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Geosynthetic clay liner application at road construction in water-protection-areas: Site report motorway A 96 and general reflections

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ABSTRACT: The A 96 motorway from Munich to Lindau skirts Leutkirch for approximately 6 km, through the planned 'Leutkircher Heide' water-protection area. As this is the third largest ground-water area in Baden-Württemberg, it calls for special protection. In the approval procedure, the water administration authority imposed conditions regarding the cross-section of the road, the selection of building materials and the control of the pipe system when in operation. Building materials, cross-sectional design and operating conditions are closely inter-related and were given equal consideration. The water administration authority, and the Institute for Soil Mechanics at the University of Minich, as experts, were both involved in the process of decision making. At the same time, details of manufacturers' current products were obtained. A closed pipe system constructed in cast steel, with geosynthetic clay liners situated under the drainage, was installed. The criteria for the materials were laid down in the usual way for motorway administration: specification, installation instructions and control tests. When going to tender, special tenders for sealing and the pipe system were not excluded. But the specific proposals made could not be accepted. The pipe system and the GCL proved really problem-free in installation. It proved possible to put the plans into practice without any restrictions. For the GCL, the weight, water content, share of montmorillonite minerals and the permittivity of the total system were checked.

1 INTRODUCTION

The A 96 motorway from Munich to Lindau skirts Leutkirch for approximately 6 km, through the planned 'Leutkircher Heide' water-protection area. As this glacia-age gravel field contains the third largest ground-water area in Baden-Württemberg, it calls for special protection.

In the approval procedure, the following conditions were therefore imposed by the water administration authority:

- Zone II water protection area (immediate protection zone):
  the complete subgrade is to be covered with a liner sheet.
- Zone III water protection area (further protection zone):
  the longitudinal pipes are to be separated from the subsoil with a geomembrane.
  Any surface water that seeps through near the road surface will be collected.
- Special requirements are made on the drainage system (pipes, connections, shafts).
- When the motorway is in operation, water seepage is to be checked, and the complete drainage system is to undergo leakage tests.

2 SELECTION OF CONSTRUCTION MATERIALS AND CROSS-SECTIONAL DESIGN

In the course of the approvals procedure and preparing for construction, the conditions and requirements were converted into detailed planning.
Construction materials, cross-sectional design and operating conditions are closely inter-related and were given equal consideration. This applied to both the liner and the drainage system.
For the latter, conventional concrete pipes and a cast pipe system were considered. The decisive factor was the operating condition, as a repeat check for leakage is necessary. For practical, time and economic reasons, an excess water pressure test to DIN 4033 can be dispensed with. The cast pipe system, however, offers favourable opportunities for low-pressure air checks.
Initially, a 2 mm thick geomembrane was envisaged as a seal, with sand bedding and geotextile covering.
For some years, GCLs have been available as an alternative to geomembranes. The basic differences, as well as their advantages and

Figure 1. Installing GCL over a whole area in the immediate water protection zone at below zero temperatures and fixing the overlaps by a shear strip.

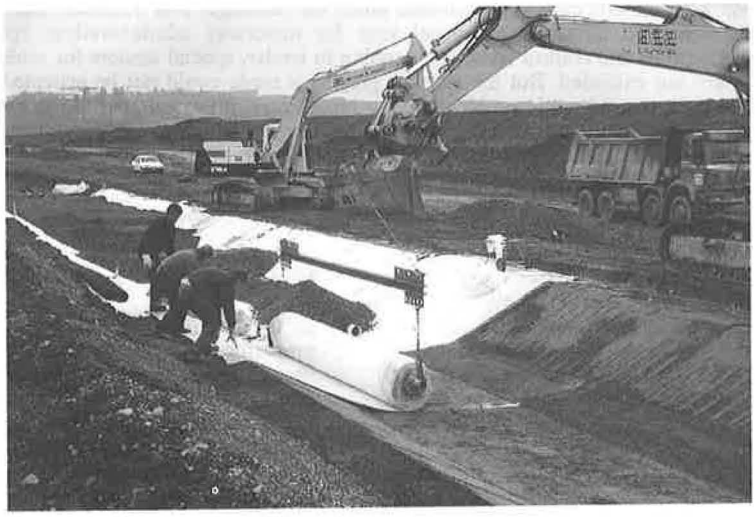

Figure 2. Installation of GCL in the further water protection zone in the area of the drainage pipe.

