APPROPRIATION OF RECYCLED MATERIAL AND LOCALLY WON SOILS AS FILLS IN GEOGRID REINFORCED STRUCTURES: CASE STUDIES

Omar Naciri[1] & Theo Huybregts[2]

[1] *Tensar International, Germany (e-mail: naciri@tensar.de)*
[2] *Tensar International, Netherlands. (e-mail: huybregts@tensar.nl)*

Abstract: Geogrid reinforced soil structures have been shown to have significant cost benefits over more traditional construction methods such as reinforced concrete in many published studies. As the acceptance of reinforced soil grows, these benefits are being realised and the scope of the applications is becoming much wider.

This paper presents 5 different examples of reinforced soil structures using geosynthetics with recycled and locally won soils with, and without, lime stabilisation. The case studies describe the use of the more marginal, compressible, soils as fills and a project where a reinforced soil retaining wall system was adopted as a direct alternative to reinforced concrete to save time and money on an award winning scheme.

Keywords: Geogrid, economics, environment, reinforced slope, reinforced structures, case study

INTRODUCTION

Geosynthetic-reinforced structures demonstrate economic and ecological benefits over traditional concrete structures and have become established as an alternative construction method. The economic advantages of this construction method compared to traditional solutions have been evidenced in various publications and studies. Past experience shows a comparatively high savings potential of up to 50 percent. This aspect has definitely contributed to the success of this construction method.

Ecological aspects, such as designing eco-friendly and aesthetic structures, which additionally help to save natural resources, are becoming increasingly adopted as the preferable option by all parties involved in a project.

Resulting from an increased public awareness of resource protection, the German government has come up with new legal provisions regarding the introduction of closed material cycles. The land filling of waste materials shall in future only be permitted in exceptional cases, which places increased emphasis on the recovery of secondary raw materials.

Geosynthetic-reinforced soil structures demonstrated decisive advantages in this respect, for instance, recycled materials from construction and demolition works can be used as interfill between the reinforcement layers.

In addition to the use of recycled materials, locally won soil can also be used as backfill in geosynthetic-reinforced soil structures. Several case studies from Germany and the Netherlands are presented on the following pages, providing an overview of the potential applications.

USE OF RECYCLED MATERIALS

General

The German law regarding closed material cycles and waste management requires all persons and organisations involved in the relevant processes to submit evidence on sustainable impacts. This often happens in the form of an eco-balance or life cycle assessment, where all stages of a product covering production, use and disposal are taken into consideration. At European level, a so-called eco-credit system is currently under debate. Such a system shall create incentives ensuring that in addition to purely economic aspects also sustainability plays an increasing role in the assessment profile of construction projects. The avoidance and/or minimisation of waste and other residual materials shall be given priority. Another important target will be the prevention of unnecessary mass transports, which can be accomplished by using on-site materials wherever possible. This is the case for instance, when existing buildings and their premises are used in the construction of new projects and the arising demolition material is reprocessed into recycled building materials which can then be used on site (Figure 1). This helps to save natural resources such as sand and gravel. Today, recycling plants for construction and demolition waste and the reuse of bituminous materials from road excavations, milling waste, etc. demonstrate technical and economic maturity and therefore help to cut costs considerably.

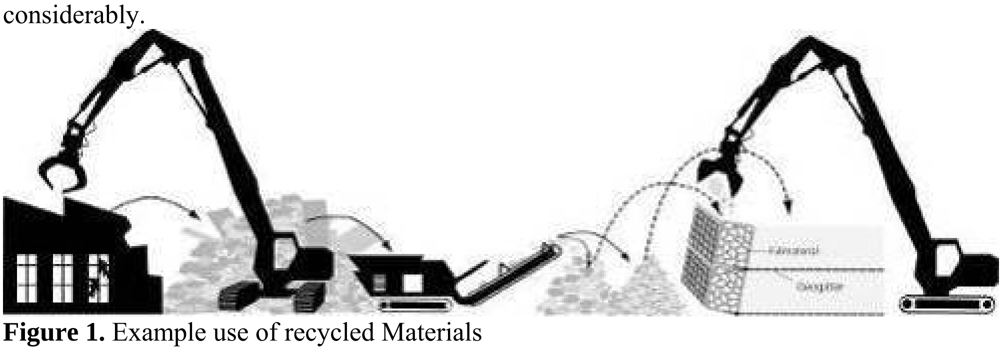

Figure 1. Example use of recycled Materials

Practical case studies (use of recycled materials)

Case study 1: Geogrid-reinforced gabion wall for noise protection

The premises of an abandoned British military base in the south of Duisburg were to be transformed into an attractive residential area with an adjoining commercial zone. The contract-winning landscape architects had the idea to structure the available space by varying heights and sloping planes. The waste material arising from the demolition of the barracks as well as the additionally excavated soil was to remain on site for further use in the execution of the project. Apart from serving for terrain modelling, the material was also put to use in noise protection systems.

