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CLAY OR GEOMEMBRANE FOR MUNICIPAL WASTE LANDFILL?

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1. Waste deposits in Romania

One of the major problems that mankind has to face at the end of the 20th century is that of environment degradation. In this respect, waste depositing is one of the main elements that lead to a degradation not only of the environment, but also of people's health and the landscape.

Romania is also affected by consequences of uncontrolled, wild depositing of city wastes.

A new trend of thought regarding the construction of ecological landfills for solid wastes has been brought forth by a number of factors such as:

- the new regulations that were issued (Law 137/1995, Regulation 125/1996, Law 107/1996);
- the obligation to comply with the regulations operating within the European Community;
- the fact that the uppermost fill level has been reached in 80% of the existing waste deposits;
- the poor conditions of the environment in the area where such deposits are under operation.

As a result, the way to deal with design and construction matters has also improved.

2. Content of the projects

The landfill design has been achieved according to the following scheme:

a) Facilities design: comprising the slope, lining, rainwater collecting, leachate collecting, gas discharge installations, monitoring system.

b) Equipment design: comprising: scales, watchman's quarters, office quarters, warehouse for recycled materials, carwash platform, water tank, electric power supply, telephone facilities, fencing, technological platform, protected area, access road.

The first waste landfills that were designed according to a new, up-to-date conception, taking into account the environment protection, are under construction in the cities of Câmpulung and Sighisoara, with full monitoring to take place both during and after the filling period.

Besides these two landfills, another fifteen have already been designed.

The lining/sealing system to be applied at the base of the landfill has led to extended discussions within the technical community in Romania.

Since generally in Romania the locations of waste landfills are on clay soils or close to clay deposits, the idea of using geosynthetic materials has been forwarded.

Modern landfills designed in Romania

3. Case-study: the waste landfill in Sighisoara

3.1. Location:

In the absence of available land for the landfill location, it was decided to encapsulate the existing waste deposit and to extend it both vertically and over the neighbouring natural soil.

3.2. Design plans

3.2.1. First solution: lining by means of geosynthetic materials.

A. Lining of compartment 1:

- natural soil foundation;
- natural biological barrier, well-compacted, over 0.30 m thick, $K = 10^{-6}$ cm/s;
- geotextile layer meant for the protection of the geomembrane;
- 1.5 mm, rough HDPE geomembrane;
- geotextile layer for protection;
- mineral drainage layer 0.50 m thick.

B. Lining of compartment 2:

- foundation on the existing deposit, to be achieved above the reinforcing layers (biaxial grid and 0.40 m thick gravel);
- GCL geocomposite clay liner;
- geotextile layer;
- mineral drainage layer 0.50 m thick.

The idea of using such sealing (and reinforcing) systems for the landfill base was strongly opposed by some of the Romanian specialists as well as by the Client's foreign Consultant, who suggested the following plan:

- excavation of the waste down to the natural soil;
- a well-compacted clay layer 0.80 m thick, for sealing purposes;
- inserting a bentonite layer for addditional safety;
- the wastes that were excavated are to be restored to their previous place.

3.2.2. Second solution: clay liner

In order to study the possibility of using clay to seal the waste landfill base, full data on the physical, chemical and mechanical properties of the material are necessary, both in its natural state and under stresses such as the ones particular to the construction.

The problems to be solved are connected to the nature and geotechnical characteristics of the clay, based on which the material will be selected so as to provide as low a permeability factor as possible, and also to allow it a sealing function and an appropiate mechanical behaviour (erosion resistence, bearing capacity).

The local sealing material (clay) comes from a deposit located 7 km. away from the site.

3.3. Geotechnical trials

3.3.1. Trials made for to assess the nature and composition of the clay

When carrying out the innitial visual survey of the clay samples taken in Sighisoara, it was noticed that it has a schistous aspect, displaying a stratification of the clay material with fine sand insertions, gray colour, a dry condition that encourages a tendency to break down in planes parallel to the stratification, which results in parallelepipedic fragments of large dimensions (ranging in tens of centimeters). Geotechnical trials were carried out on this material, according to the provisions comprised in both the Romanian and the international norms and standards in operation.

In this respect, trials were carried out to determine the granulometric composition of the material and the other physical and structural elements (values of density, volume-weights, pore sizes).

To establish the humidity condition of the material in its natural state, the humidity value, saturation coefficient and consistency index were measured.

The plasticity condition was assessed by measuring the plasticity limit (w_l, w_p) and calculating the plasticity index (I_p).

These values, which are presented in Table 1, allow the description of the clay material in Sighisoara as dusty clay in a solid state, with a high plasticity value (I_p=20-35%) and low activity (I_A=0.608), containing and average value of 10.3 % $CaCO_3$.

3.3.2. Trials to determine the behaviour of the material when in contact with liquids

The main element that characterises the soil materials to be used in sealed barriers is the permeability coefficient.

For the material in Sighisoara, the permeability was measured according to the provisions of the ETC-8 Instructions of the International Society for Geotechnics and Foundations. These compacted samples were prepared at optimum humidity, obtained by the Proctor test (w_{opt}=19%).

