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An early important application of geosynthetics in Italy: The Seveso case-history

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ABSTRACT: The paper deals with the use of geosynthetics in the barrier systems of two basins, built between 1981 and 1983 at Seveso (Northern Italy), for the safe storage of materials contaminated by dioxin. A very low permeability layer ($k=5x10^{-10}$ m/s), composed of a mixture of sand, gravel and bentonite, was first laid both on the bottom and on the slopes; HDPE geomembranes (thickness: 2.5 mm) were subsequently placed in order to constitute a composite liner able to give an appropriate containment of the contaminated material.

1 FOREWORD

The Icmesa Company plant was a medium-dimension chemical plant, manufacturing intermediate materials for cosmetic and pharmaceutical industry: the plant was located in the area of Meda municipality, about 25 km North of Milano.

On July 10th 1976, owing to an uncontrolled exothermic reaction, the temperature and the pressure inside the vessel for production of 2, 4, 5-Trichlorophenol (TCP) increased to an unacceptable level causing the explosion of the safety pressure disk.

A mixture of chemical compounds brust out into the atmosphere: glycol-ethylene, trichlorophenol, caustic soda and even 2, 3, 7, 8 - Tetrachlorodibenzopara-dioxin (TCDD), a compound which is usually present as an impurity, reached the remarkable level of several hundred grams because of the exothermic reaction (the letal dose for the guinea pig is 3.1×10^{-9} grams per kg of body weigth). The cloud was seen to rise to some 50 meters, then to subside and, driven by wind towards South-East, fall back to the ground, contaminating about 18 km² of a densely populated area.

Therefore, it caused damage inside and outside the factory, where a wide area (named Zone A), of 1.08 km² with 733 inhabitants, was evacuated and persons living in the surroundings were subjected to a number of hygienic regulations, including the prohibition of consuption of local agricultural products.

2 SOIL RECLAMATION STUDIES

Seveso was in the Seventies the first pollution event that interested a large area outside of the fence of an industrial area, caused by a very stable, toxic and unknown chemical.

The only previous studies available were related to the research done by USAF (United States Air Force) for health effects due to the Agent Orange distruction. For this reason, natural methods and chemical-physical methods were developed in order to investigate any possibility for the soil reclamation.

In fact, the option of soil incineration was not technically considered in Seveso, because of the strong opposition of the local population.

Among the natural approaches, agronomic methods, laboratory microbiological methods and use of compost were taken into account.

Among chemical-physical approaches, photo-degradation of TCDD on the surfaces of the polluted buildings, reclamation of the soil with ozone, extraction of the TCDD from the soil with a solvent, dechlorination process of TCDD and degradation of TCDD through gamma rays were considered.

The above mentioned research studies and experiments, although not practically useful for reclamation, reinforced the belief in what had been done, both at scientific and social levels, dispelling the suspicions that somebody wanted to carry out a preconceived plan at any cost. Therefore, the adopted solution was the safe storage of the contaminated materials.

3 BASINS CHARACTERISTICS

Owing to various political reasons, two basins were built up. In fact the zone A comprises two municipalities: Meda and Seveso, each of them had to look after its part of contaminated material.

The capacity of the first basin, placed in Meda municipality, has been estimated of 80.000 m³, whereas the second in Seveso of 160.000 m³.
Essential planivolumetric data of the two basins were as follows:

	First basin	Second basin
top surface	m² 9.300	m² 21.875
bottom surface	m² 4.457	m² 4.480
maximum depth	m 9	m 10
maximum height	m 5	m 6
slope	1V/2H	1V/4H

According to Piepoli et al. (1984), the principles followed for the basins design were:

- studies of geological and geotechnical conditions of the selected zones, in order to ascertain embankment feasibility;
- creation of various barrier systems, so as to prevent the poisonous substance from spreading in the environment;
- construction of a drainage system easy to check;
- development of a basin monitoring system for periodic controls.

4 IN SITU INVESTIGATIONS

In situ investigations were carried out in the area under examination (radius of about two kilometres); in this area wells, springs and streams flooding zones were determined. In total, eight borings were carried out at different depths, in any case more than 20 m below the basin bottom: Fig. 1 shows, as example, the geological map and the geological cross-section of the second basin.

The in situ investigations pointed out that the basins area mostly consists of alluvial deposits and rests on an alluvial conglomerate layer. The in situ investigations found also the existence of a continuos clay layer at 25÷30 m from the basins bottom: this layer was sufficient to constitute a separation bed from the underlying groundwater level.

5 BARRIER SYSTEMS

The barrier systems were formed by composite liners, made of a suitably studied mixture, composed of aggregate (sand and gravel) and bentonite, on which an HDPE geomembrane was applied.

