# Road noise barriers as longitudinal waste deposits - Lined slopes with geosynthetics protecting the environment

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ABSTRACT: Worldwide more and more road noise and view-blocking barriers are being built along roads, motorways and railway lines, with a core that is made from mineral waste. This waste material can be in the form of slag, ash from municipal waste incineration plants or contaminated soil from the rehabilitation of contaminated sites, residue from construction waste recycling or industrial processing residue (slag, ash, foundry sands, conditioned sludges etc.). These waste products have to meet certain environmental-chemical requirements and must be provided with a surface sealing for groundwater protection. This sealing system can be designed as a mineral sealing (compacted clay liner, CCL) or it can be made of geosynthetic material (geosynthetic clay liners GCL, geomembranes). The commonly required drainage layer can also be of gravel or crushed stone or it can comprise geosynthetic materials (geosynthetic drainage system). Many noise barriers have relatively steep slopes because there is limited space and the higher the barrier and the steeper the slope the greater the noise protection. The sealing and drainage systems therefore frequently require reinforcement in the form of geogrids to ensure slope stability.

*Keywords: noise barriers, contaminated sites, geosynthetic clay liners, geomembranes, environmental protection*

## 1 REASONS AND LEGAL FRAMEWORK FOR WASTE RECYCLING IN GERMANY

The protection of natural resources is a major goal of a functioning close loop recycling management, and this is also stipulated in the Closed Substance Cycle Waste Management Act (KrW/AbfG) of 1994 for the Germany (amended to an act in 2012). Besides strategies for avoiding the occurrence of waste, the material recycling of waste material is also required as a substitute for the extraction of new raw materials from natural resources and ranks second in the waste hierarchy. Many raw materials such as sand and gravel are not available in unlimited quantities, this already being due to the fact that there will be a shortage of excavation sites in densely populated areas in Germany. Reuse or recycling is therefore a key objective in a functioning circular economy and also essential in view of the huge quantities of mineral waste (approx. 200 million tons per year in Germany in 2011). If these vast quantities had to be disposed of, it would exceed the resources of existing landfills. In 2011 some 51 million tons of waste ended up in approx. 1,170 landfills in Germany (German Statistical Federal Bureau 2011). On the other hand, there is the problem that recycled construction materials or industrial waste may contain harmful substances (environmental-chemical pollutants), these either coming from their production process, their use or through the mixing with other contaminated materials (e.g. during demolition work). Disposal in places other than landfill sites therefore also involves the risk of material with harmful contaminants being spread over large areas in, around or beneath civil engineering constructions. This has led to a conflict of aims or an area of tension between, on the one hand, the protection of resources through the recycling of used building materials and waste products from industrial production processes or from municipal waste incineration plants in the most sustainable manner possible – these then being spread over large areas in or beneath structures - and a reliable and safe disposal in central landfills. As the recycling of mineral waste is absolutely essential for the above given reasons, it is therefore necessary to impose conditions such as compliance with threshold values, placement restrictions and technical protection measures.A recycling of waste that does not cause harm to man or the environment, especially surface water and groundwater, is required in both the German Closed Substance Cycle Waste Management Act (KrWG 2012) and in the German Federal Soil Protection Act / Soil Protection Ordinance (BBodSchG 1998, BBodSchV 1999), as in the Federal Water Resources Act (WHG 2009), as well as in Groundwater Requirements (GrwV 2010). In the construction industry the recycling of construction debris and its reuse as recycling material has been an established procedure for many years. Many other industrial sectors also produce industrial waste in their production processes (slag, ash, foundry sands, tailings) that can be recycled and used as construction materials (waste for recycling). Recycled construction materials can be used as a substitute for natural products (sand, gravel, crushed stone, and stones), also concrete aggregates such as cement clinker can be replaced by foundry sands from blast furnace slag, fly ash and silica fume, and asphalt aggregates such as crushed stones and bitumen can be replaced by reclaimed road construction waste and milled asphalt. These materials are therefore considered as substitute construction material. Other residual materials that occur in large quantities are slags from metal smelting, municipal waste incineration slags, foundry sands and tailings from gravel washing plants. These can be used as a full, or in most cases at least as a partial substitute for natural raw materials (substitute construction material). In 1994, the LAGA (federal state working group for waste) published the Guideline M20 on “Requirements for the material recycling of mineral residues/wastes – Technical Regulations “that was implemented in most of the German Federal States by decree in its revised form of November 6, 1997, and later as Technical Regulations on Soil in the current version of 05.11.2004 (LAGA TR Boden 2004). The LAGA Guideline M20 currently still governs the recycling of mineral waste in the Federal Republic of Germany, even though some Federal States have drawn up their own codes of practice, these, however, being basically in line with the LAGA Guideline. The preferential reuse is for road or also railroad embankments and in noise and sight barriers, without or with the defined technical protection measures, depending on the contamination class. Technical protection measures are water impermeable surface layers of asphalt or concrete (road surface) for road embankments and mineral sealing systems (CCL), synthetic liners (geomembranes) and geosynthetic clay liners (GCL) for road slopes and noise barriers. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has taken on the job of issuing a German regulation in the form of the Combined Ordinance (2nd Revision of MantelV), including the Substitution Construction Material Ordinance (ErsatzbaustoffV 2010), a change of the Ground Water Ordinance (GwrV), a change in the German Federal Soil Protection Act (BBodSchG) and a change in the Landfill Directive (DepV). In this Combined Ordinance (MantelV 2012) it should be regulated what conditions are recommended for the use of recycled construction waste material in technical structures as well as use of soil substitute material, which are not considered as waste. The current version of the construction tables from the Substitution Construction Material Ordinance (ErsatzbaustoffV 2010), appendix 2, Table 1, also includes construction methods from M TS E (2009).

