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Application of geosynthetics in a subsoil pollution containment and a hazardous waste landfill

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ABSTRACT: The present paper describes the application of geosynthetics in two projects of environmental engineering recently faced in Italy: (a) the containment of subsoil pollution due to a chemical plant; (b) the construction of a very large hazardous waste landfill.
For both problems, composite liners which were employed proved to perform very well. In particular, geosynthetics were used in the construction of both impervious barriers and drainage systems.

INTRODUCTION

In Italy, today, geosynthetics are confidently proposed and frequently used in projects of environmental engineering. However trust regarding geosynthetics was uncertain until the recent past due to some evident defectiveness ascribing mainly to the lack of a proper engineering approach. This lack produced some negative consequences, as:

a. use of bad products, often not adequately certified;
b. wrong applications of good products;
c. absence of controls during and after installation;
d. overestimation of the performance of geosynthetics.

For example, until few years ago, a single geomembrane was erroneously considered an effective landfill liner, while at present geomembranes are correctly used in composite liner systems. In the following two different kinds of composite liner systems are described, which proved to perform very well. In the description of the case histories, attention is focused on geosynthetics; further details on the projects are given in the references.

1. GROUNDWATER POLLUTION CONTROL

After 100 years of activity,"ACNA-Organic Chemical Plant" produced serious pollution of the adjacent Bormida river. Therefore, to protect the river against pollution and to avoid the loss of over 700 jobs with the closing down of the plant, an innovative composite containment barrier was designed and built (Fiore & Manassero 1990).

Fig. 1 summaries both the soil profile of the site and the main features of the project.
The soil profile essentially consists of a first layer of alluvional deposits resting on a marl bedrock. The polluted alluvional deposits (sand and gravel in silty-sandy matrix with occasional cobbles and boulders) have a thickness ranging from 3 to 12 m and a hydraulic conductivity which varies from 10^{-2} to 10^{-4} cm/s. The marl bedrock has a thickness of over 150 m and a hydraulic conductivity less than 10^{-7} cm/s; signs of pollution were not found in the marl.

A project was therefore developed, consisting of two main features:

- a continuous vertical impervious diaphragm, well keyed into the marl, to contain the polluted water;
- an internal dewatering system to lower the water table inside the plant area.

The proposed solution is well suited to oppose the migration of pollutants towards the river, combining the containment barrier with a hydraulic gradient from the outside of the area towards the inside (Manassero & Viola 1992).

Geosynthetics were used in both the vertical barrier and dewatering system; in the following some construction details are given.

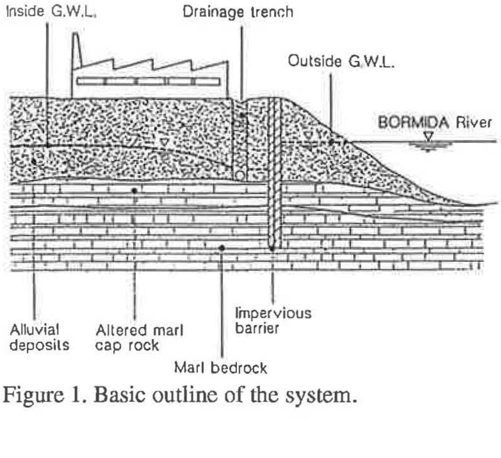

Figure 1. Basic outline of the system.

The vertical barrier consists of a cement-bentonite slurry wall with a high density poliethylene geomembrane 2.5 mm thick, placed in the middle of the wall (fig. 2).

This sölution was selected taking into account that composite liners are strongly recommended for hazardous and toxic waste disposal (US-EPA 1984).

The construction sequence of the vertical barrier was particularly complex for the need to assure an adequate penetration in the marl bedrock (Manassero 1989) and a controlled installation of the joints between geomembranes (fig. 3).

The construction was carried out according to the following main steps.

a) A first cement-bentonite slurry wall, 120 cm thick was built with conventional clamshell equipment down to the base of the alluvional deposit. This first operation also allowed to remove the large boulders occasionally found at the base of the deposit.

b) After the setting of the mixture of the 120 cm thick slurry wall, a series of drill-holes 60 cm in diameter, were made inside the first slurry wall, at about 1.5÷2.0 m spacings. The borings reached 2.0 m inside the marl and were drilled without using any fluid or casing. The cement-bentonite mixture was then cast by tremie.