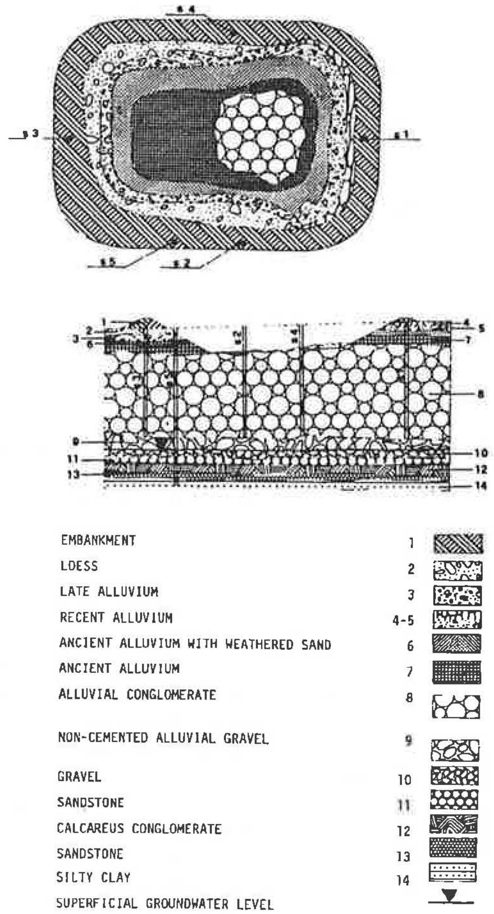

Fig. 1 - geological map and geological cross-section of the second basin, with the positions of the five borings (s1 to s5)

The work of mixing, laying and compacting the aggregate and bentonite layer was extremely difficult and required the development of particular working methods. The results obtained by this placing method were finally satisfactory: in fact, modified Proctor density values higher than 98% and permeability values of about 5 x 10^{-10} m/s were recorded.

The layer of sand, gravel and bentonite was covered with a bitumen emulsion, as protection from dehydration or washing due to meteoric agents.

The choice of HDPE geomembranes was made in view of their high resistance to the actions of chemical-physical and environmental factors, after an accurate comparison of the various characteristics obtained by experimental tests on different synthetic products.

The geomembranes used in the two basins were supplied and placed by two different industrial firms, using different laying and welding systems.

In the first basin, the HDPE geomembrane was supplied by Schlegel and placed by an associate German company (GFA). The cross-section of the first basin and the geomembrane positions are shown in Fig. 2.

The geomembrane sheets were supplied in rolls, 2.5 mm thick, 10 m wide and 150 m long: they were precut according to a particular placing plan and laid first on the slopes, then on the bottom surface. Sheets were overlapped for about 0.20 m; surfaces were roughed, using abrasive grinding wheels, then fastened down with Leister, so as to prevent relative movements of the two sheets. These operations required a certain length of time, but allowed the two sheets to have the same elongations. Afterwards, welding by extrusion of a 40 mm colourless, pure HDPE, was made. Geomembrane sheets were heated by means of two halogen lamps placed in front of the extruder.

Welding visual control was easy: in fact, impurities, steam bubbles or not properly welded spots were clearly detectable for material transparency. Welds were also submitted to ultrasonic inspection. A welding sample was taken every 500 m and subjected to tensile tests on the site.

In the second basin the HDPE geomembranes were supplied by Sarna Italia, made under licence of the homonymous Swiss company. The cross-section of the second basin and the positions of the geomembrane are shown in Fig. 3.

The geomembrane sheets were supplied in rolls, 2.5 mm thick, 2.5 m wide and 185 m long: they were placed from edge to edge following the basin shorter side. There were some difficulties in laying the sheets on the top edges. The welds were executed by a radiant-wedge system performing a double parallel weld, leaving inside a groove for pneumatic control: the groove was subjected to a pressure of 150 kPa, which had to remain unchanged for about 10 minutes. Also in this second basin, in situ tensile tests on the welds were performed every 500 m.

On the arrival at the yard, the geomembranes were checked to ascertain their conformity to the established requirements. A sample was taken every 3000 m² and submitted to the following physical and mechanical laboratory tests:
- thickness;
- mass per unit volume;
- tensile test.

The tests were carried out in Milano, both at the Plastic Materials Laboratory of the Technical University (Politecnico) and at the Special Materials Laboratory of the Research Center for Hydraulics and Structures (ENEL Spa): laboratory tests results on 80 samples for both types of geomembranes are given by Piepoli et al. (1984).