The trial was carried out by means of triaxial compression equipment, by keeping a constant hydraulic gradient and inducing an isotropic strain within the cell, higher by 30 kPa than the water pressure in pores.

The average permeability coefficient resulting from the laboratory tests was $k = 10^{-10}$ to 10^{-11} m/s.

On the other hand, permeability tests were performed on the leachate resulting from the Sighisoara waste deposit. These tests were carried out in the variable level permeameter on uncompacted samples obtained by a settlement of the crushed clay in the liquid (which lead to a compaction coefficient of approx. 70%).

Thus, the permeability coefficients obtained ranged from 10^{-8} to 10^{-9} m/s. These values confirm the strong influence that clay structure and installation procedures have on the permeability values.

To follow up the behaviour of the clay when in contact with liquids (water or leachate) and its capacity to retain polluant elements by cation exchange, free swelling tests were also carried out.

The behaviour was followed up at regular time intervals, while the swelling process was relatively stable. In contact with the leachate, a stronger swelling was noticed during the innitial 8 hours, while after 24 hours the swelling decreased, which led to an overall smaller swelling than in the case of contact with water.

In addition to these common tests, a special one was also carried out, which is comprised in the international norms (Monjoie, 1992) to assess the risk of clay material erosion within the sealing layer. This trial, which is called "the TS test", simulates the erosion process by stirring the water on top of a clay sample.

The values obtained are based on the percentage of material going into the water after the erosion process, and they are presented in the following table:

Sensitivity to erosion	Percentage of eroded material
large	> 50%
medium	10 - 50%
low	< 10%

The results of these trials on the Sighisoara clay showed approx. 25% losses in the material, which allows a classification of this clay as a material having a medium sensitivity to erosion.

3.3.3. Trials to determine the mechanical behaviour of the clay

According to the provisions of international norms, the elements regarding the mechanical behaviour of the clay to be used as a sealing layer were obtained by means of trials meant to give information on its strain characteristics, as well as trials regarding its shear strength.

By means of consolidometer trials on clay samples compacted to the optimum humidity value obtained by Proctor test (w_{opt}=19%) and saturated with water and leachate, the swelling pressure of these clays was obtained, i.e. 120 kPa for the leachate and 90 kPa for the water. On the other hand, the values of the consolidometric modules M obtained between levels 200 kPa and 300 kPa are slightly different, depending on the saturation liquid, i.e. they range between 5,000 and 6,000 kPa. These values classify the material as a medium compressibility soil (M = 5,000 - 6,000 kPa). Considering that these values of the consolidometric modules are situated at the lower limit of the scale, it is noticed that in case of insufficient compaction and flooding of the layer the material will behave as a highly compressible soil (M = 1,000 - 5,000 kPa).

The factors regarding shear strength were assessed by means of a direct reversible shear device (ELE-type) on saturated samples, with average values: c = 82 kPa, f = 10°6

3.3.4. Chemical trials

To assess the effect of leachate on the sealing material, during the innitial phase, trials were carried out to establish its chemical composition.

- pH = 8.2 - mildly alkaline;
- very high total hardness = 72.8° G;
- very high mineralization: residue 105° = 16.3 g/l;
- losses after calcination = 8.2%;
- prevailing ions:
  - sulphates - 6.4 g/l;
  - chlorides - 3.0 g/l;
  - sodium and potassium - 5.0 g/l;
  - bicarbonates - 1.33 g/l;
- organic matters in high, oxidable concentrations with $KMnO_4$: CCO-Mn=953 mg/l.

At a subsequent stage, the leachate was placed in contact with the clay and filtered through it. It was noticed that:

- the organic matters within the leachate are adsorbed on clay in a percentage of 54.6%, while in passing through the clay this reached 55.5%;
- regarding the ion retention on clay, a slight reduction in the dissolved salts was noticed.

The comparative results are presented in the following table:

Table 1

Element	*Unit of measure*	*Leachate*	*Leachate after contact and filtering through clay*
aspect	-	coloured, no dry suspensions	coloured
colour	-	brown-yellow	bright yellow
smell	-	rotten leaves	-
Ph	-	8.26	9.2
total alkalinity	meq/l	21.8	-
permanent alkalinity	meq/l	-	7
total hardness	meq/l	26	24
HCO_3^- bicarbonates	mg/l	1330	-
Ca^{2+}	mg/l	400.8	400.8
Mg^{2+}	mg/l	72.9	48.6
Cl^-	mg/l	3000	3177
SO_4^{2-}	mg/l	6400	7400
total Iron	mg/l	10	-
$Na^+ + K^+$	mg/l	4945	-
Na^+ (flame-fotometer)	mg/l	5000	6000
K^+ (flame-fotometer)	mg/l	1500	2300
oxidable organic matters with $KMnO_4$	mgO_2/l	953	424
residue 105°C	mg/l	16380	-

Remarks:

The residue after burning, 440^0, indicates the existence of volatile (organic) substances in a percentage of 8% of the constant residue.

