PORTUGUESE MULTIMUNICIPAL LANDFILLS: DESIGN AND CONSTRUCTION

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SUMMARY: In the last few years, an important effort has been made in Portugal in order to change the waste management policy. The open dumps are being closed and several sanitary landfills are being constructed. In this process, geosynthetics are playing an important role. However, the application of geosynthetics requires new earthworks concepts and new geotechnical approaches to design, which were almost absent until recently in Portugal. This paper focuses its attention on the preliminary data collected from the Multimunicipal Solid Waste landfills already constructed. The main design requirements adopted, for which some international specifications were followed, the Construction Quality Assurance prepared by National Laboratory of Civil Engineering (LNEC), and, finally, the main construction problems detected are reported in the paper.

1. INTRODUCTION

In Portugal, about 3 x 10^6 tons of Municipal Solid Waste (MSW) is produced per year. From these, 60% is placed in open dumps without any treatment, 14% is placed in controlled refuse pits and only 27 % have an adequate final destination being distributed by 5 composting plants and 13 MSW landfills (QUERCUS, 1995).

In the last few years, with the growth in the concern for environment issues, an important effort has been made in Portugal to change the waste management policy. In 1996, a MSW strategic plan was approved. In this plan, the main guidelines of the waste management policy were drawn. It comprises an integrated approach that includes the recycling, composting, incineration and landfilling. The first priority is the construction of forty new landfills, before the year 2000, and the closure of three hundred open dumps.

In 1997, the Ministry of Environment with the Municipal Councils took over the responsibility of the installation of the landfills (Figure 1). Several acceptance criteria were used on site selection. Nevertheless, the location of these sanitary landfills has been ultimately a political decision. Therefore, from a geothecnical and environmental point of view, the sites selected were not the most suitable for installing the waste disposal facility.

The Ministry of Environment, through the *Instituto dos Resíduos* (Waste Institute) and the Company *Geral de Fomento, S.A.*, requested the collaboration of the LNEC, to control the design and construction quality of the Multimunicipal Solid Waste (MMSW) landfills. Since they were the biggest ones, hence the most hostile to environment, special design criteria and a more detailed construction quality control have been adopted.

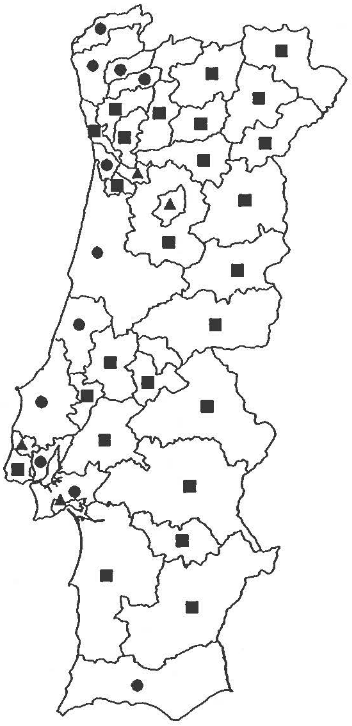

Figure 1. Location of the Portuguese sanitary landfills (adopted from PERSU, 1997)

2. DESIGN CONSIDERATIONS

In the design of Portuguese MMSW landfills special attention was paid to the lining system, since this is essential to minimise the potential groundwater contamination. Reference should be made to the fact that geosynthetics played an important role in the liner systems concept. Geosynthetics present some advantages in comparison with traditional materials, hence are nowadays more often used. They make it possible to increase the storage capacity of the landfills. They are more homogeneous, easier to handle and to install, and their construction quality control is easier to perform. However, the application of geosynthetics requires a new geotechnical approach to design and a new earthworks concept. Formerly, Portugal did not have any national specification for the design and application of geosynthetics in sanitary landfills. Geotextiles with 300g/m^2 and geomembranes 1,5 mm or 2,0 mm thick have been regularly employed and supplier recommendations have been frequently followed.

During the last few years, considerable progress has been achieved. For the MMSW landfills, design basic rules of the liners and covers were established, mainly based on international experience aiming at a justifiable degree of safety with respect to the environment.

As a general trend, a multilayer landfill liner design, composed by mineral and geosynthetic materials, was used. A high density polyethylene (HDPE) geomembrane, with a minimum thickness of 2 mm, was required. Typically, geomembranes were associated to either a low permeability subgrade ($k < 10^{-9}$ m/s), with a 1m thickness, or a Geosynthetic Clay Liner (GCL). Since the geomembranes are rather thin and sensitive to mechanical damage, in each case, a protective coverage formed by a geotextile and a sand layer was used.

To prevent any build up of leachate pressure head above the sealing layers, a drainage blanket with about 0,5 m of an aggregate (ϕ = 20 to 50 mm) was incorporate in the basal lining system.

Finally, a geotextile filter was usually placed between the drainage blanket and the waste to maintain the long-term performance of the drainage system.

Usually, MMSW landfills were designed aiming at achieving the steepest slopes possible to increase the storage volume. Therefore, not only global stability but also for internal stability analyses have been checked (failure mechanism of which sliding plane lies completely or partially within the contact plane of geosynthetics have been examined).

In order to minimise the geomembrane tensile stress particular attention was paid to the evaluation of shear conditions above and underneath geomembrane, to ensure that the mobilised friction at the lower surface of geomembrane is higher than at the upper surface.

Final covers were also designed. They were based on Draft proposal for a Council Directive on the Landfill of Waste (1997) recommendations. The main components of the cover systems landfills are: a regulating soil layer immediately above the waste body; a gas drainage layer; a sealing layer; a drainage layer thicker than 0,5 m; and a top soil cover thicker than 1m. The sealing layer has not always been associated with a geomembrane. In the later case it included at least a clay liner with 0,5 m thickness, so as to prevent the infiltration of the rainwater.