## 2 PROTECTING THE ENVIRONMENT DURING THE RECYCLING OF RESIDUES AND WASTEGENERAL SPECIFICATIONS

In Germany, as in other European countries like the Netherlands, protecting the environment during the recycling of waste is carried out using three barriers, similar to the disposal of waste in landfills:

1. Hydraulic conductivity of the subsoil, depth to groundwater table, groundwater-protecting cover layers
2. Limitation of pollutant load through assigned threshold values
3. Technical protection measures using water impermeable cover and sealing layers

The LAGA Guideline M20 (1994/97) and TR Boden (2004) as well as other comparable codes of practice control the recycling of “Z materials. For the disposal of polluted soil according to LAGA TR Boden (2004) additional requirements for the subsoil, the depth to groundwater table and the groundwater-protecting cover layers in consideration to Figure 1 are defined as follows:

- Z0 material (classification group)
  => uncontaminated soil
  => open placement possible anywhere
- Z1.1 material (classification group)
  => slightly contaminated waste, e.g. crushed concrete and bricks etc.
- Z1.2 material (classification group)
  => waste with slightly higher contamination, e.g. construction waste, slag, foundry sands etc.
  => open placement only possible in hydrogeologically favourable areas, i.e. with a 2 m cohesive cover layer protecting the ground water
- Z2 material (classification group)
  => highest contamination class for recycling outside of landfills, e.g. polluted construction waste, slag, ash, foundry sands etc.
  => placement only using technical protection measures (surface sealing system made of water impermeable cover layers of concrete or asphalt pavement, compacted clay liners, geomembranes, geosynthetic clay liners)

According to the LAGA TR Boden (1994) and the VWV Bodenverwertung (2007) the barrier capping system should be equivalent to a 0.5m thick clay liner with a hydraulic conductivity k of $k \leq 1$ x 10-9 m/s, similar to the requirements of the Landfill Directive (DepV 2009). The hydraulic conductivity of a geosynthetic clay liner is regulated in the VWV Bodenverwertung (2007) with $k \leq 5$ x 10-11 m/s. The thickness d and the quality of the recultivation layer was recommended with $d \geq 1$m in the LAGA TR Boden 2004 and with a frost-resistant and desiccation-safe design for the sealing.

## 3 STATE-OF-THE-ART CONSTRUCTION METHODS

Experiences gathered from landfill capping systems during the nineties and at the beginning of this century in test fields and excavations, especially concerning the desiccation behavior of weather-sensitive sealing systems (e.g. compacted clay liners, geosynthetic clay liners(GCLS)), were added with different structures in 2009 in the Guidelines on construction methods for protection measures in earthworks when using soils and construction materials that contain environmentally relevant substances (M TS E). In doing so, a distinction has been made for the first time between sealing elements that are resistant to weather conditions (mostly geomembranes $d \geq 2mm$) and weather-sensitive sealing elements (compacted clay liners, GCLs), giving different requirements regarding the thickness of the cover soil layer. The use of drainage layers over the sealing layer and the resulting difference in the permeability coefficient requirements reflect the experiences gathered from the landfill cap constructions. The construction methods A, B and C are particularly important for the placement of geosynthetic materials. The most significant changes compared to earlier guidelines, e.g. LAGA M20 (1994/97 and also the Technical Instructions on Soils (LAGA TR Boden 2004) are the substantially increased thicknesses of the recultivation layer (cover soil $d \geq 1.5m$) above the sealing system in weather sensitive systems. The requirements regarding the permeability of mineral sealing systems with $k \leq 5 \times 10\text{-}9$ m/s are derived from the Technical Instructions on Municipal Waste (TA Siedlungsabfall 1993) and the Landfill Directive (DepV 2009). Properly installed geomembranes can be considered as impermeable, while mineral sealing systems are dimensioned based on their permittivity. To be able to compare different thicknesses of mineral sealing systems with each other, the hydraulic conductivity k is calculated to a thickness d independent permittivity value $\psi$.