Compared to the requirements mentioned in the international standards, and taken into account the results of themainly geotechnical trials that were carried out in the Laboratory for Geotechnics and Foundations of the Bucharest University of Civil Engineering, the following points should be considered:

- from the point of view of the nature and structure, the clay material proves to be within the suitable limits to be used in a sealing layer;
- from the point of view of its behaviour in contact with liquids (water, leachate), this material shows a tendency to expand its volume, medium sensitivity to erosion and permeability values strongly influenced by the condition of the material, which sometimes exceed the acceptable limits for sealing layers ($K < 10^9$ m/s);
- from the point of view of the capacity to retain some of the polluant elements in the leachate, the only aspect noticed was the capacity to reduce the quantity of organic matters;
- from the point of view of behaviour under stress, the material shows a tendency to deform, which can lead to settlement;
- from the point of view of the structure and condition of the clay material in its natural state, it is difficult and costly to install in site, because it requires a technological process comprising many operations (crushing till it is brought down to centimeter-size lumps, thin compacted layers, good planning, uniform compaction humidity of around 19% etc.).

Therefore, it is unlikely to be able to obtain a degree of compaction that would prove to have the permeability coefficient established in the laboratory ($K=10^{10}....10^{-11}$ m/s).

CONCLUSIONS:

- The aim of the study was to achieve laboratory trials (geotechnical and chemical) that would predict what would happen if clay was used as a sealing layer on the base of the waste landfill in Sighisoara.
- The specific requirements that base sealings have to fulfill were established, as well as the specific characteristics of the clays that are included in these layers, with detailed and practical trials in the laboratory, so that laboratory parameters of the clay materials can be obtained.
- A number of aspects connected to the installation of the clays in sealing layers were studied, since these layers can tremendously affect the behaviour of the landfills during operation.

The second solution requires an intricate technology implying:

- excavation of the existing waste;
- installing a large volume of clay that will reduce the total volume of waste fill (around 1 cu.m/sq.m);
- the quality of the works will depend on local (random) factors (climate, manpower) which should lead to the achievement of a homogenous sealing layer;
- clearing the existing waste deposit area in oder to seal it with clay would require the temporary use of another piece of land in order to deposit the excavated material, but the adjoining land is occupied by private farmers, who do not agree to let their land be affected in any way by the new works;
- the construction period would be extended, because the work system would be slow and would require a large number of heavy construction equipments in a confined space, simultaneously with the operation of daily depositing of the collected city waste;
- there is a danger of affecting the environment, which is already badly affected by the existing deposit;
- there are bigger risks connected with the stability and sealing when using clay, compared to the use of geosynthetics;
- the costs when installing clay are higher than those of using geosynthetics, i.e. around 22 \$/ton of deposited waste for clay, compared to 15 \$/ton with geosynthetics.

Therefore, it is appreciated that the use of clay, in successive layers around 1.00 m thick, for sealing the base of the Sighisoara landfill is not appropriate, neither technically nor economically.

This study can offer an answer to the question: "Clay or geomembrane?", which turns up whenever a new project is being prepared. The conclusions that were reached after the above-mentioned analysis have a general character, and they should be taken into consideration whenever a new project is started.

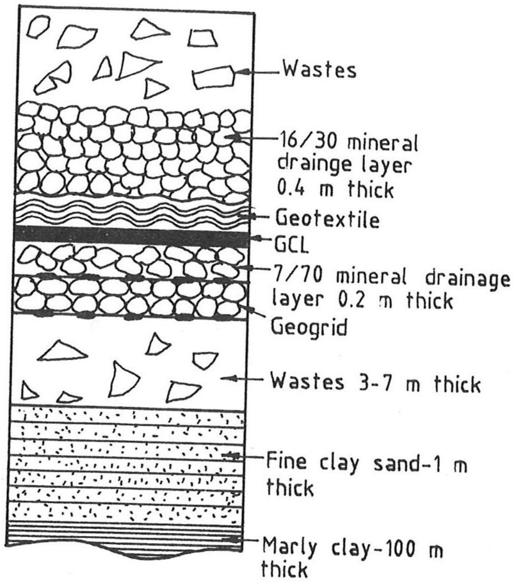

Figure 1: Base Seal - Compartment No. 2

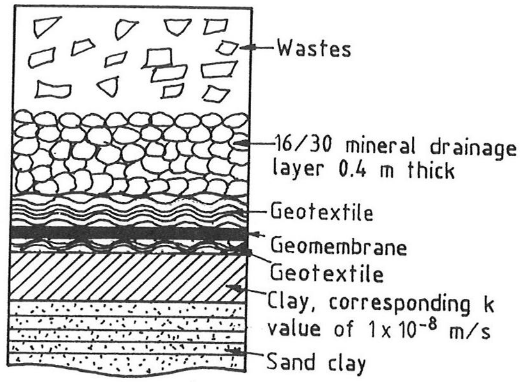

Figure 2: Base Seal - Compartment No. 1

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