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Vittel road platform waterproofing

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ABSTRACT: The Vittel (France) bypass which was constructed in 1995 is located within the protection area of the well known mineral water nammed Vittel. In order to meet the requirements of the french regulation for the protection of the ground-water, the road platform was lined with a geomembrane lining system. The design, the installation, the quality control and the quality assurance related to the installation of the lining system are described in this paper.

1 PROJECT DESCRIPTION

The local authorities of the *Departement des Vosges* (France) has initiated an ambitious programme of road construction to connect the major activity areas of the *Departement* to the main national roads (motorways and national highways) crossing its territory. The bypass of the famous thermal city of Vittel is so included in this programme.

The bypass has a length of five kilometers, and is entirely located within the protection area of the mineral ground-water of Vittel. The Vittel mineral water contains specific mineral elements and is well known to be benefit for the human health. The ground-water is exploited for both drinking water and thermalism purposes.

The ground-water is setting within the limestones (*calcaires à entroques*) belonging to the *Muschelkalk Supérieur* geological structure, and the marly dolomites of the sommital part of the *Muschelkalk Moyen* geological structure. The geological structure is detailed on Figure 1.

The aquifer is naturally protected from a surface pollution by the *calcaires à cératites*, and by the *Vittel dolomite* (*Muschelkalk Supérieur*). The *calcaires à cératites* geological structure is a marly calcareous stratification of which thickness is about 25 to 30 meters and which has a low permeability. The profile of the bypass is located within these geological structures, as indicated on Figure 1, and the natural protection is so partly removed along the road cuts.

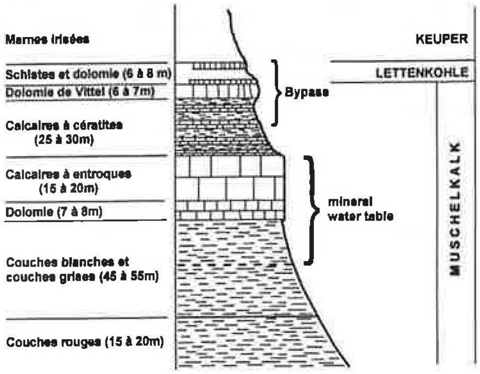


Figure 1. Vittel area geology.

According to the french regulation for the protection of mineral waters of public interest, the bypass project, which could generate a pollution of the ground-water, was submitted to the advise of the *Conseil Supérieur d'Hygiène*. The agreement given by the *Ministère de la Santé* enforced very strict requirements for the protection of the ground-water :

- waterproofing of the road platform;
- collection of run-off waters, pavement drainage waters and treatment;
- collection of accidental pollutions.

To meet these requirements a lining system was installed within the subgrade layer of the road structure according to the typical cross-section

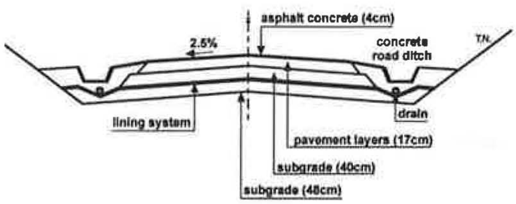


Figure 2. Typical cross section of the Vittel bypass.

shown on Figure 2. The structure of the lining system consists of (from top to bottom):

- a protective geotextile;
- a geomembrane;
- a support geotextile.

2 THE LINING SYSTEM

The geomembrane which was choosen is an HDPE geomembrane which is characterized by a chemical inertia, particularly, to hydrocarbons and various solvents which represent 90 % of the dangerous substances carried on the french road network. The characteristics of the geomembrane are presented in Table 1.

Table 1. Main characteristics of the HDPE geomembrane installed on the Vittel bypass.