3. CONSTRUCTION QUALITY ASSURANCE PLAN

Within the scope of the technical advice given by LNEC to the *Instituto dos Resíduos* and the Company *Geral de Fomento, S.A.*, a Construction Quality Assurance (CQA) plan was established for all multimunicipal landfills. Its goal was to assured that the sanitary landfills were constructed as specified in the design.

For geosynthetics, the fixed CQA plan specifies as follows:

- responsibilities of the parties involved;
- inspection activities (observations and tests) to verify if they fulfilled the design criteria and specification;
- sampling procedures (in view of location, size, frequency, acceptance criteria);
- documentation required (to provide by manufacturers, inspection data sheets, daily, weekly, final and acceptance reports).

The majority of the CQA was associated with HDPE geomembranes. LNEC assistance attended to the quality of the materials used and the quality of the construction works. From that point of view, the work carried out comprised:

- supervision of transport, marking, delivery and storage of geosynthetics;
- preliminary visual observations completed by tests to detect any defect that could endanger the performance of the materials;
- *in situ* verification of the geomembrane seams quality, namely by assessing the non-destructive tests results performed by the installer (air pressure and vacuum tests);
- assessment of the destructive tests results performed by the installer (peel and shear tests),

complemented by the execution of the same destructive tests both in laboratory and *in situ*;

- examination of documents from the internal control performed by construction supervisor (analysis of the daily, weekly, final and acceptance reports produced during the geosynthetics installation).

4. CONSTRUCTION CONSIDERATIONS

Each multimunicipal sanitary landfill was constructed as specified in the design, after a design quality control carried out by LNEC.

During the construction, several interesting and sometimes unexpected problems, especially related with the geomembranes, have been observed. Some of the most important problems are described below.

4.1. Weather influence

Installation of geomembranes requires favourable weather conditions. High temperatures as those recorded in Portugal during the summer, apart from being unbearable for the workers, affect the quality of the geomembranes installation and the quality of the welding. During the day, with the increase in the temperature, HDPE geomembranes expanded forming waves. These waves produced apparent material excess that disappeared as soon as the temperature dropped and the contraction took place. According to the general specifications for welding of geomembranes, welding must be done for temperatures neither higher than 40° C nor lower than 10° C. When the MMSW construction works were taking place, temperatures frequently went up above the specified limits (often exceeding 40 °C, *in situ*). To solve this problem, the geomembrane rolls were stretched at full length on the sanitary landfill and were weld only before the 11 a.m. or after the 05 p.m.. Apart from that fact, the work was only done when adjacent rolls had the same degree of expansion. These limitations were a negative factor, because it did not allow taking advantage of the whole working day, not even for *in situ* quality control purposes.

Another problem related with temperature fluctuations has arisen. The destructive seam tests (shear and peel) carried out at the *in situ* laboratory, without air conditioning, produced bigger peel and shear load values when performed at ~~higher~~ temperatures than those indicated in the standard. Destructive seam tests carried out in laboratory, in compliance with the standard temperatures, displayed that field tests gave inaccurate results, since they showed that the welds were satisfactory when they were not.

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4.2. Seagulls damage

In one of the sanitary landfills where a geomembrane leakage detection system was installed, a peculiar problem has been observed. For general surprise, more than half detected damages were due to the seagulls. They transport on the beak and feet objects, namely small bones that remained on the geomembrane producing holes (Figure 2).

The above mentioned system was useful on the one hand because it emphasised the importance of carrying out thorough visual inspections before installing the geomembrane protective layer. On the other hand, it made it possible to detect small imperceptible tears (for instance made with a cutter on a patch execution) that can turn the geomembrane liner inoperative.

Figure 2. Example of geomembrane damage caused by the seagulls

4.3. Anchorage problems

A significant problem arose due to slipping of the geomembranes on the side slopes. In spite of a proper anchor trench design, geomembranes slipped down forming big waves on the slope bottom. These waves were visually identical to the ones caused by thermal expansion of the geomembranes (Figure 3), but they did not disappear when the temperature dropped, because they resulted from inadequate anchor trench weight.

Figure 3. Example of geomembrane waves

4.4. Effects of exposure on geomembranes

The effects of exposure on geomembranes are not well known yet. However, there are several evidences showing that the sun exposure can affect shear test results. Peggs' studies (1991), suggest that the elongation of the geomembranes during a shear test are an indicative factor of the weld quality in terms of stress cracking resistance. In order to evaluate this influence, and taking in to account the Portuguese weather conditions, a research programme is under way. For each sanitary landfill where LNEC has given technical support, a sample was removed from the seam and exposed *in situ* to weather conditions for several years. Subsequently, five specimens will be removed from the samples every year and will be submitted to shear tests. Until now, it is not possible to draw any conclusion since the work is at the beginning.

5. FINAL REMARKS

The experience achieved with the Portuguese MMSW landfills leads to the following remarks:

- Minimum requirements for geosynthetics to use in Portuguese sanitary landfills design must be established. Within that scope, LNEC is preparing a guide definition for management technical specification for municipal waste confinement. This document is issued from international experience enriched by the know how meanwhile achieved in Portugal;
- Emphasis must be given to quality assurance (manufacturing and construction), in order to obtain an effective performance of the liner systems. It would be an improvement if a leakage detection system, able to localise possible defects in the geomembranes, could be required on construction quality assurance. It would allow the repair of any possible damage before the beginning of the refuse disposal;
- In places where high weather fluctuation occurs, geomembrane installation requires extra-care handling and a severe seam control.

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