ACTIVE AND PASSIVE FACING SYSTEMS FOR REINFORCED SOIL STRUCTURES

Abstract

Facing elements of Geosynthetic Reinforced Structures (GRS) can be constructed in various front-end design systems such as concrete and concrete blocks, gabions, curved steel mesh as lost formwork and much more. Further separation have been driven between passive facing elements which do not support the load transfer of the construction's own weight and traffic load and further active wall systems, which takes loads from the structure. The development of the new construction of the Geosynthetic Reinforced Structures was initiated by the contracting companies in order to create a suitable system for the application on large-scale surfaces with low maintenance intensity and intervals. Typical applications are wing walls at bridge abutments and noise barriers.
Often such reinforced earth are mostly built up using the passive construction method using the wrap around method with temporary facing. This means that the front elements are not actively loaded by the earth pressure. In an active system, front elements such as e.g. prefabricated concrete panels attached and connected via a connecting element with the geogrid. The front elements are thus burdened even by the earth pressure of the construction. The earth pressure that acts on the front element is conducted via connecting elements in the geogrids and anchored in the earth body. Due to the large-scale precast concrete parts, the distance of the geogrid can be made larger compared to the common KBE systems. This results in very high connection forces, which, as mentioned above, require a secure connection between the front elements and the geogrids.

Thomas SILBER-HASSLACHER [1], Jozef SŇAHNIČAN [2]

1 Introduction

For traffic route construction, in which terrain jumps often have to be carried out in confined spaces in the immediate vicinity of existing structures and the resulting effects, geotextile reinforced structures (GRS) with facings systems made of reinforced or unreinforced precast concrete elements are an alternative to conventional construction methods. Such system solutions also meet important selection criteria with regard to the operating phase for applications in railway construction, are comparatively easy to set up and economically advantageous. In addition, concrete as a building material for the exposed outer skin of the construction is a well-known and proven building material in the construction industry, the quality of which can be tested and assessed using proven standard methods. The use and processing of concrete or prefabricated parts made of it also represents a familiar and low-risk variant for many engineers or builders.
The possibilities, but also the special requirements for planning and execution, which result from the combination of a ductile, reinforced with geosynthetic soil and a rigid concrete element will be discussed.

1.1 Overview of facing elements

Facing elements of Geosynthetic Reinforced Structures (GRS) can be constructed in various front-end design systems such as concrete and concrete blocks, gabions, curved steel mesh as lost formwork and others.

[1] Thomas Silber-Hasslacher, Dipl.-Ing., HUESKER Synthetic GmbH, Im Schlantenfeld 19, 4040 Linz, Austria.: + 43 6604458737, hasslacher@huesker.com
[2] Jozef Sňahničan, Ing., GEOSOUL s.r.o., Rusovská cesta 13, 851 01 Bratislava, tel.: + 421 918929747, info@geosoul.sk

Often such reinforced earth are mostly built up using the passive construction method using the wrap around method. This means that the front elements are not actively loaded by the earth pressure. (Fig. 1) In an active system, front elements such as e.g. prefabricated concrete panels attached and connected via a connecting element with the geogrid. The front elements are thus burdened even by the earth pressure of the construction. (Fig.2)
The earth pressure that acts on the front element is conducted via connecting elements in the geogrid and anchored in the earth body. Due to the large-scale precast concrete parts, the distance of the geogrid can be made larger compared to the common KBE systems. This results in very high connection forces, which, as mentioned above, require a secure connection between the front elements and the geosynthetic grids. The construction and compaction need to be taken with due care, because any failure on loss compaction leads to movements to the front elements and further deformations of the structure.

