Site Investigation and Landfill Construction I

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Contents

Site Investigation | Base Liners | Base Drainage | Covers & Geotechnics

- Testing the hydraulic conductivity with stand-pipes
- Compaction of a mineral base liner
- Construction of the leachate collection system
- Different covers at Breitenau experimental landfill in Austria
One Landfill – Three Barriers

1. Liner – technical barrier
2. Site – natural ("geological") barrier
3. Waste as a barrier (waste treatment)

Groundwater

Geological Barrier

“Geological Barrier” (after Austrian Landfill Ordinance)

Thickness of barrier

5 m, if hydraulic conductivity after Darcy $k < 1.0 \times 10^{-7}$ m/s or
3 m, if hydraulic conductivity after Darcy $k < 1.0 \times 10^{-8}$ m/s
Geological Barrier

Geology of the Damascus Basin

Conclusion
Around many urban areas an appropriate natural geological barrier is not available; thus, it has to be constructed:

- Man-made geological barrier
- Natural underground (aquifer)
Site Investigation

Geotechnical site properties

- Strata (type and position of sediment or rock layers)
- Hydraulic conductivity
- Shear strength (shearing angle $\phi$; cohesion $c$)
- Deformation behaviour (modulus of elasticity)

Methods
Geological mapping, core drillings, trial pits, geotechnical field and lab experiments

Hydrogeological site properties

- Groundwater table
- Groundwater flowing direction
- Hydraulic gradient
- Groundwater flow velocity
- Hydraulic conductivity, transmissivity
- Groundwater quality

Methods
Drillings, tracer experiments, pumping tests, grain-size analyses, geophysical methods (e.g. geoelectrics) groundwater sampling, chemical analyses
Site Investigation

Properties to be determined (Austrian Standard S 2074-2)

- **Compressibility** (quality control: Proctor Test)
- **Plasticity** (quality control: load-plate test)
- **Thickness** (quality control: test pit)
- **Hydraulic conductivity** (quality control: stand-pipe test)
- **Incline** (2 % - 3 %; quality control: geodetic)

<table>
<thead>
<tr>
<th></th>
<th>Proctor density D&lt;sub&gt;pr&lt;/sub&gt;</th>
<th>Modulus of elasticity E&lt;sub&gt;1-1&lt;/sub&gt; [MN/m&lt;sup&gt;2&lt;/sup&gt;]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse grained soils</td>
<td>$\geq 100 %$</td>
<td>$\geq 30$</td>
</tr>
<tr>
<td>Mixed grained soils</td>
<td>$\geq 98 %$</td>
<td>$\geq 15$</td>
</tr>
<tr>
<td>Fine grained soils</td>
<td>$\geq 95 %$</td>
<td>$\geq 7.5$</td>
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</tbody>
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Site Investigation

Load-plate test
## Site Investigation

**Stand-pipe test**

![Image of a site investigation scene](image)

## Base Liners – Austrian Landfill Ordinance

<table>
<thead>
<tr>
<th>Landfills for demolition &amp; construction waste</th>
<th>Landfills for:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>• MSW</td>
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<tr>
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<td>• Residues from incineration</td>
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<tr>
<td></td>
<td>• Residues from MBT</td>
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</tbody>
</table>

- HDPE (2.5 mm)
- 20-27 cm
- 20-27 cm
- 20-27 cm
- 75 cm

- „Geological barrier“
Construction of Mineral Base Liners

- Natural silt/clay or silty sand/gravel with bentonite
- mixed-in-place or mixed-in-plant with rotary hoes
- Water content ($w_{95}$ on wet branch of Proctor-graph)
- Layers of 35-40 cm
- Compaction with drum rollers

- “Test field” to optimize working procedure
Construction of Mineral Base Liners

Base Liners – Geomembranes

- **High-Density-Polyethylene** (HDPE, PE-HD)
- 2.5 mm thick
- **Chemical resistance** (acidic and alkaline conditions, organic solvents, hydrocarbons, stress-crack causing substances – tensides etc.)
- **Mechanical resistance** (contact to drainage/waste)
- **Biological resistance** (microorganisms, roots, rodents)
- **Welding**: double seam with test channel
- **Protection**: non-woven geotextile > 1200 g/m²

Channel for leak-detection with compressed air

Seams

> 45 mm
### Leachate Collection System

#### Drainage layer
- thickness > 50 cm
- 16-32 mm gravel
- Lime content < 30 m-%
- $k_f$ after Darcy > $1\times10^{-2}$ m/s

#### Leachate collection pipes
- PVC
- Gradient 2-3 %
- Diameter > 20 cm
- 30 m distance
- Protection: non-woven geotextile
Leachate Collection System

Leachate Collection System – Gravity Drainage

“Hole”

“Pile”

“Slope”
Landfill Covers

Why do we have covers?

**Traditional functions**
- prevent rainfall ingress
- prevent gas emissions
- provide medium for plant growth

**Recent developments**
- oxidise low level methane emissions
- allow flushing of landfill

Standard Cover of MSW Landfill after Austrian Landfill Ordinance

- 50 cm recultivation layer (soil + vegetation)
- 50 cm run-off collection layer (gravel)
- 50 cm mineral liner (2 layers)
- 30 cm gas collection layer (gravel)
- 50 cm compensation layer (shredded waste)

Total thickness: 2.3 m
Landfill Covers

Alternative covers
- Geosynthetic clay liners (bentonite)
- Asphalt liners
- Capillary layers
- Evapotranspiration layers

Evapotranspiration layers
- Combination of substrate and vegetation
- Minimisation of water ingress by maximisation of evapotranspiration
- Water from precipitation out of vegetation season is stored in pores of substrate
- Restriction in areas with humid/alpine climate

Evapotranspiration Cover (example)

- 50 cm infiltration layer (soil + vegetation)
- 150 cm water storage layer (graded grain-sizes)
- 50 cm compensation layer (shredded waste)
- Total thickness: 2 m
Geotechnical Properties of MSW

Main failure mechanisms

1. Surface-near and deep-seated slope failure (along the liner and drainage system)
2. Sliding of the perimeter embankment
3. Sliding of the capping system
4. Spreading in the toe zone
5. Base failure
6. Subsoil settlement
7. Settlement of the waste material
8. Lateral displacements
9. Sliding of the waste
10. Failure of perimeter embankments/berms
11. Sliding along the working joints of the landfill

Geotechnical Properties of MSW

- Clay
- Silt
- Sand
- Gravel
- Stones

Mesh minus [%]

Grain size [mm]

0.001 0.01 0.10 1 10 100 1000

MSW 15 years old

MSW fresh

Turczinski (1988)
Geotechnical Properties of MSW

**Density**
\[ \rho = 0.4 \text{ (not compacted)} - 1.3 \text{ (highly compacted)} \, \text{t/m}^3 \]

**Shearing angle**
\[ \varphi = 40^\circ \text{ (fresh MSW)} - 26^\circ \text{ (15 years old MSW)} \]

**Cohesion**
\[ c = 50 \, \text{kN/m}^2 \text{ (fresh)} - 10 \, \text{kN/m}^2 \text{ (15 years old)} \]

Turczynski, 1988

Settlements

- Settlements due to consolidation (max. 25 %)
- Settlements due to biodegradation
- (Subsoil settlements)

Overall settlements up to 50 % of original height
Thank you for your attention

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