Thickness (ASTM D 751)	> 2 mm
Density (ASTM D 1505)	0.948
Tension at yield (ASTM D 638)	> 16 kN/m
Tension at failure (ASTM D 638)	> 27 kN/m
Break elongation (ASTM D 638)	> 600 %
Tear strength (ASTM D 1004)	> 260 N
Puncture strength (FTMS 101, 2065 Method)	> 420 N

For the design and the selection of the geotextiles to protect the geomembrane from the puncture by the adjacent material, it only exists index laboratory tests to measure the puncture strength of the geomembrane or of the lining system. These tests could not be representative of the conditions on site. Due to the specificity of the project and the surface of geomembrane to be installed, it was decided to carry out a pilot test on site, prior to the installation, to test different geotextiles. The structure, which was tested, represents the subgrade layer of the road structure and consists of (from top to bottom):

- a layer (0.35 m) of 0/40 mm crushed limestones;
- the lining system (geotextile-geomembrane-geotextile);
- a layer (0.35 m) of 0/40 mm crushed limestones, covered by a 0/20 mm calcareous sand layer (0.03 m).

The pilot test was constructed on an area of 100 m x 15 m. The granular materials used for the pilot test were compacted according to the french recommendations GTR 92 (*Guide pour les Terrassements Routiers*) in order to reach the requested bearing capacity for the subgrade layer of the road structure. Thirteen combinations of twelve different geotextiles were tested. All geotextiles were needle punched nonwoven geotextiles, manufactured with polypropylene or polyester short or endless fibers. The mass per unit area of the geotextiles, which were tested, was choosen between 300 g/m^2 and 700 g/m^2 for the protective geotextile, and between 125 g/m^2 to 300 g/m^2 for the support geotextile.

After the placement and the compaction of the upper granular layer, the soil was carefully removed in order to evaluate by a visual inspection the damages of the geomembrane. A preliminary visual inspection was performed and ten samples of geomembrane (1 to 2 m^2) were cut for a detailed visual inspection and evaluation of damages (Photograph 1).

Photograph 1. Sampling of geomembrane on the pilot test. Vittel bypass.

Each sample was inspected by the Project Manager Quality Assurance Team. A first classification was so achieved. The samples of geomembranes were then passed to the laboratory of the Project Manager Quality Assurance Team. A detailed visual inspection was performed by a technician who did not participate to the pilot test, and who reported the number of damages, their sizes and deepness. A final selection was thus performed.

The choice of the protective geotextile and the support geotextile took into account the results of the pilot test and economical criteria. The geotextiles which were installed are geotextiles manufactured by Sommer BTP: (i) protective geotextile Geosom PR 500, and (ii) support geotextile Geosom PR 300. The main characteristics are presented in Table 2.

Table 2. Main characteristics of the geotextiles installed with the geomembrane on the Vittel bypass.

	PR 500	PR 300
Mass per unit area (NFG 38 013)	500 g/m²	300 g/m²
Thickness (NFG 38 012)	5,3 mm	4,1 mm
Puncture strength (NFG 38 019)	> 1,9 kN	> 1,2 kN

Note: the structure which was constructed is a little different from the structure tested in the pilot test. The structure was modified according to the results of the pilot test and can be described as follows:

- a layer (0.40 m) of 0/40 mm crushed limestones;
- the lining system;
- a layer (0.48 m) of 0/40 mm crushed limestones covered by a 0/6 mm sand layer (0.03 to 0.05 m).

3. INSTALLATION OF THE LINING SYSTEM

3.1 *General information*

The installation of the lining system occured during a summer period from june to october 1995. A surface of 85 000 m^2 was installed during 12 weeks of work.

3.2 *Lining system*

Prior to the placement of the lining system a subgrade acceptance was performed between the earthwork contractor, the lining system installer and the Project Manager. The acceptance was performed by zone according to the progress of the subgrade.

The lining system was installed according to the typical cross section presented on Figure 2. Geosynthetics, which were delivered on site as rolls, were unrolled along the road axis (see Photograph 2). Four rolls of geotextiles and three rolls of geomembrane were so usually installed within the width of the platform.

Geotextiles were placed with an overlap of 0.30 m with hot seaming by point in order to guarantee the function of protection for the geomembrane. The maximum length of geomembrane which was placed at a time was about 100 m (roll length).