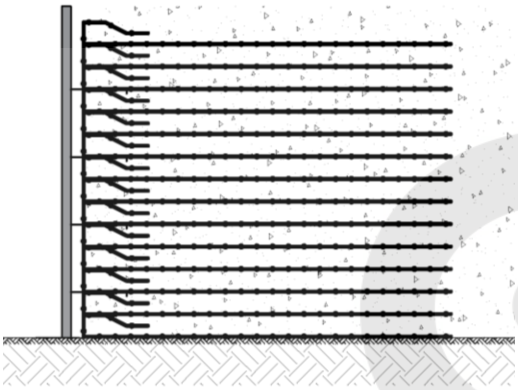


Figure 1 Passive System

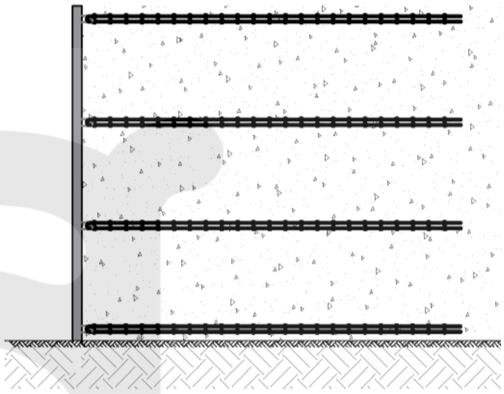
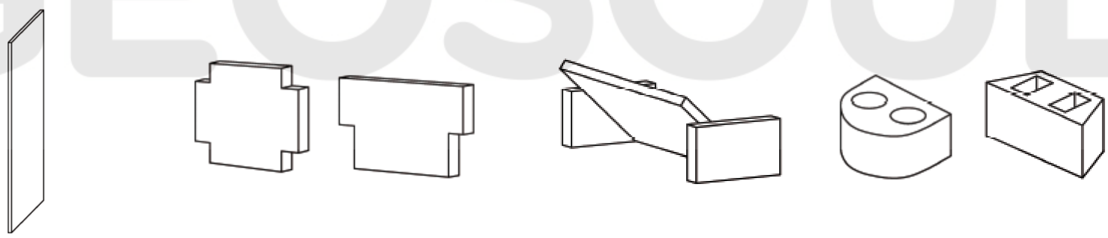


Figure 2 Active System

2. Active Wall Systems - Components and systems

In addition to the RiL 836 "Earthworks and other geotechnical structures plan, build and maintain" (Ril 836) of the DB Netz AG, which founded and fixed the planning and execution of e.g. flexible support structures in railway construction regulates KBE constructions acc. DIN EN 14475 [2] characterized by their external facing construction. The group of Concrete facings includes components with full or partial height, plant troughs or blocks and therefore counts to the non-deformable or slightly deformable outer facing structures. Figure 3 shows various types of components as examples.



a) Panels in full height **b) Panels in partly height** **c) Plant trug** **d) Block Stones**

Figure 3 Various types of components

2.1 Concrete panels

Concrete panels are usually reinforced concrete components, which can be manufactured in various shapes and surface finishes. They are often used when GRS constructions with large viewing areas and straight-line layout are required in the floor plan. In addition, especially when using concrete panels full height a fast construction progress can be achieved. Transporting and handling the elements, however, requires a suitable lifting device, usually mobile cranes, whose use can be a costly factor for the construction project.

Regardless of their size, the choice of a suitable connection between the finished parts and the geosynthetic reinforcement is of great importance.

2.2 Concrete block stones

As an alternative to large-format panels mostly unreinforced, solid blocks or hollow blocks can be used. Often, these are used in landscape architecture demanding areas. Due to the small stone formats, it is relatively easy to make small radii, corners or jumps, but this requires more manual labor. Furthermore, smaller stone formats are favorable to endure damage from differential settlement of the ground damage.

Another advantage of geosynthetically reinforced block walls is the extremely ductile behavior under high dynamic loads. However, documented findings on this are limited to earthquake loads (Tatsuoka et al.) [3] or (Ling et al.) [4], as such systems, to the knowledge of the authors, at least in the network of DBAG, not yet established in the sphere of influence of railway loads were.