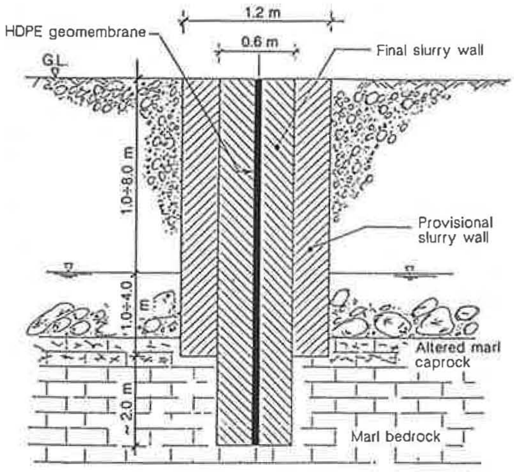

Figure 2. Detail of the barrier (vertical section).

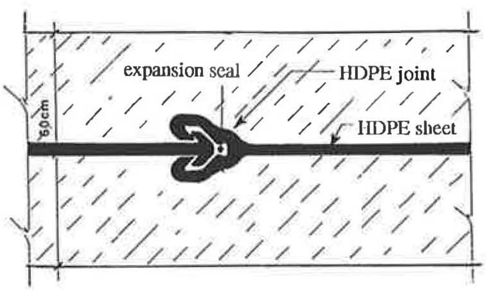

Figure 3. Joint between geomembrane sheets.

c) The material between the drill-holes was then excavated using conventional clamshell equipment; in this way a second 60 cm thick slurry wall was obtained keyed 2 m into the bedrock.

d) Before setting of the mixture of this second slurry wall, the interconnected HDPE panels were lowered by a counterweighted steel frame into the centre of the wall and then suspended by steel bars crossing the head of the HDPE panels and resting at ground level.

e) For long-term joints the following solution has been worked out (fig. 4): the space created by a special sheet pile inserted into the trench, at the end of the casting operation, is firstly washed with water and then filled with sand. By pulling out the sheet pile, this kind of joint allows to insert correctly the adjoining HDPE sheet even after the hardening of the cement-bentonite mixture, thus permitting the long-term extend of the barrier.

The dewatering system within the barrier area was built using two solutions: drainage trenches and permeable diaphragms. The drainage trenches were excavated, covered with a non-woven geotextile filter and filled with gravel (grain size = 4÷7 cm) after placing a microslotted HDPE pipe at the bottom (fig.5).

Where the marl bedrock was at significant depth, permeable diaphragms were realized excavating in presence of biodegradable muds. The sequence of the construction of the permeable diaphragms is shown in figure 6.

The drainage diaphragms were excavated by grab down to the marl bedrock; the excavation was supported by polymeric biodegradable muds, which efficiency was sufficient to complete panels 30÷35 m long (fig. 6a).

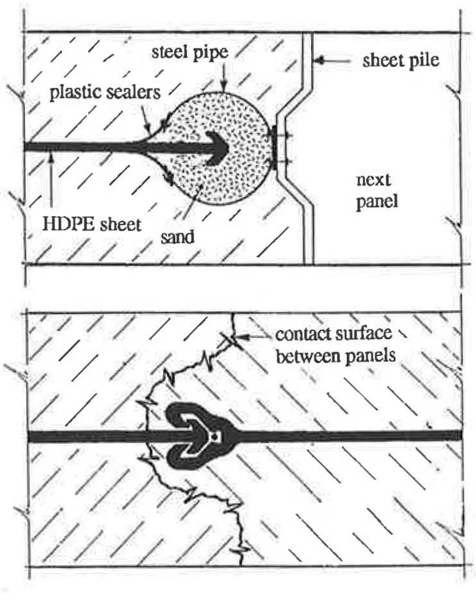

Figure 4. Long term joint.