disadvantages, are well-known and are not elaborated upon in this paper. The decision to use a GCL was based on practical construction considerations. As with this system, fewer difficulties are to be expected in the installation, particularly regarding its dependence on temperature or weather conditions. The lower costs should also be mentioned. While a geomembrane system makes for a more effective seal than a GCL, this was not necessary, as it had already been decided that a sophisticated drainage system would be installed.

After selection of the construction materials, the road cross-sections shown in Figures 1 and 2, for water protection zones II and III, may be described as follows. Drainage would be carried out as a sealed, cast pipe system. The rectangular manholes, open at the bottom, would be placed in position afterwards, for the purpose of checking and maintenance of both the pipe system and the seepage pipe, which is in direct

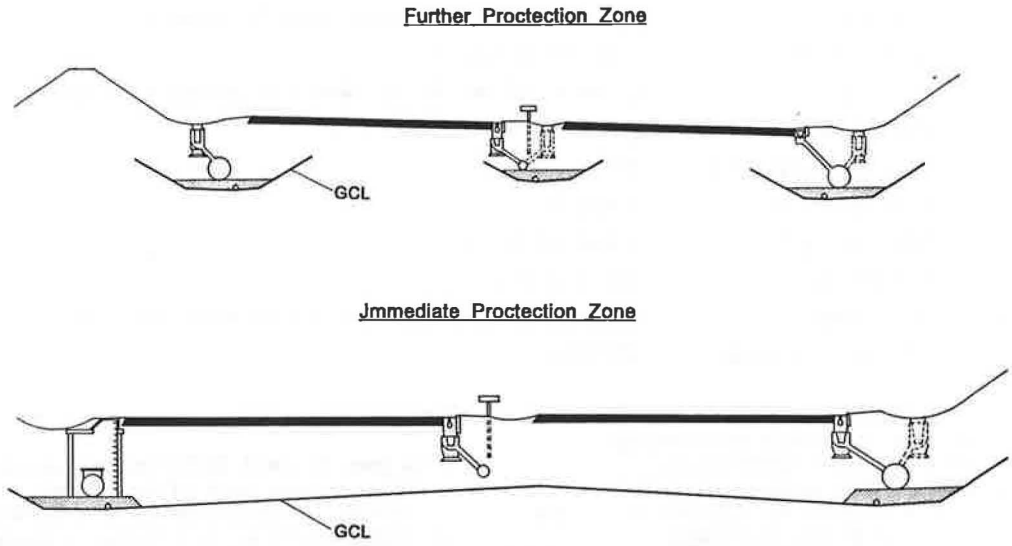

Fig.3. Cross - sections of the different water protection zones

contact with the liner. The pipe area in water protection zone III is seales with GCL in the form of an oversize pipe trench. The geometric boundary conditions are:

- position of manhole cover in the shoulder of the road
- width of manhole
- minimum cover between seepage pipe and bottom edge of manhole
- minimum gradient to seepage pipe
- maximum inclination of GCL (30°)
- lateral expansion of liner to edge of splash (1.5 m height of slope projected downwards).

The liner sheet in water protection zone II is laid over the whole surface, with the edges formed in a similar manner, see Figure 3. The high reference elevation ot the GCL here is represented by the minimum distance to the drainage pipe below the centre strip. An eccentric layout was used to provide a leak detection system, as any pollutants entering this area may be clearly allocated to the centre strip, or to one of the two outer seepage pipes.