The project area was subdivided into three different zones of use extending from east to west. The eastern part was to be converted into housing developments, while the western part was intended for commercial use. In the area between these two zones a 3.3-hectare public park was to be created, forming a buffer zone for visual and acoustic separation with a wedge-shaped embankment 6 meters in height. The required height of 6 metres was obtained from a noise emission assessment. To ensure optimal functioning of the noise protection system, the structure was endowed with a steeper slope facing the commercial zone.

Because of its exposure, emission control installations were needed and also an aesthetic design solution had to be found. Therefore, the facing of the embankment was to be constructed as a gabion wall. The gabions were backfilled with on-site clinker fragments (75/100 mm particle size) derived from the demolition of the barracks. The gabion wall had a face angle of 85°. The gabions were reinforced with geogrids by mechanical connection according to static requirements; the geogrids had to be highly resistant and robust. Using recycled material (RCL I class) as backfill may lead to high pH values, which the installed products must have the chemical durability to withstand. Moreover, the geogrids had to be resistant to mechanical damage likely to result during the installation and compaction of the coarse, angular backfill material (Proctor density = 100 %).

The embankment was then capped with 1.70 m of fill material and 30 cm of topsoil. On the slope facing the residential area - with a gradient of 1:2 to 1:6.5 - trees, bushes, meadows and lawns were planted.

The Office of Town Planning and Project Management imposed stringent safety requirements on the total concept. The steep edge of the embankment, for instance, had to be protected by a 1.80-metre-high bar grate fence and no high-growing vegetation was to be planted in the immediate proximity of the fence.

Owing to the combined construction method, some 50,000 m³ of recycled material could be reused without having to sacrifice design, aesthetic and safety considerations. An analysis of direct costs compared to alternative solutions resulted in cost savings of approximately 65 %.

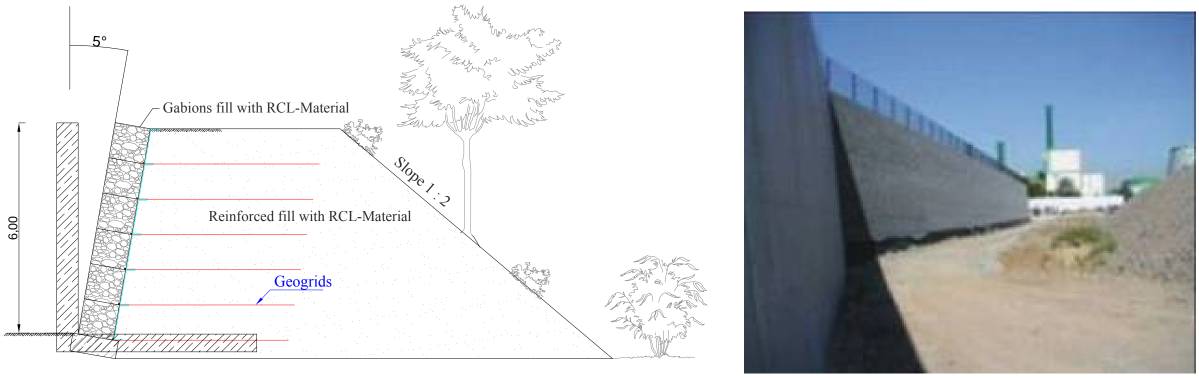

Figure 2. Cross section of constructed geogrid reinforced structure and picture

Case study 2: Retaining structure with precast concrete blocks

A supermarket was to be built on a steeply inclined site in Remscheid, for which the terrain had to be adequately re-levelled which required a 7.5-m-high retaining wall along one edge of the site. The contractor decided to install a geogrid-reinforced retaining structure with a facing of precast concrete blocks. The concrete debris resulting from on-site building demolition works was used as a backfill for the construction. After preparing the foundation, the Tensar Wall System comprising concrete blocks, uniaxial geogrids and connecting elements was installed.

