countries in the European Union have to comply with these requirements/regulations. Each country in the European Union can have an additional regulation which must fulfil the requirements of the European Union, but is more specific. Additional regulations were introduced in slightly different ways in different EU countries. In Germany, for example, additional requirements for the drainage layer are documented (see German Federal Government 2009). Here, the hydraulic conductivity must be ≥ 1 mm/s (k-value) and a thickness of ≥ 0.30 m is deemed sufficient for the capping of sealing systems. Similar requirements to those in Germany have been in force in the Netherlands for many years. In case alternative drainage layers are planned, documentation of adequate long-term drainage capacity of the product is required. For geosynthetic drainage layers, the long-term drainage capacity must be calculated.

Several calculations and practical cases in many European countries have shown that geosynthetic drainage layers with a core weight of an average of 500 g/m² (as an average of different product and production types) are suitable as drainage layers for final capping of sealing systems.

Table 1 shows specific values of the drainage layer for both alternatives.

Table 1 Specification of two alternative landfill drainage constructions

Parameter	Unit	CASE 3A - conventional -	CASE 3B - geosynthetics -
landfill size	m²	100,000	
drainage layer gravel 16/32 mm	cm	50	-
geosynthetic drainage core	g/m²	-	500

The typical working life of 100 years can be assumed to be similar in both cases.

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 – LANDFILL CONSTRUCTION DRAINAGE LAYER*

The following tables summarise the results of the cost calculations in a much condensed form. Due to the simplification of the tables, rounding errors may occur in the presentation, as the number of decimal places has also been limited.

The following table contains the cost results of the individual titles for the installation of a drainage layer. The sum of all costs is related to the total finished drainage area.

Table 2 Results of the cost calculation for filter layers (cost basis third quarter 2021)

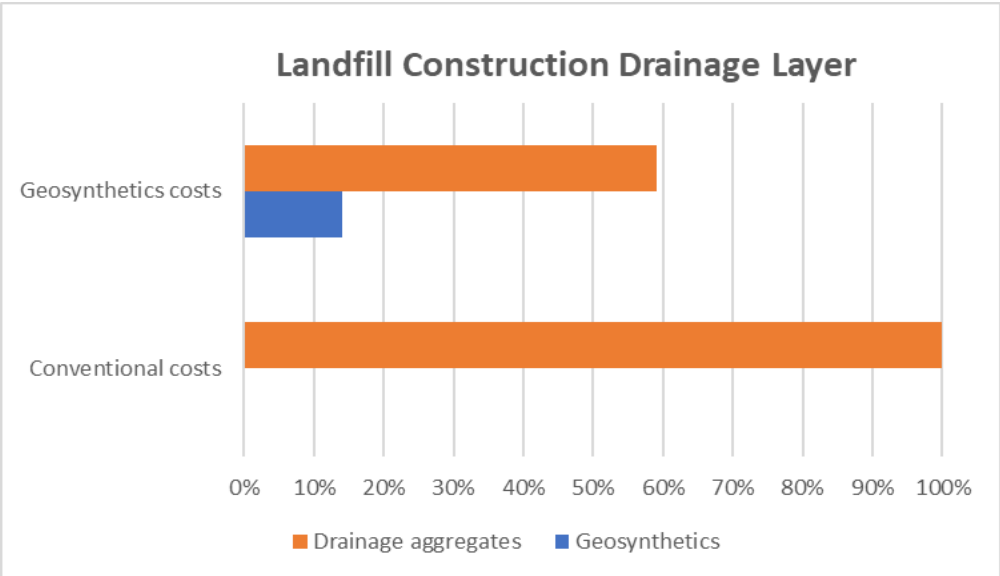
		CASE 3A - conventional -			CASE 3B - geosynthetics -		
	Unit	Unit	Unit price	Costs	Unit	Unit price	Costs
Site preparation	Pcs.	1.0	€ 3,128.00	€ 3,128.00	1.0	€ 1,564.00	€ 1,564.00
Supply and lay geosynthetics	m²	212.000	€ 2.63	€ 557,339.97	106.000	€ 8.36	885,975.78
Supply and install granular drainage layer	m³	50.000	29.72	€ 1,486,030.16			

4 COST COMPARISON – LANDFILL CONSTRUCTION DRAINAGE LAYER

Table 3 Cost comparison for drainage layers (cost basis third quarter 2021)

	CASE 3A - conventional -	CASE 3B - geosynthetics -
Site preparation	€ 3,128.00	€1,564.00
Geosynthetics	€ 557,339.97	€ 885,975.78
Drainage Aggregates	€ 1,486,030.16	-
Total costs without site preparation	€ 2,043,370.13	€ 885,975.78
Cost comparison	230 %	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 3, the geosynthetics selected fulfilled the drainage function of a 0.50 m thick granular drainage layer.

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.

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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