$$\psi = k/d \ [1/s] \quad (1)$$

Based on the experience that without the use of a drainage layer a higher accumulation is to be expected at the border between sealing layer and cultivation layer, and a higher hydraulic gradient (i) also causing increased seepage, the lower permeability value $k \leq 5 \times 10\text{-}10$ m/s is derived for this solution (without drainage) instead of $k \leq 5 \times 10\text{-}9$ m/s (with drainage layer). A drainage layer is also advantageous in regard to stability, as accumulating seeping water together with pore water and flow pressures always have a detrimental impact on the stability.

Table 1. Summary of requirements as stated in RiStWag and MTSE, Germany

| Requirement according to regulation | | GM: Thick-ness [mm] | GCL: Permittivity [1/s] | Cover soil [m] | Remarks |
|---|---|---|---|---|---|
| RiStWag | | 2.0 | - | 0.6 | For chemical durability the DIBt certification applies; protection layer 0.1 m sand or nonwoven geotextiles according to BAM regulation |
| | | - | $\psi \leq 1 \cdot 10^{-7}$ | 0.8 | Frost/thaw and dry/wet testing required; resistance against hydrocarbons and salty conditions(1) |
| MTSE A | | - | $\psi \leq 1 \cdot 10^{-9}$ | 1.5 | Permeability of cover soil must be 1000 times larger than the permeability of the sealing system; multi-component GCL with polymer coating |
| MTSE B (2) | (I) | - | $\psi \leq 1 \cdot 10^{-8}$ | 1.5 | Verification of internal shear resistance; products according to TL GeoK E-StB<br>- 1,5 m cover soil - GCL<br>- 0.8 m cover soil multi-component GCL with polymer coating as desiccation and root barrier |
| | (II) | - | $\psi \leq 2.5 \cdot 10^{-10}$ | 0.8 (3) | |
| MTSE C | (I) | 2.0 | - | ≥ 0.1 (4) | GM (HDPE) with DIBt certification, ≥ 2.0 mm; overlaps welded; installation plan; certified installer; protection layer 0.1 m sand or nonwoven geotextiles (≥ 300 g/m², d ≥ 2.5 mm and GRK 5 |
| | (II) | 2.0 | $\psi \leq 1 \cdot 10^{-9}$ | 0.8 (3) | Multi-component GCL with polymer coating as desiccation and root barrier |
| MTSE E | (II) | 2.0 | - | ≥ 0.1 | Base liner with geosynthetic drainage system as leak detection system |

(1) $\psi \leq 5 \cdot 10^{-9}$ 1/s (data sheet) with performance certification
(2) as A, with mineral drainage system or geosynthetic drainage system
(3) reduced cover soil thickness with multi-component GCL with polymer coating as desiccation barrier
(4) requirements according to vegetation and erosion control