The choice of a geogrid-reinforced structure provided a low-cost solution with considerable benefits over traditional reinforced concrete solutions.

An analysis of direct costs compared to alternative solutions resulted in cost savings of approximately 50 %.

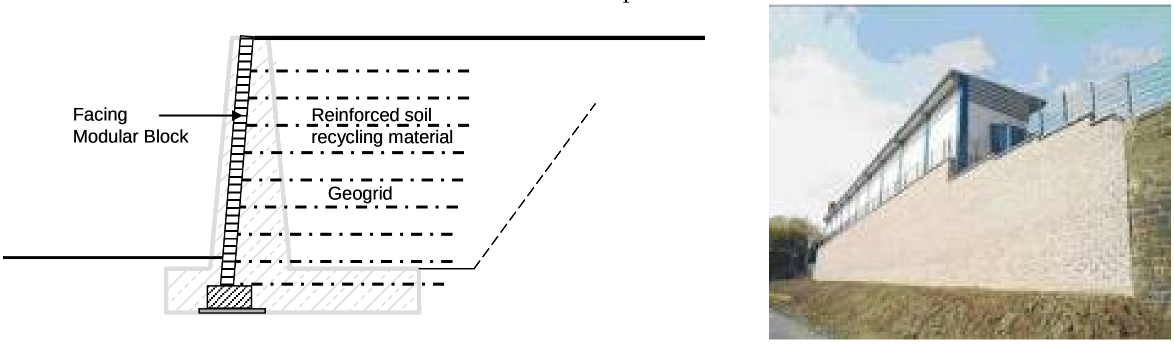

Figure 3. Cross section of constructed geogrid reinforced structure and picture after the construction e

USE OF ON-SITE SOIL MATERIAL

General

Reusing local soil or soil material obtained from on-site construction works (such as in terrain modelling) for backfill offers a huge savings potential. This for example, may be of great advantage in the construction of noise protection systems. The steadily increasing road traffic and the growing size and weight of transport vehicles not only necessitate roads with a higher load-bearing capacity, but also cause more noise. Politicians have responded to this need in recent years and have reduced the permissible noise emission limits. This naturally increases the demand for efficient noise protection systems.

In addition to the cost of such structures, environmental and aesthetic aspects need to be taken into consideration. Does the noise protection wall fit neatly into the surrounding landscape or does it even add a “green touch” to an asphalt- and concrete-dominated environment?

Geosynthetic-reinforced soil structures kill two birds with one stone: they allow using on-site soil material and create a neat facing system that can optionally be covered with vegetation.

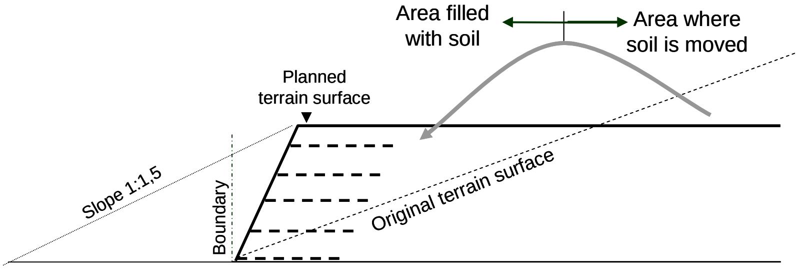

Figure 4. Example of use of on-site material

Practical Case studies (use noise protection wall)

Case study 3: Noise protection wall alongside a motorway

A noise protection wall was to be installed next to a motorway exit as part of a motorway expansion project at Mainzer Ring (BAB A 60).

When designing the noise protection wall, the typical properties of a central urban area had to be taken account of. To allow an optimal use of the area under construction, the noise protection system was to occupy only a minimum of space. It was also important to keep the cost of maintaining the noise protection wall low and to design the wall so that it matched the surrounding landscape.

For the installation of the wall system, designers were able draw on large masses of excavation material from other construction projects in the Greater Mainz Area and from the adjoining new town development area. This excavation material consisted of solid to semi-solid loess loam/lime. To render the project economically efficient, the excavation material was not be disposed of and the cost of procuring adequate soil material was to be kept to a minimum.

The noise protection wall was to have a height of up to 10 metres and a inclination of 60°.

