Cost comparison of geosynthetics versus conventional construction materials, a study on behalf of the EAGM, CASE 2: Foundation stabilisation

J. Retzlaff
GEOscope GmbH, Germany (j.retzlaff@geoscope.eu)

ABSTRACT: 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. 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 is compared to the performance of competing construction materials used.

Keywords: geosynthetics, costs, foundation stabilisation, 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 were 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 stabilization
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. This paper reports the results for the application CASE 2 foundation stabilisation.

2 CASE 2: FOUNDATION STABILISATION

The following description of the compared structures was given by Elsing, A.; Fraser, I. (2012). In road construction the sub-base needs to meet defined requirements for compaction and bearing capacity. Improvement of some soil characteristics may be necessary when building on weak soils. An alternative to the construction of a conventional road with a non-frost sensitive gravel/sand layer (CASE 2A) is a stabilisation using geosynthetics (CASE 2B). CASE

2B leads to a reduced thickness of the gravel/sand layer. Typical geosynthetics for this application were considered.

All products included had an ultimate tensile strength of 30 kN/m in both directions and were manufactured from polypropylene or polyester. The case of a conventional road (2A) is compared to a road reinforced with geosynthetics (2B). The example considered is a class III road with the same finished surface level in both cases. The road is built on a frost-sensitive soil, class F3. In regions where the frost penetration depth does not reach the frost-sensitive soil, this soil does not need to be removed. This is seen as the standard case, CASE 2B. In a sensitivity analysis, the frost-sensitive soil is removed and replaced by a soil which is not frost sensitive and meets the class F2 soil criterion (CASE 2B). Figure 2 shows the profiles of the two alternatives.

Figure 1 Schematic drawing of the cross sections of a standard road (CASE 2A, left and a road using geogrid reinforcement (CASE 2B, right)

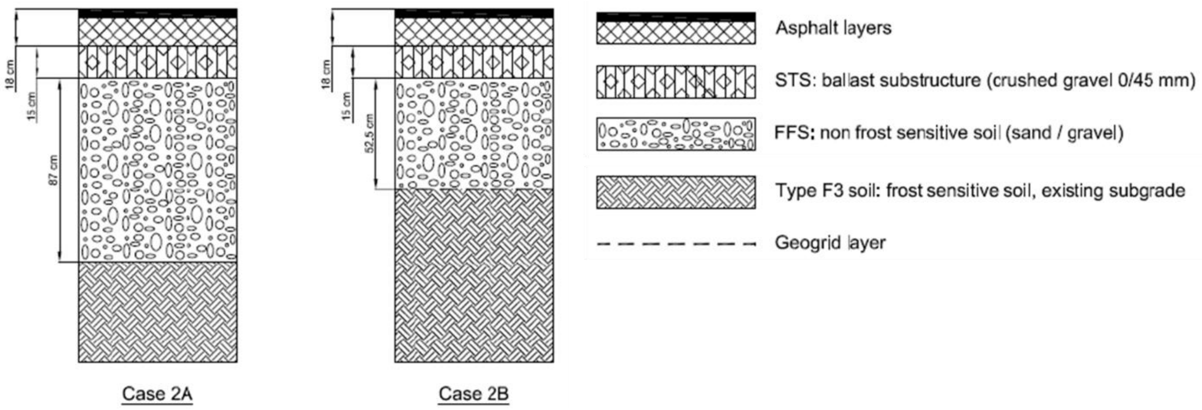

Table 1 shows specific values of the roads for all alternatives in their base case.

Table 1 Specification of road foundations

Parameter	Unit	CASE 2A - conventional -	CASE 2B - geosynthetics -
road width	m	12	12
geogrid	kN/m	-	30
separation and filtration geosynthetic	g/m²	-	150
grade and subgrade frost-protection layer	cm	87	52.2
ballast substructure	cm	15	15
asphalt layer (total)	cm	18	18
asphalt surface layer	cm	4	4
asphalt binder course	cm	14	14

The foundation is considered as having a working life of 30 years because of the demanding conditions of the weak subgrade. The asphalt layer is assumed to consist of a 4 cm surface layer with a working life of 15 years. The 14 cm binder course has a working life of 30 years.

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 - FOUNDATION STABILISATION*

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 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 sub-base layers (cost basis third quarter 2021).