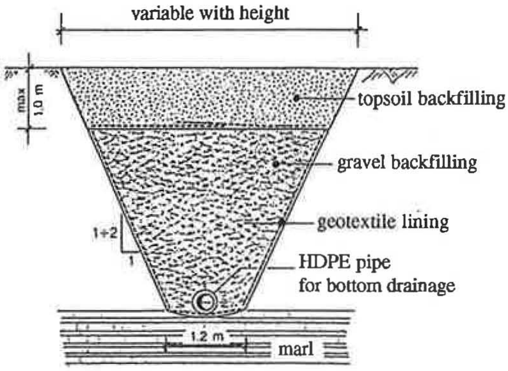

Figure 5. Drainage trench (vertical section).

At the extremes of each panel, about 1 m deep holes were drilled in the marl bedrock. Special sheet-wells were then placed upon each hole, allowing:
- the supporting of the filling gravel inside the panel during the excavation of the adjacent one;
- the placing and fixing of the collection pipes;
- the use of bailing pumps with a sufficient height of suction (fig. 6d).

Like the trenches, the diaphragm walls were also covered with non-woven geotextiles, put inside by expendable metal frames and by the sheet-wells mentioned above (fig. 6b). This procedure allowed the overlapping of the geotextile sheets also between the panels.

The collection pipes were increased in weight and pushed down, placing the extremes in guides previously obtained by welding alluminium sheets to the sheet-wells (fig. 6c).

The measured piezometric levels and pump flow rates demonstrated that the efficiency of the drainage diaphragms realized with this technology was comparable to that of the trenches.

2. A HAZARDOUS WASTE LANDFILL

Barricalla landfill is situated near Turin, in one of the most industrialized areas of Italy; it is located in an old abandoned quarry and has a total capacity of about 600,000 m^3.

In order to maximize the landfill capacity, the bottom of the abandoned quarry was lowered as much as possible and the side slopes were excavated as steep as possible. At the end of excavation, the slopes were 15 m high and 40° steep.

The executive design of the first part of the landfill was carried out in 1987. After 1992 an enlargement of the landfill of about 250,000 m^3 was designed and built (Manassero & Pasqualini 1993). As far as the second part of the landfill is concerned, a project with the following main features was proposed:
- on the bottom, a double composite liner made of compacted clay layers coupled with geomembranes;
- on the sidewalls, a double sealing barrier formed of only geosynthetics; in particular, a geomembrane was suggested underlaid by a geosynthetic clay liner plus a geonet and a second geomembrane (fig.7).

The public authorities in charge of the design examination accepted the design of the bottom, while the design of the sidewall barrier was not approved. A compacted clay liner at least 1 m thick was required also on the sidewalls. This new solution needed a new sidewall configuration with slope angles of about 18°÷20° in order to allow the placement and long term stability of the compacted clay liner. This had a great impact on the available volume of the landfill, with a loss of about 33,000 m^3 and of about 11,000,000 \$. This of course became a big problem for the owner society and also for the community, considering that it is very difficult to find sites for landfilling. Therefore, a solution was necessary to build the mineral liner of the sidewalls about 11 m high and 40° slope. To solve this problem, a research was carried out to investigate the suitable natural

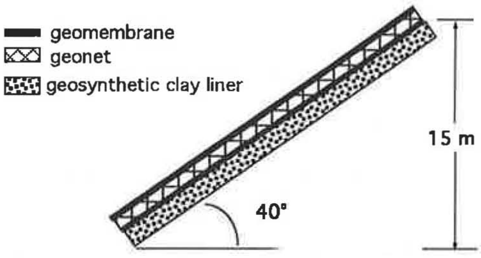

Figure 7. Proposed sidewall double sealing barrier.

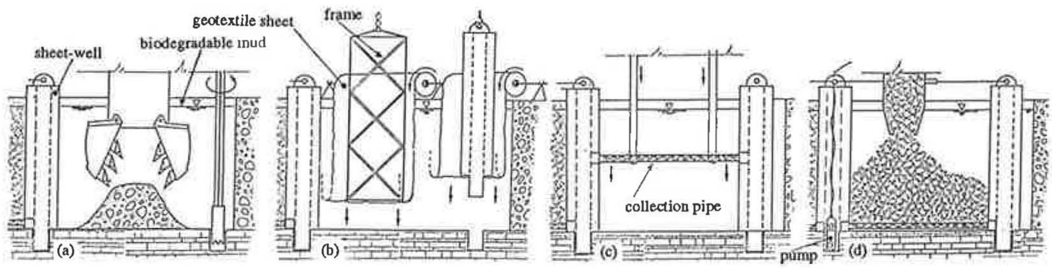

Figure 6. Construction procedure of the drainage diaphragm: (a) excavation; (b) geotextile and sheet-well placement; (c) collection pipe placement; (d) filling with gravel.