The building contractor developed a concept jointly with the geogrid manufacturer, proposing the construction of a geogrid-reinforced steep slope and the use of on-site soil material mixed with a bonding agent for improvement. The backfill material used for constructing the noise protection wall was installed by means of a sandwich-type technique, with a 30-cm layer of recycled material alternating with 2 x 30 cm layers of upgraded loess loam. Steel mesh was added to the slope facing for protection. An erosion control mat was placed behind the steel mesh and hydroseeding was applied to establish new vegetation.

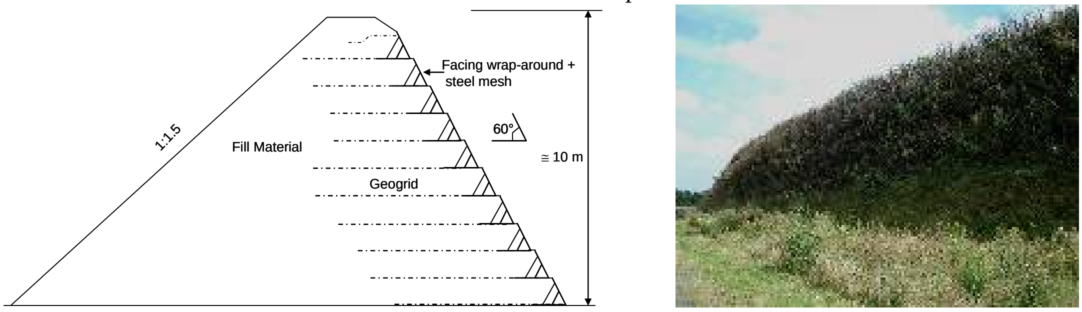

Figure 5. Cross section and picture after full vegetation

Case study 4: Noise barrier Berlin

Due to the dramatic increase in traffic density in the northern railway corridor in the area of Hohenschoenhausen, the Berlin Senate decided to adopt adequate noise abatement measures. In a 1.5-km-long section of the railway line a noise barrier was to be installed, using the slightly contaminated soil material on site for construction. The side slope of the embankment facing the rail bed had to be optimised by making it a little steeper, while the other face was to be constructed with a normal slope angle of 1:1.5. For design reasons a height of 9.6 metres was required. Various options for designing a steeper slope were investigated, including a reinforced concrete wall and a new type of slope supporting system backed by geogrids that can be covered by vegetation. After a thorough comparative assessment of the parameters of all available options, the system incorporating a vegetated cover was definitely considered to be the best solution. Economic as well as ecological criteria were taken into account in the decision-making process. The construction method chosen had the following advantages:

- Eco-friendly construction covered by vegetation
- Short construction period
- Only one soil structure with no interfaces
- Relatively even contact pressure distribution for a 9.6 m high structure (imposed bearing pressure ≈ 200 kN/m²)

This last advantage was regarded as crucial in the assessment of the possible options as in some areas of the 1.5-km-long construction insufficient load-bearing capacity was expected. On account of the aforementioned benefits, it was easy for the Berlin Senate as the builder-owner to opt for this solution. The front side of the completed slope supporting system consisted of a corrosion-resistant steel wire mesh (bottom grid/front grid), which had welded eyelets on either end to accommodate adequate connection. The geogrid layers were embedded in the embankment for reinforcement and were connected to the steel mesh construction using mechanical connection with steel pins.

The slightly contaminated on-site sand was used as backfill and topsoil was spread near the surface area to facilitate the planting of vegetation. The backfill material was compacted in accordance with ZTVE-StB requirements to obtain optimal shear strength parameters.

The project goals could be accomplished to the full satisfaction of all parties involved in construction. In a subsequent calculation, the expenses incurred for constructing the 1500-m-long sound barrier were compared to the cost of a reinforced concrete wall, which had been envisaged as an alternative option (Nimmesgern 1999). The latter would have amounted to 4200 €/m compared to actually 1260 €/m (excluding soil), which is only 30 % of the cost. Not accounted for in the calculation are the additional costs resulting in the areas with insufficient load-bearing capacity.

Adding the amount of fuel needed for material streams and assembly as an additional cost factor in the economic comparison results in approx. 5000 litres of diesel for the completed construction as compared to 85,000 litres of diesel required for a massive reinforced concrete wall (approx. 17 %!).

Summing up it can be said that the chosen option - using the slightly contaminated on-site material as backfill and a flexible geosynthetic-reinforced retaining structure - was the perfect construction method for this specific project.