The geomembrane was seamed with a double track fusion seam made with a dual hot wedge machine. Transversal seams at each section of 100 m, or less if needed by the geometry of the bypass, were seamed according to the same method and completed by an extruded fillet at each multiple junction (T shape). These transversal seams were seamed according to the progress of the placement of the upper granular subgrade layer in order to avoid damage of the lining system by crushing the wrinkles.

3.3 *Granular subgrade layer of the road*

The granular subgrade layer of the road was placed on the lining system by the earthwork contractor following the progress of the installation of the lining system. The material was unloaded on the layer itself and then spread out by a bulldozer in order to reduce excessive displacement of the geotextile on top of the geomembrane. The placement of the granular subgrade layer was performed only during the morning to avoid the placement on large wrinkles occuring with the air temperature increasing during the day. The existing wrinkles were pushed by the earthwork workmens up to the next transversal junction of the geomembrane which was not seamed.

Photograph 2. Installation of the lining system on the Vittel bypass.

3.4 *Difficulty of installation related to climatic conditions*

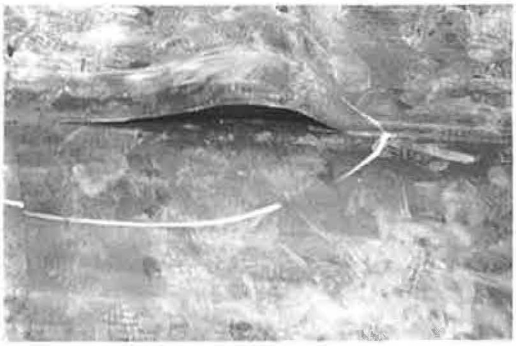
One major concern during the installation of the geomembrane and the seaming, as well as during the placement of the granular subgrade layer of the road on top of the lining system, was the wrinkles of the geomembrane.

The installation was performed from june to october 1995 and the air temperature and solar radiation were typical of continental summer climatic conditions. As a consequence the temperature of the geomembrane could reach 40 to 50 °C during the day, as measured on site. The increase in temperature induces wrinkles of the geomembrane due to the thermal expansion of the material. Wrinkles which were observed could be described with the following average dimensions:

- Width 0.40 to 0.60 m
- Heigth 0.10 to 0.20 m
- Spacing 20 to 40 m

The temperature of the geomembrane can also vary quickly during a short period of time when the sun is hidden by clouds. A typical example of this phenomena is show on Photograph 3. A rapid decrease of the temperature of the geomembrane between its placement and the seaming operation has produced a contraction. The amplitude of the displacement did not allowed the seaming with the double hot wedge machine, the external seam being outside of the geomembrane. The seaming operation was stopped and moved 1 m forward. The seam was then capped at the this location.

Wrinkles were also a problem during the placement of the granular subgrade layer of the road on top of the lining system. Specific working conditions were so adopted, as discussed in section 3.2 and 3.3.



Photograph 3. Seam defect due to variation of the air temperature. Vittel bypass.

4. QUALITY CONTROL AND ASSURANCE

4.1 *Organization*

The Quality Control and Quality Assurance (QCQA) related to the installation of the lining system was organized and performed by three teams:

- the Installer QC Team on site;
- the Installer QA Team (third party);
- the Project Manager QA Team (third party).

The QC also involved the manufacturer of the geomembrane and the geotextiles.

The controller of the Installer QC Team was full time on site, while the control by the Installer QA inspector and the Project Manager QA inspector was performed during, respectively, weekly visits and random visits. All activities related to QCQA for the installation of the lining system are described in a Quality Assurance Plan written by the installer prior to the beginning of the work. This document was used as reference for the QCQA performed by the Installer QC Team and the Installer QA Team during the installation of the lining system.

4.2 *QCQA Activities*

QCQA activities are described hereafter according to the following items:

- conformance of geosynthetics;
- conformance of the installation;
- conformance of the geomembrane seams.

4.2.1 *Conformance of geosynthetics*

Both manufacturers of geotextiles and geomembrane have a QC system to control the conformance of the geosynthetic characteristics to the technical data of the product accepted for the project. The characteristics which were controlled and the frequency of the controls for the Vittel project are presented in Table 3 .