		CASE 2A - conventional -			CASE 2B - 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
Remove topsoil and store temporarily in the construction site area	m³	7.8	7.78	€ 60.68	3.7	€ 7.78	€ 28.79
Construct and compact the formation	m²	12.0	€ 0.60	€ 7.20	12.0	€ 0.60	€7.20
Supply and install geogrid	m²	-	-	-	12.0	€ 3.12	€37.40
Supply and place base course 0/45 mm	m³	10.4	€ 26.18	€ 273.30	6.3	€ 26.18	€163.97

4 COST COMPARISON - FOUNDATION STABILISATION

Table 3 Cost comparison for base courses (cost basis third quarter 2021)

	CASE 2A - conventional -	CASE 2B - geosynthetics -
Site preparation	€ 4,692.00	€ 4,692.00

	CASE 2A - conventional -	CASE 2B - geosynthetics -
Preparatory work	€ 67.88	€ 35.99
Geosynthetics	-	€ 37.40
Base course	€ 273.30	€ 163.97
Total costs/m without site preparation	€ 341.18	€ 237.36
Cost comparison	143 %	100 %

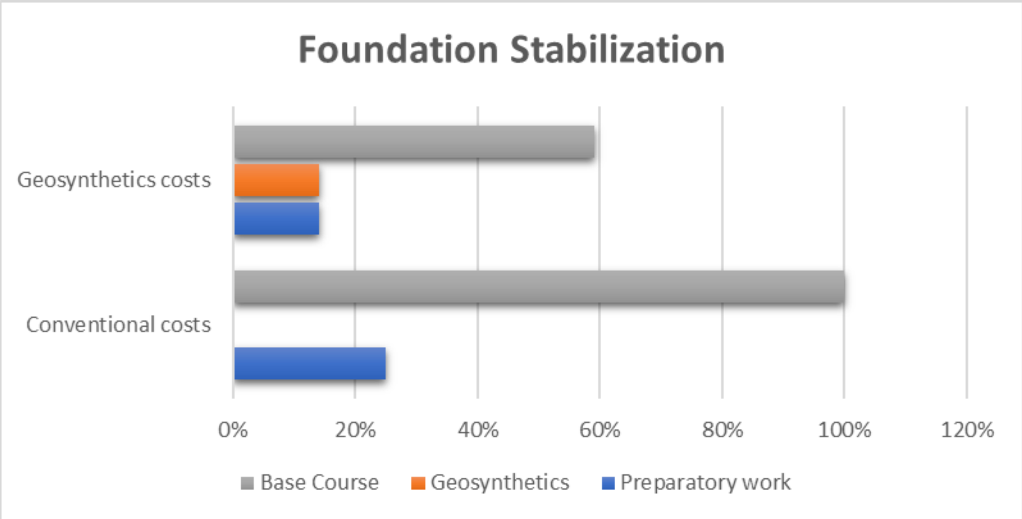

Figure 2: Schematic comparison of geosynthetics versus conventional costs

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 2 the load-bearing capacity of an unbound sub-base layer was examined, considering not only its thickness but also the application of a geogrid.

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 configurations examined, the cost saving was more than 30 %.

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.

6 REFERENCES

Ehrenberg H.; Mermet J.P. (2012), Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials, a study on behalf of the EAGM, General, EUROGEO 5, Valencia, Spain

Fraser I.; Elsing A. (2012), Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials, a study on behalf of the EAGM, CASE 4, Soil Retaining Wall, EUROGEO 5, Valencia, Spain

Laidié N.; Shercliff D. (2012), Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials, a study on behalf of the EAGM, CASE 1, Filter Function, EUROGEO 5, Valencia, Spain

Stucki M. et al. (2011), Stucki M., Büsser S., Itten R., Frischknecht R. and Wallbaum H., Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Material. ESUservices Ltd. commissioned by European Association of Geosynthetic product Manufacturers (EAGM), Uster and Zürich, CH.

Werth K.; Höhny S. (2012), Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials, a study on behalf of the EAGM, CASE 3, Landfill Construction Drainage Layer, EUROGEO 5, Valencia, Spain

Elsing, A.; Fraser, I. (2012), Comparative Life Cycle Assessment of Geosynthetics versus Conventional Construction Materials, a study on behalf of the EAGM, CASE 2, Foundation Stabilisation, EUROGEO 5, Valencia, Spain

Berthold, C.; Drees, G.; Krauss, S. (2019): Calculation of construction prices. 13., revised and extended edition. Berlin: Beuth

Kuhne, V.; Kattenbusch, M. (2017): Plümecke – Price determination for construction work. 28., revised and updated edition. Cologne: Rudolf Müller