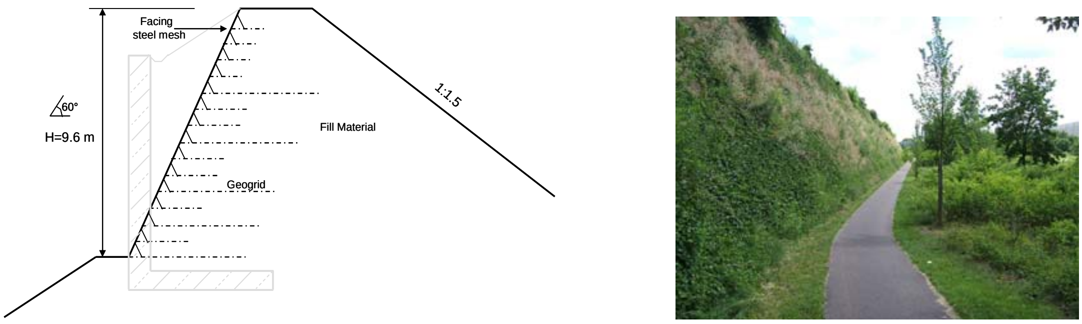

Figure 6. Cross section and picture after full vegetation

Case study 5: Project Amsterdam A2/A9

The Amsterdam A2/A9 project is the extension, of an intersection between two major highways in the Netherlands. A part of the project involves constructing landscape mounds over very soft soils and uses as fill the soft soils that came free during the construction of the intersection, thus preventing costly removal and disposal. In the landscape project three major embankments up to 12 m high were constructed. These mounds of soft soil are intersected by 4 clefts. These clefts, required a total of 8 steeps slopes up to 65 degrees, which were designed incorporating a geosynthetic reinforcing system. Predictions of deformation and settlements of the soft soil embankment and sub-soil were made and subsequently compared with actual deformation on the site. The design and construction of this landscape art project has resulted in valuable experience in using reinforcement with and on soft soils.

Several different methods of forming the steep clefts were considered. The consultant compared these methods and selected the geogrid reinforced soils solution as the most economical. From a preliminary calculation the geogrid reinforced structure is 30% cheaper compared to a more traditional method. The fill material of reused soft soils is reinforced with horizontal layers of geogrids using the wraparound facing method. The advantage of this flexible construction is that settlements in the subsoil and any settlement of the embankment fill have no negative influence on the stability of the construction itself. This results into an integral system, which is enough flexible to follow the expected settlements and internal setting. This type of construction is able to follow normally differential settlements up to 10%.

The subsoil underneath the three embankments is highly variable and in places consists of 4-5 m of peat and soft clay. The fill material for the embankment was site-won from the construction of the intersection which was also very variable, including soils affected by previous soil improvement techniques.

Figure 7. Scaffolding during construction

For this wraparound method the previous layer is wrapped around the front and connected to the next of geogrid using a polymer bodkin full strength connection. On the inside of the wraparound face a geotextile liner has been used to separate and prevent erosion of the fill material. The wraparound construction requires a scaffolding in order to be able to compact the fill material.

Figure 8. Cleft after finishing construction

A steel plate covering about one year after finishing of the construction will cover the slopes. Almost all major settlements will have occurred by then. The other sides of the embankment will be planted with maintenance free vegetation (salix repens).

CONCLUSION

Five different case studies of reinforced soil structures using geosynthetics with recycled and locally won soils with, and without, lime stabilisation have been presented. These structures demonstrate economic, ecological and environmental benefits over traditional concrete structures; they are extremely cost effective, showing a comparatively high savings potential of up to 70 percent.

Corresponding author: Mr Omar Naciri, Tensar International, Brühler Straße 9, Bonn, 53119, Germany. Tel: +49 (0) 228 9139226. Email: naciri@tensar.de.

REFERENCES

Nimmesgern, M. 1999. Geokunststoffbewehrte Bauwerke: steil-sicher-grün. Anmerkung aus ökologischer und ökonomischer Sicht, Geokunststoffkolloquim der Naue Fasertechnik, Espelkamp.

Meisner, E., Huybregts, Th., Uijting, B. 2000. Amsterdam A2/A9 project; embankments using reinforced soft soils on very soft sub-soils, Proc. Of the second European geosynthetics conferece, Bologna, p. 257-260

ZTVE-StB 94, Zusätzliche Technische Vertragbedingungen und Richtlinien für Erdarbeiten im Straßenbau