3. Connection of facing and geosynthetic reinforcement

In addition to the stiffness of a facing element defined in [2] as a distinguishing criterion, it is important to distinguish whether the external facing is part of the supporting system or in addition to the aesthetic component both in terms of proof of stability and serviceability but also in terms of durability must only fulfill a protective function. Figure 4 and 5 shows the difference of load distribution between the two systems (active & passive wall) schematically, whereby the passive construction is understood to mean a body protected in the return-envelope method and the front elements are not subjected to earth pressure as shown in Fig. 4 in the passive construction. In an active system as shown in Fig. 5 the concrete elements are non-positively connected to the geogrids using suitable mechanisms. The front elements are thus charged directly by the earth pressure of the backfill. This action must then be transmitted through the connecting element in the geogrid reinforcement and anchored back in the earth.

Figures 6 and 7 show possibilities for the execution of active and passive connections, which have proven themselves in practice, see also Rüegger et. al. [5].

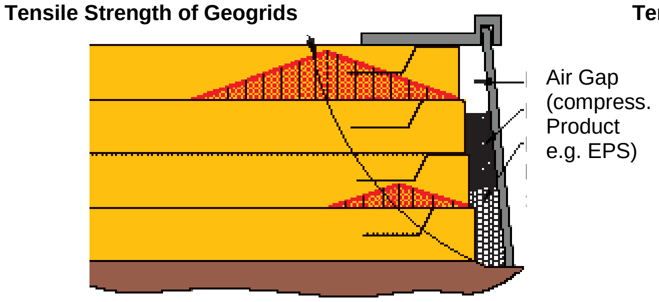


Fig. 4: Load Distribution Passive Wall

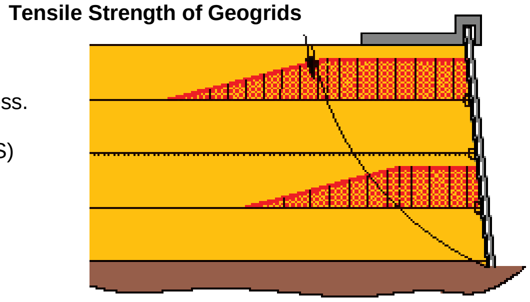


Fig. 5: Load Distribution Active Wall

Fig. 6 Active System Full height panels connected via steel rod to geogrid C. Brok, HUESKER B.V.

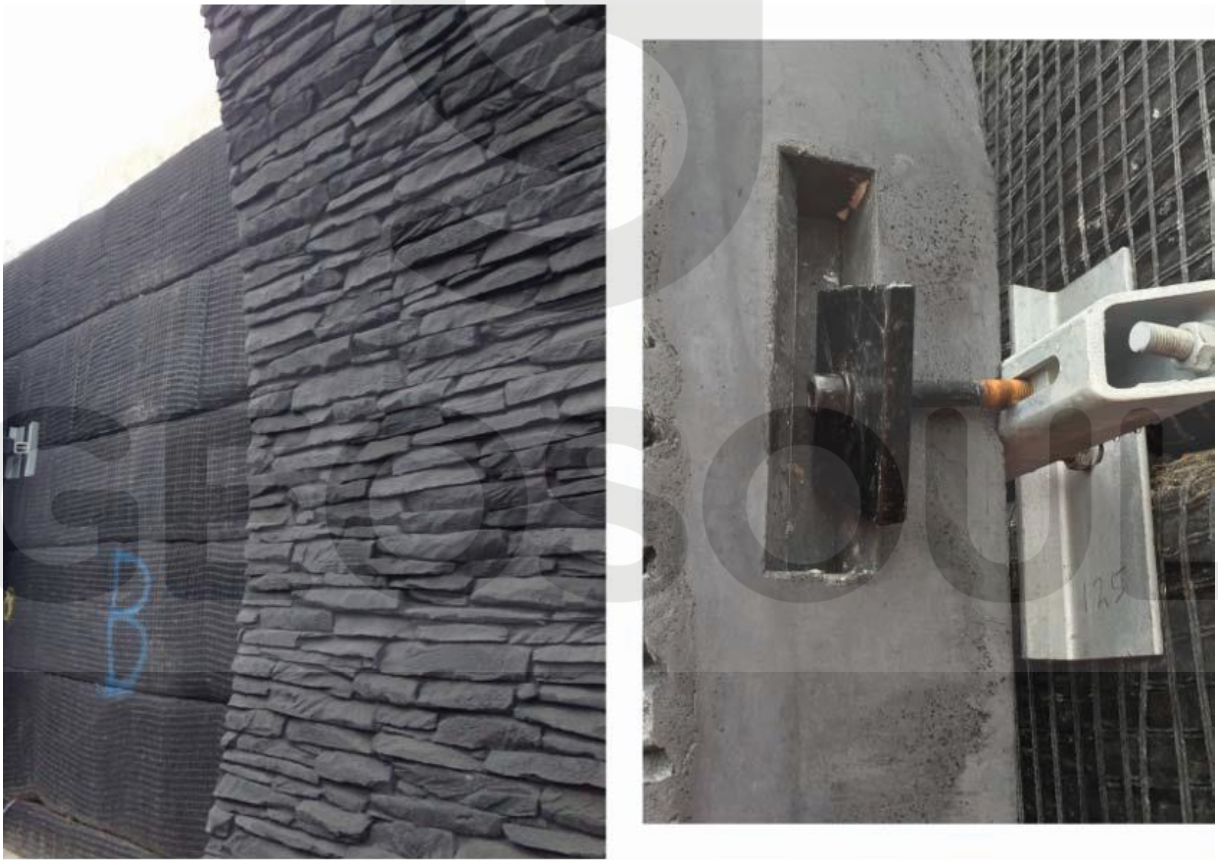
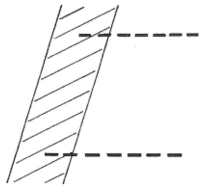