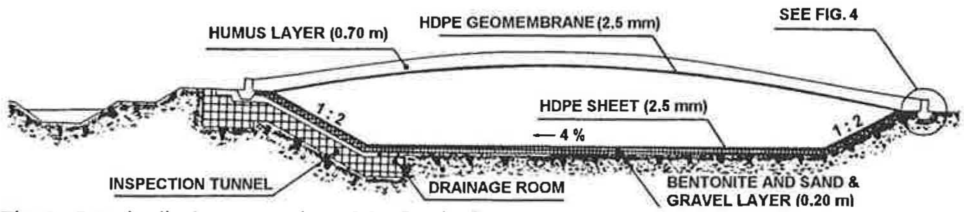

Fig. 2 - Longitudinal cross-section of the first basin

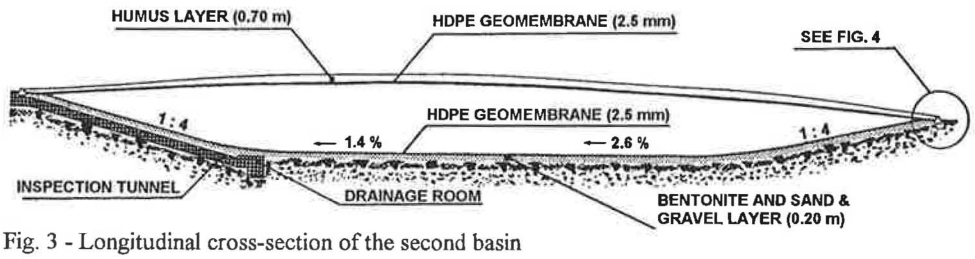

Fig. 3 - Longitudinal cross-section of the second basin

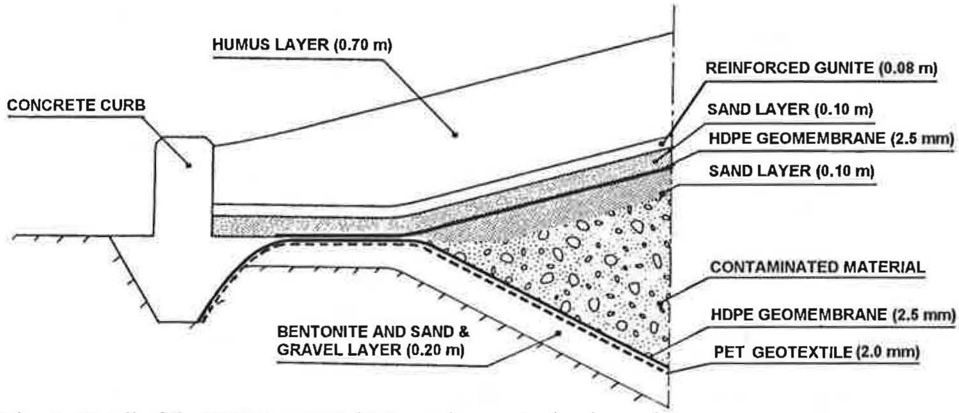

Fig. 4 - Detail of the HDPE geomembrane anchorage to the slope edge

6 BASINS CONSTRUCTION DETAILS

The anchorage of the HDPE geomembrane to the slope edge is shown in Fig. 4. The other construction details (drainage system, filling methods and basins covering) are described hereafter.

For the drainage system, basins slopes converge below the lining layers to a point, in which a reinforced concrete room has been built, in order to collect liquids inside the waste basin.

Apart, another pipeline collects for control liquids between the HDPE geomembrane and the gravel-sand-bentonite layer. The drainage room is accessible from the embankment through an inspection tunnel at the beginning of which a forewell made it possible to install treatment plants and to place a dressing-room for technicians employed on control.

Plants inside the tunnel are explosion-proof for the presence of biogenetic gas. Before placing contaminated material in the basins, a sand layer was spread out on the bottom for both draining function and main mechanical protection of geomembranes.

Access ramp to the first basin was built up with some difficulties using contaminated material. For the second basin, the ramp was foreseen during construction, so that filling works were made easier.

An adequate protection for HDPE sheets was arranged along the down ramp, so that damages caused by heavy vehicles transit were avoided. The contaminated material was placed on the basin bottom and separated from the draining layer by an additional PET geotextile.The material placed in a layer, 0.80÷1.00 m thick, was carefully rolled before proceeding to the next.

Concerning basins covering, when the filling operation was at the end, the material was levelled, than a PET geotextile was stretched out and fastened down using a bitumen emulsion. The HDPE geomembrane was placed and welded to the one of the bottom (as illustred in Fig. 4). Then, a 0.20÷0.30 m thick layer of mixed quarry material was layed, on which a reinforced-concrete covering casting with adequate joints was placed, so that differential settlements were possible. On the top, a layer of cultivable soil, 0.70 m thick, was placed, with the aim of hill grass regeneration.

7 MONITORING SYSTEMS

The two basins were equipped with a monitoring network to check any environmental change vs. time and to evaluate any possible modification caused by the construction of the basins. The monitoring systems (described by Cazzuffi & Piepoli, 1996) were as follows:
- settlements monitoring system;
- permeability control system;
- groundwater monitoring network.

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