3 SPECIFICATION AND LAYOUT

Concensus agreement with all parties involved in the decision-making process is of decisive importance in the choice of construction materials and cross-section preparation. This particularly applies to the subsequent invitation to tender and the awarding of contract.
Where the GCL was concerned, there was an orientation towards the products available on the market at that time. Any requirements exceeding those product qualities claimed by the manufacturers are given below.
The technical requirements were described in the standard way used for additional technical constractual conditions. This is divided into requirements, construction specifications, and tests:

3.1 *Requirements*

(Relavanced to the current regulations of the ministry of traffic Baden-Württemberg (Germany)

Bentonite is to be placed between two geotextiles as a sealing element. The supporting layer and the covering non-woven geotextile must be connected to each other by needling over their whole surface or close sewn (max. 3 cm).
Supervision is to be carried out by an independent inspector, in accordance with DIN 18200 (Quality supervision of building materials, components and types).

3.2 *Construction specifications*

Provisions were made for installation, overlapping, backfill, hydration and setting up a field test site.

The most important requirements were:

- observation of the manufacturer's installation instruction
- submission of an installation plan
- avoidance of overlapping in high and low reference points

Bentonite:	at least 3,5 kg/m^2 (dry-weight) natural Na-bentonite
Water content:	max. 15 % by weight
Cover layer:	Geotextile at least 200 resp. 300 g/m^2 (depending of fill material)
Carrier layer:	geotextile at least 200 g/m^2
Share of Montmorillonit:	75 %
Swelling volume:	at least 25 ml
Water adsorption:	at least 650 %
Permittivity:	max. 1 x 10^{-8} s^{-1}
overlapping:	at least 30 cm with using a shear strip for sheat transmission
Max. tensile strength:	10 KN/m

- overlapping in the style of roof shingles
- preventing any leakage in the overlaps
- shear strength in overlap regions
- watering of the workings, if required
- any GCL which has hydrated and is not covered by fill ist to be replaced
- in the context of a field test site, the contractor must supply basic proof of his full proficiency in installation
- optimization of the overlap as shown in Figure 4.

3.3 *Tests*

Proficiency tests would check the requirements for proof of suitability. If requested by the water administration authority, proof of the GCL's safety against erosion caused by flow stresses is also to be given.
Quality control monitoring and checks are particularly concerned with the montmorillonite content, the coefficient of permittivity, and the mass per unit area, as decisive parameters.
As well as the installation plan, the contractor had also to record the time and place of installation of each roll.
In the context of quality control checks, the coefficient of permittivity was also checked by the geotechnical test office of the Technical University at Munich.

3.4 *Planning*

When going to tender, further requirements and specifications were made of the subgrade and fill material, in addition to the specifications described above for the GCL. Secondary tenders were neither specifically required nor ruled out. The same applied to the cast pipe system. Secondary tenders were received for both the sealing and the drainage system. Neither an improved concrete tube construction nor an asphalt seal could be accepted as equivalents.
Accordingly, the importance of having a sound draft before going to tender should again be emphasized. In awarding contracts, secondary tenders assume great importance, sometimes out of proportion, as they may play a decisive role in the award of the contract. Any calculation or technical vagueness in the secondary tender gives room for bargaining, in the course of which economic interests may compromise the draft invitation to tender. Above all, because of the consistent cooperation of the decision-makers, it was possible to keep to the envisaged plan without reservation.