Fig. 7: Concrete Facing with passive facing, photos: C. Brok, HUESKER B.V.

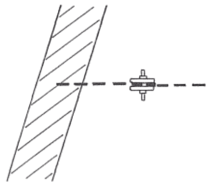
If the connection is made by setting in concrete with the facing element (fig.8a), the durability of the geogrid must be ensured in contact with concrete. This necessarily results in the choice of a geosynthetic material which is produced from an alkali-resistant raw material (e.g., PVA). The concreting rigidity and immovably connects the geogrid to the facing element. Potential settlements of the filling material can therefore not be compensated and, if necessary, lead to impairment of the connection strengths.

Furthermore, damage to the geogrid must be avoided at all times, as subsequent replacement is not possible. This can also be a disadvantage when short-term changes in the required geogrid strength become necessary. Special attention must therefore be paid to appropriate planning and installation planning.

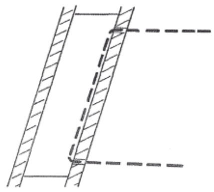
a) Concrete
b) Connections with Clambs
c) Looping in
d) Friction between the elements
e) Friction and Toothing
Fig. 8 Possibilities for carrying out a connection of earth body and facing [5]



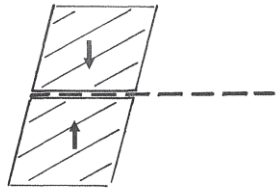
a) Concreting



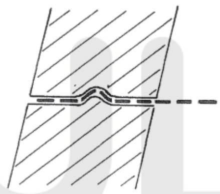
b) Connection with Clambs



c) Looping in



d) Friction between Elements



e) Friction and Toothing

Fig. 4 Possibilities of connection between geosynthetic earth wall and concrete facing

Fig. 9: Coupling of large concrete elements, photo: C. Brok, HUESKER B.V.

A connection via clamps or other connecting elements, which are first mounted in the construction field (Fig. 8b), can offer more flexibility for the construction process, in contrast to concreting. Depending on the useful life of the construction, the proof of sufficient durability must then also be provided for the connecting element. To avoid additional stresses on the connectors, it is also advantageous to choose a design that can compensate for any differential settlements between filler and facing, see e.g. van Keßel et al. [6]

If the geosynthetic reinforcement is connected to the concrete facing by looping in (see Fig. 8c), the adaptation of the reinforcement width to the slots provided in the facing element must be taken into account. Frequently, therefore, no full-surface reinforcements but reinforcing ribbons are used in this construction method.