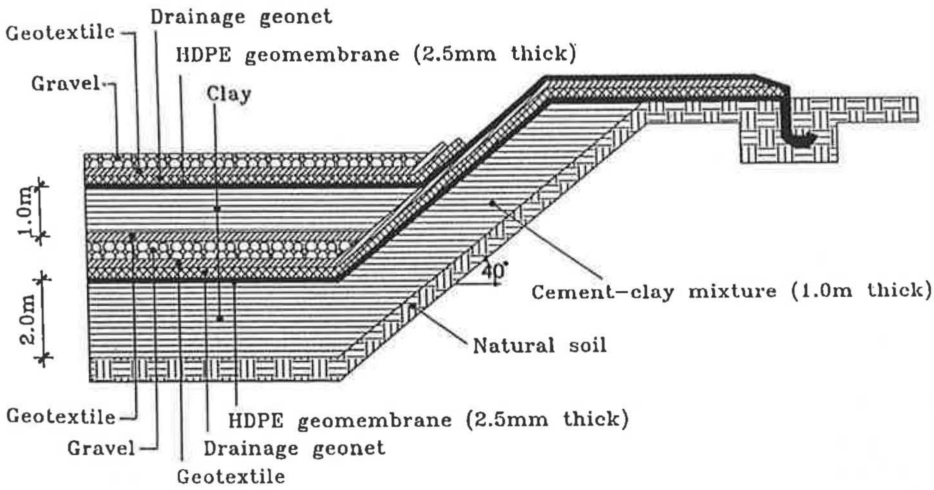

Figure 8. Adopted lining system.

material that assures the requirements for low permeability and safe stability. The solving of this concern led to the choice of a cement-clay mixture. Details of this research are given in Manassero et al. (1994) and Bellezza et al. (1995).

In the following, a description is given of the final adopted lining system (fig. 8).

The bottom lining system is made of two composite liners; in particular:

- compacted clay layer at least 2 m thick directly placed on in situ soil,
- 2.5 mm thick HDPE geomembrane,
- HDPE geonet,
- non woven geotextile,
- at least 20 cm thick pea-gravel drainage layer,
- non woven geotextile,
- at least 1 m thick compacted clay layer,
- 2.5 mm thick HDPE geomembrane,
- HDPE geonet sheet,
- at least 30 cm thick pea-gravel drainage layer.

The sidewall lining system consists of an artificial liner plus a composite liner and is formed of two 2.5 mm thick HDPE geomembranes, one of them directly placed on the 1 m thick compacted clay-cement mixture layer. Above each HDPE geomembrane, a HDPE geonet with a drainage function and a protective non woven geotextile were placed (fig. 8). Geosynthetic materials and their sequence were chosen taking into account the potential failure modes that can occurr along the lining system.

Geosynthetics were also used in the lining monitoring system. The lining monitoring system of each cell of the landfill was made up of two 300 mm HDPE pipes. The first is a slotted pipe which runs through the cell from one edge to the other, while the second comes to a halt in the lowest part of the hydraulic section. In the pipe which crosses the whole section of the storage cell, a periodic inspection for the direct control of the efficiency of the sealing system is provided by means of a telecamera.

The second pipe permits the housing of an alarm and sampling system. The alarm system is made up of a high sensitivity transducer which signals the minimum presence of liquid in the monitoring pipes; the sampling system (lysimetric cell) is made up of a compressed air sampling pump, which permits the lifting of the liquid indicated by the transducer, verifying if the liquid is condensed humidity or leachate coming across the above composite liner. Therefore, the monitoring system is triple: a direct controlling system by means of a telecamera, an alarm system and a sampling system (for more details see Di Molfetta 1993).

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