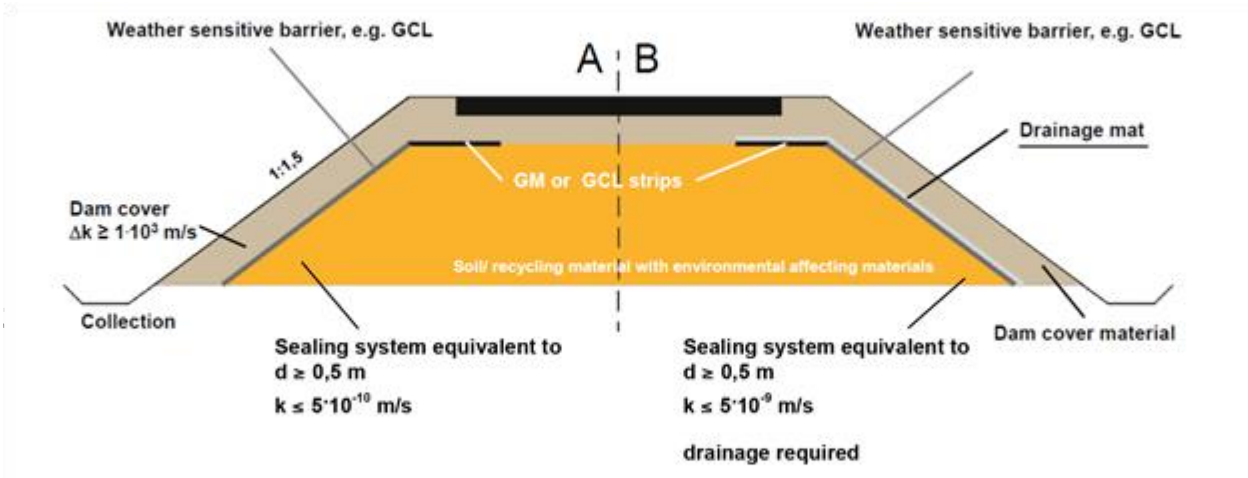


Figure 1: Method A (left): Weather sensitive barrier without drainage/ Method B (right): Weather sensitive barrier with drainage

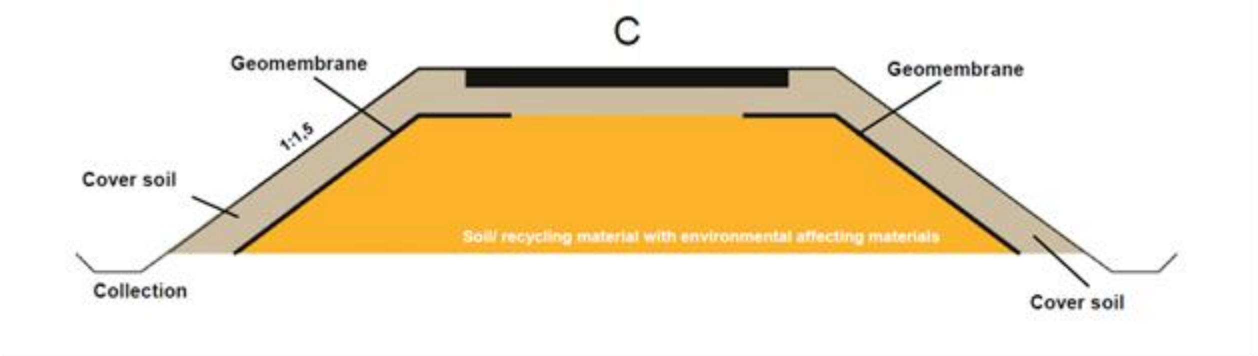


Figure 2: Method C: Dam construction (barrier system not weather sensitive)

When constructing traffic routes it is possible to use encountered contaminated soil and also non-contaminated and contaminated soils from other excavation sites in embankments as well as in dam constructions. It is also possible to use other mineral waste and industrial waste (e.g. ash, slags, recycled construction debris, foundry sands, tailings etc.). In the Netherlands slags from municipal waste incineration are used as construction material in noise barriers and dams. These contaminated materials must receive effective protection against the entry of precipitation through technical protection measures (sealing systems), these also preventing respective emissions into the underlying subsoil and groundwater. The Guideline M TS E (2009) of the German Road and Transportation Research Association provides the road construction engineer with a reference from which he can select appropriate sealing methods and their framework conditions.

## 4 SUMMARY

Due to the huge amounts of mineral waste produced and the shortage of natural building material resources (e.g. sand, gravel, crushed stone) it is a primary task to recycle this mineral waste material according to the Closed Substance Cycle Waste Management Act (KrW/AbfG 1994). Based on their production process, their reuse or the mixing with contaminated construction materials during demolition work, these mineral wastes often contain substances that have a harmful impact on the environment. It is therefore necessary, when recycling these materials in traffic route embankments and noise or vision barriers, to apply protection measures (sealing systems) that prevent the entry of precipitation and the leaching of harmful substances into the groundwater. There are a number of suitable sealing materials available for this purpose, including geosynthetic clay liners and geomembranes. When designing these liners the following must be taken into account:

- permeability coefficient requirements:
  - For mineral sealing systems (CCL) without drainage layer very strict requirements concerning permittivity of the CCL and the permeability of the cover layers are formulated, compare chapter 3, table 1, Method A. To be more efficient a system with CCL or GCL with drainage layer can be used, compare chapter 3, table 1, Method B.
- weather sensitiveness of mineral sealings:
  - For CCL and GCL substantially thicker recultivation layers ($d \geq 1.5$ m) are required.
  - For this application, geomembranes or multi-component GCLs (with polymer coating, thickness approx. 0.2 mm to 1 mm, structured) can be proven to be suitable for this application.
  - Thinner cover soil layers might be possible with site-specific plant requirements.