In addition to the above-mentioned types of connection, the reinforcement elements can be clamped between two facing elements (see Fig. 8d or Fig. 8e). The connection mechanism is based on friction and toothing. The geosynthetic reinforcement must not be disproportionately damaged by the pinching. Block and form bricks with a large footprint are therefore better suited for this type of connection than slim concrete panels. When hollow bricks are used, they can be filled with crushed stone, which increases the bond strength between the blocks and the geo-plastic reinforcement.

3.1 Foundation of the facing

As a matter of principle, it is recommended for all facings systems in supporting and noise protection constructions made of concrete elements, block laminations or gabions (M Gab) [7] to carry out at least one leveling or supporting layer between the base and the sole of the facing elements. When constructing concrete slabs, however, it is recommended to use a frost-free, reinforced strip foundation in order to achieve precise alignment of the elements and sufficient stability against breakage.

3.2 Design Analysis

The basics and concepts for demonstrating the stability and serviceability of a GRS are contained in the recommendations for the construction and calculation of earth bodies with reinforcements made of geosynthetics (EBEGO) [8], which are available through the Iron-Bail-specific Construction Regulators (EBRL) [9] and the RiL 836 is anchored as a regulatory framework for railway construction. However, the execution of KBE structures under the influence of railway loads currently requires individual approval and is therefore still rare. Especially with regard to consistently positive experiences with executed constructions, see e.g. Hangen [10] is likely to change in the medium term, though. An up-to-date overview of long-term experience as well as practical information regarding special requirements for the design and dimensioning of KBE in railway construction can be found in Lieberenz, Göbel, Fischer and Großmann [11], [12]. Requirements for the design of the connection between CFU and outer skin are dealt with in section 7.6 of the EBGEO. Based on the gem. [2] introduced assignment to not or conditionally deformable systems can therefore be determined acting on the front elements horizontal stress. Similar to the procedure for dimensioning support bodies made of reinforced steel (M SASE) [13], the earth pressure is correspondingly reduced with the aid of adaptation factors. The size of these adjustment factors should be selected according to EBGEO, Table 7.2. The verification of the internal stability of the concrete elements shall be carried out in accordance with [7]

3. 3 Durability

The durability of a reinforced plastic reinforced support structure depends, as with other engineering structures, on the conditions of use and environmental conditions as well as on the durability of the building materials (geosynthetics, soil, concrete, fasteners).

All components are claimed during their service life by chemical / biological influences or by mechanical effects, for example. During installation or impact. In contrast to the reinforced earth body, the facing of a supporting structure is also suitable for all external influences, such as UV radiation, regular or exceptional temperature load, de-icing salts, herbicides, pesticides or aggressive groundwater. In order to ensure the durability of the concrete elements and thus also the protection of the reinforced earth body, it is therefore necessary to take these into account in the planning and to demand corresponding requirements and quality standards for the production. Apart from the compressive strength and chemical resistance of the concrete, criteria for coloring and edge design must also be taken into account. Compared to other building materials, it is advantageous in this regard that the production, quality assurance or testing of concrete components in construction is well known and widely used. Furthermore, thanks to sophisticated machine technology, high quality is generally achieved. An overview of the requirements for non-standard concrete products, including small-scale unreinforced concrete blocks, is available e.g. in BGB-RiNGB [14]. However, these usually refer to the standardized procedures for standardized concrete components. Furthermore, in BGB-RiWPK [15] a recommendation for a factory production control is made. A documentation on the durability of concrete blocks under real project conditions was published by the Federal Highway Administration (FHWA) in the US [16]. Less concretely regulated are the requirements for fasteners. In general, the suitability of a compound in accordance with EBGEO [8] is therefore considered in proficiency tests, s.g. Connection tests on the entire system proved.
The fundamentals and test methods for demonstrating the durability of the geosynthetic reinforcement are u.a. in [8] or CUR Building & Infrastructure [17], but further details are not given in this context.