4 CONSTRUCTION QUALITY CONTROL

On the basis of the specified requirements, the

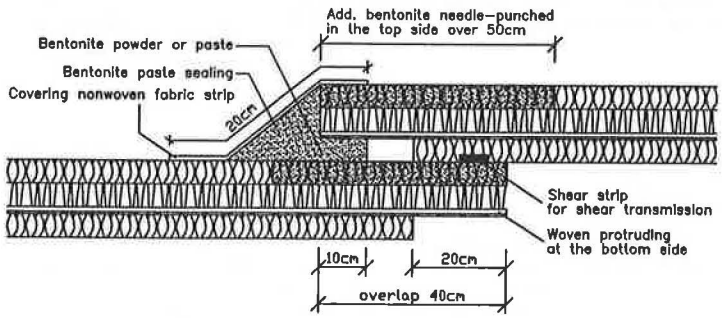

Fig. 4.Optimizing the overlap area regarding the infiltration of water and the mechanical connection

manufacturing company used two methods for overlaping the GCLs which were a great improvement on previous practice. Firstly, transmissivity in the non-woven geotextile in the GCL below the overlap was prevented by working bentonite into the edge of this layer of non-woven teotextile. Secondly, an integral velcro-type fastening was used for connections, recall Figure 4.
The manufacturer had demonstrated the effictiveness of this connection method in sheaar tests with this kind of overlapping. These showed that the shear plane always occurred in the GCL and not in the boundary area between the overlapping layers with velcro-type fastening. This simple cennecting method proved acceptable, because the subsoil was resilient during installation, and because these connections are particularly suitable in preventing displacement of the GCLs towards one another.
The field test site was set up sufficiently in advance of the planned date for construction. The cross-section envisaged in water protection zone III, which was considered the most critical from an installation point of view, proved viable. In particular, laying the GCL on a 30° slope proved no problem. However, it should be pointed out that the slopes where the GCL were installed were relatively short, only 1 m to 2 m. Some of the subgrade had gravel which proved too coarse, and in a few areas had to be covered with finer-grain material. Further tests gave findings on the effect of different fill material and the influence of construction operations.
It proved possible to install the GCL with great accuracy, because of the optimized boundary formation, the geometrically even installation surface and the short sheet lengths. The overlaping was therefore reduced from 40 cm to 30 cm in standard cross-section in water protection zone III.
Even in the very rainy autumn of 1992, installing the GCL proved exceptionally trouble-free. The installed sections were covered daily with gravel, so moistening never reached the point where the uncovered GCL had hydrated so much that the section had to be replaced.
Examinations carried out by the text office for Geotechnics, Soil and Rock Mechanics of the Tchnical University, Munich showed, as did experience during construction work, that GCL installation is also possible during conditions of frost, down to approximately -10° C. This is, however, dependent on having a dry frost.

5 CONCLUSION AND GENERAL REFLECTIONS

In the roadway cross-section designed for the use of specific materials to meet the requirements of the water authority, both the novel drainage system and the use of GCL have shown themseves to be effective, economical and, in practical construction terms, an exceptionally advantageous system for ground water protection.
To the advantages of GCL's and the marginal conditions of application shall be pointed especially:

5.1 Advantages of the Geosynthetic Clay Liner (GCL) during construction of a work

- independent of temperature
  - no waves or folds at high temperatures
  - installable until approx. -10°C
- independent of weather
  Little rainfall is insignificant as long as the filling is finished before the swelling process starts.
- Many construction possibilities at joints and connections by disintegration of the composite into its single components 'geotextile' and 'bentonite'.
- Quick construction progress (approx. 90 m/day) has altogether a positive effect on the costs of a site.
- Quality reserves of the GCL
  - "Self-healing effect":
    Small perforations (up to "nail thickness") are closed by bentonite that flows in.
  - Increasing "blocking action" of the cover nonwoven by sedimentation of cohesive soil particles.
- Failures due to coarse grains:
  - usually no crack, but only elongation of the GCL and displacement of the bentonite
  - "Clogging effect" of the remaining grain in connection with "self-healing effect".

5.2 Marginal conditions

Designing the cross-section of the road following marginal conditions and possible limits of application are to be considered:

- Suitability of the cover material under consideration of construction works.
- Influence of static and dynamic loads
- Influence of dry-wet-cycles
- Influence of root penetrations
- Influence of frost-thaw-cycles

- Influence of thawing salt and hydrocarbons
- Influence of the hydraulic gradient.

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