On site the Installer QA inspector identified each roll, controlled its designation and reviewed the

Table 3. QC of geosynthetics. Vittel bypass.

Geotextiles	Geomembrane
Mass per unit area: 1/800 m^2	Thickness: 1/2400 m^2
Thickness: 1/800 m^2	Density: 1/2400 m^2
	Tensile strength: 1/2400 m^2
	Tear strength: 1/2400 m^2
	Puncture strength: 1/2400 m^2

control certificate issued by the manufacturer at each delivery. During the installation of the lining system the Project Manager QA Team took samples of geotextiles and geomembrane. Tests for the control of the characteristics were performed in accredited laboratories and are described in Table 4 with the corresponding number of tests.

Table 4. QA of geosynthetics performed by the Project Manager Quality Assurance Team. Vittel bypass.

Geotextiles		Geomembrane	
Mass per unit area:	4 tests	Thickness:	2 tests
Thickness:	4 tests	Volumic mass:	2 tests
Tensile strength:	1 test	Tensile characteristics:	2 tests
Puncture strength:	4 tests		

4.2.2 *Conformance of the installation*

Conformance of the lining system installation was focused on the placement and overlaps of the geotextiles, the placement and seaming of the geomembrane, and the connexion to rigid structures.

Specific actions were performed by two of the three QCQA teams:

- Installer QC Team:
  ✓ control of the geosynthetics placement;
  ✓ record of the placement on a layout drawing;
  ✓ control of the overlap for geotextiles;
  ✓ identification of each seam of geomembrane with the record of the seaming conditions;
  ✓ daily trial seams, peel tests and record.

- Installer QA Team during the weekly visits:
  ✓ control of the lining system structure;
  ✓ control of the geosynthetics placement;
  ✓ control of the seaming conditions;
  ✓ review of the QC documents issued by the installer QC team;

4.2.3 *Conformance of the geomembrane seams*

Conformance of the geomembrane seams was evaluated with (i) non destructive tests (air pressure, vacuum box) to control the seam continuity, and (ii) destructive tests (shear and peel tests) to control the seam strength.

QCQA activities related to the geomembrane seams were organized as follows:

- Installer QC Team:
  ✓ non destructive control of all seams;
  ✓ sampling of seams every 200 m of seam.
- Installer QA Team:
  ✓ non destructive control of seams made during the day of the weekly visits;
  ✓ shear and peel tests of the seam sampled (every 200 m) in the third party QA laboratory.

During the visits of the Project Manager QA inspector the non destructive tests were controlled, and seams were sampled to be tested in shear and peel tests by its laboratory. The first sample of seam taken by the Project Manager QA inspector was choosen on a seam already sampled by the Installer QA inspector in order to have a common reference.

4.3 *QCQA Results*

The QCQA activities decribed in section 4.2 gave the assurance to the local authorities managing the bypass, and the Vittel Mineral Water Company that:

- the characteristics of the geosynthetics which were installed are consistent with the specifications;
- the lining system was installed according to the specifications and the construction drawings;
- all geomembrane seams were tested with non destructive air pressure tests to control their integrity;
- geomembrane seams were statistically tested (50 % of the total length of seams was tested) with shear and peel tests to control the quality and the mechanical characteristics of the seams.

Figure 3 shows the distribution of the shear and peel strengths at yield of the seams which were sampled during the QA activities. 51 samples of seams were so tested in the laboratory of the Installer QA (IQA) Team and 5 samples of seams were tested in the laboratory of the Project Manager QA (PMQA) Team. To pass the destructive control the seam must meet the two following criteria:

A) Failure classified as Film Tear Bond (FTB); and
B) Shear or peel strength superior to a minimum value calculated as a percentage of the tension at yield of the geomembrane.