4. Passive Wall Systems - System Muralex

The Muralex® system is a facing that can be attached to steep reinforced soil slopes or reinforced soil vertical walls (i.e. noise abutement walls, road and railway embankments, bridge abutments etc.). The front face of the system consists of a zinc coated steel panel at a defined distance in front of the reinforced soil block creating a hollow space to be filled with crushed rock. (Fig. 10) The size of the rock material has to be adjusted to the steel mesh apertures being used. The main construction is the reinforced soil wall and the Muralex® system is considered a wall facing system, only supporting its own weight. It has the following advantages:

- The Muralex® system can easily be attached to the front of the reinforced soil wall after it has been constructed or even in the course of the construction process.
- The distinct separation of reinforced soil block and the Muralex® system enables a well compacted high-grade earthwork project.
- Potential differential settlements between facing and reinforced soil block will be reduced to a minimum that don´t affect the stability and usability of either the reinforced block or the facing.
- The geosynthetic reinforcements are protected against damages by accident or vandalism.
- In the case of damage the Muralex® system can easily be replaced.
- Visually disturbing inaccuracies in the front of the reinforced wall can be obscured by the front panel.

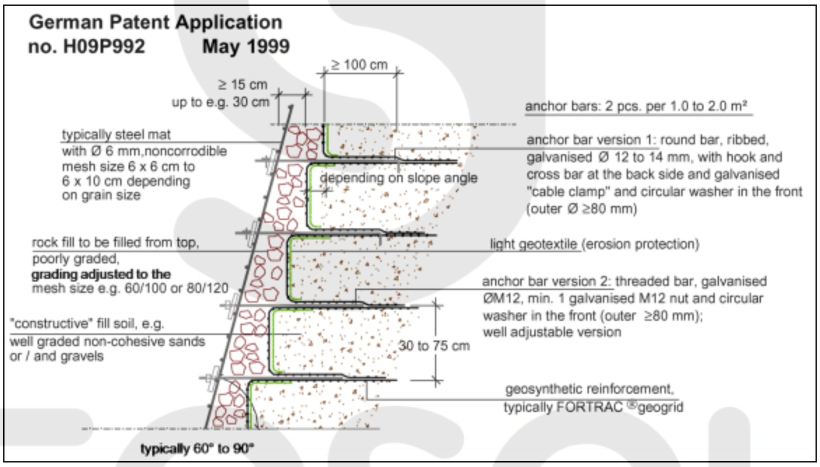


Figure 10: Passive system sketch of Muralex® system

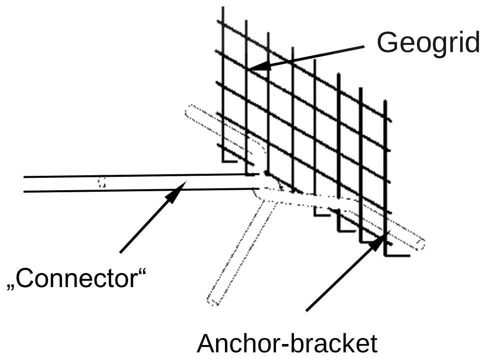


Fig. 11 System Muralex® with connector/fixing element

Fig. 12 Site Pictures of System Muralex®

Summary

Geosynthetic reinforced soil structures have long been a technically, economically and ecologically interesting alternative construction method. Selected reference projects show that this can even apply to buildings under the influence of railway loads. Concrete components offer a low-maintenance and durable possibility of protecting the geosynthetic reinforced support structure from external influences. As Concrete Facing components of different shape and size are summarized, which are non-positively connected as part of the support system with the geosynthetic reinforcement or attached as passive elements in front of the reinforced earth body. Concrete molding systems are mostly manufactured industrially and generally have consistent and high quality.

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