Both guidelines, the Dutch guidelines on the construction material ordinance „Bouwstoffen Besluit“ (CUR 1999) and the German guidelines M TS E of the FGSV (2009), provide technical information on the possible design of such protection measures and sealing components in order to meet the high stability requirements (> 100 years).

## 5 REFERENCES

BBodSchG - Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1998) Gesetz zum Schutz vor schädlichen Bodenveränderungen und zur Sanierung von Altlasten (Bundes-Bodenschutzgesetz - BBodSchG) (BGBl. I S. 502), Bonn.

BBodSchV - Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1999) Bundesbodenschutz und Altlastenverordnung (BBodSchV) (BGBL I S. 2585), Bonn.

CUR - Civieltechnisch Centrum Uitvoering Research en Regelgeving (1999) Aan het werk met het „Bouwstoffen Besluit“ Een handreiking voor het werken met het Boustoffenbesluit. Ministerie van Volkshuisvesting Ruimtelijke Ordening en Miliuebeheer.

DepV - Ministerium für Umwelt, Naturschutz und Reaktorsicherheit (2009) Verordnung zur Vereinfachung des Deponierechts vom 27. April 2009, Artikel 1 Verordnung über Deponien und Langzeitlager (Deponieverordnung – DepV). Bundesgesetzblatt Jg. 2009, Teil I Nr. 22. Bundesanzeigerverlag, Köln.

GrwV Grundwasserverordnung – Ministerium für Umwelt, Natur-schutz und Reaktorsicherheit (2010) Verordnung zum Schutz des Grundwassers (Grundwasserverordnung – GrwV).

KrWG - Ministerium für Umwelt, Naturschutz und Reaktorsicherheit (2012) Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (Kreislaufwirtschaftsgesetz – KrWG) vom 24.02.2012. www.gesetze-im-internet.de/¬bundesrecht/krwg/gesamt.pdf.

LAGA M20 - Mitteilung der Länderarbeitsgemeinschaft Abfall (LAGA) 20 (1994/1997) Anforderungen an die stoffliche Verwertung von mineralischen Reststoffen und Abfällen.

LAGA TR Boden- Mitteilungen der Länderarbeitsgemeinschaft Abfall (LAGA) (2004) Anforderungen an die stoffliche Verwertung von mineralischen Reststoffen und Abfällen: Teil II: Tech-nische Regeln für die Verwertung. 1.2 Bodenmaterial (TR Boden).

LAGA Ad-hoc-AG „Deponietechnik“ (2012) Bundeseinheitlicher Qualitätsstandard 5-5 Oberflächenabdichtungskomponenten aus geosynthetischen Tondichtungsbahnen vom 02.08.2012 http://www.laga-online.de/servlet/is/26509/BQS_5-5_Geosynthetische_Tondichtungsbahnen_12-08-02.pdf

LAGA Länderarbeitsgemeinschaft Abfall Ad-hoc-AG „Deponie-technik“ (2012) Oberflächenabdichtungskomponenten aus Geo-synthetischen Tondichtungsbahnen http://www.laga-online.de/.

M Geok E - Merkblatt für die Anwendung von Geokunststoffen im Erdbau des Straßenbaus, Ausgabe 2005. FGSV-Nr. 535, Köln

MantelV - Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2012) Verordnung zur Festlegung von An-forderungen für das Einbringen oder das Einleiten von Stoffen in das Grundwasser, an den Einbau von Ersatzstoffen und für die Verwendung von Boden und bodenähnlichem Material. „Mantelverordnung“. Art. 1 Änd. Grave, Art. 2 ErsatzbaustV, Art. 3 Änd. DepV, Art. 4 Änd. BBodSchV. Entwurf vom 31.10.2012. http://www.bmu.de/

M TS E - Forschungsgesellschaft für das Straßen- und Verkehrswesen (FGSV) (2009) Merkblatt über Bauweisen für technische Sicherungsmaßnahmen beim Einsatz von Böden und Baustoffen mit umweltrelevanten Inhaltsstoffen im Erdbau. FGSV-Nr. 559.

RiStWag – Richtlinien für bautechnische Maßnahmen an Straßen in Wasserschutzgebieten, Ausgabe 2002. FGSV-Nr. 514, Köln. Statistisches Bundesamt (2011) www.destatis.de