According to the recommendations of the French Committee of Geosynthetics (CFGG, 1995), the minimum shear and peel strength required for HDPE geomembranes are calculated as respectively, 90 % and 70 % of the tension at yield of the geomembrane. The difficulty is the definition of the reference for the tension at yield of the geomembrane to be installed. The reference was choosen by the third party Installer QA Team as the nominal value indicated on the technical data sheet of the geomembrane which was included in the PAQ. The peel strength requirement was revised to a percentage of 60 % of the tension at yield of the geomembrane according to the knowledge of the Installer QA Team (Giroud et al, 1993).

As a result of the QCQA activities, only two seams of 100 m length failed the destructive tests. A total peeling was observed on three (inside track) and four (outside track) among the five tested specimens. The average peel strength measured on these samples was superior to 60 %, but inferior to 65 % of the nominal tension at yield of the geomembrane. The reparation, after the removal of the granular subgrade layer from the top of the lining system, consisted of (i) the removal of the seams, the installation of a new patch on the entire length of the seams, and (iii) the seaming by fusion of the patch with the installed geomembrane.

Numerous data were available with the QCQA activities and a statistical analysis has been achieved on the destructive test results in order to validate, in particular, the peel strength criteria. Figure 4 shows the distribution of the tension at yield of the geomembrane as evaluated from the QC certificates issued by the manufacturer. The average value of the distribution is 37.4 kN/m.

Peel test results were considered for both inside and outside track. The average value of the distribution is 27.8 kN/m which represents 74 % of the average tension at yield of the geomembrane. A statistical calculation of the 95 % confidence lower limit comes to 24.8 kN/m for the peel strength. This lower limit represents 66 % of the average tension strength at yield of the geomembrane. Using this value two new seams would have not been accepted while the failure was classified as FTB. The criteria of 60 %, choosen by the Installer QA Team, would have not alone allowed to identify the bad seams (failure was classified as non FTB), while a criteria of 70 % would have eliminated 16 seams.

5. CONCLUSION

The Vittel bypass is a new type of application for geomembrane lining systems, and is a good example of how geomembrane could help to protect our environment. The results of the QCQA activities have demonstrated the great interest of such activities for a quality management in order to construct a structure consistent with its required performances.

The Vittel project has also pointed out the difficulty of overlying an HDPE geomembrane and the need to organize, prior to the installation, the work (placement, overlying...) in order to take into account the wrinkles, which are air temperature dependent.

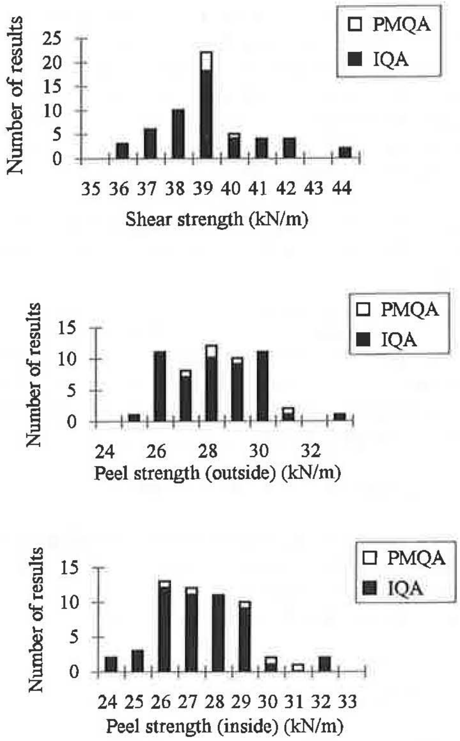


Figure 3. Distributions of the shear strength and peel strength of seams sampled for the QA activities on the Vittel bypass.

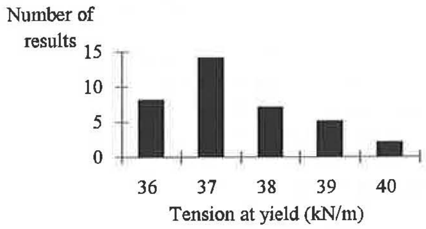


Figure 4. Distribution of the tension at yield of the geomembrane (QC certificates). Vittel bypass.

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