Technology for Transformation – Landfill Engineering Case Study: Construction of Landfill Cholwald in Switzerland with Dense Asphalt as a Lining Material

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ABSTRACT:

Bituminous materials are often used in construction works all over the world – such as surfaces for roads and pavements and also as an impervious lining material. There are many situations where impermeability is required, for example, storing and retaining of water (hydro-power, drinking water, irrigation, flood protection, shipping, and recreation) or for the containment of contaminated materials (landfill / waste deposits).

The Cholwald Landfill is situated in Central Switzerland and stores incinerator ash, sewage sludge and contaminated soil. The landfill cell constructed comprises an area of 30,000 m2 and was completed in less than four (4) months. Three (3) cells had previously been constructed using a geomembrane and clay. The initial design for the fourth cell also utilised a geomembrane but the hydraulic risk assessment, in conjunction with a reduced construction period, much steeper slopes and significant cost savings, convinced the Client to line the cell in Dense Asphalt Concrete (DAC).

1. INTRODUCTION

Bituminous seals have been used successfully for about 75 years. In addition to landfill lining, dense asphalt can be used to line compensation and pump-storage reservoirs, canals and dams, snow reservoirs, artificial lakes and ponds. Therefore, in the case of landfill construction and the up-stream side of more traditional containment systems, the construction is sealed with a multi-layered asphalt system or in case of dam core seals, constructed in the dam centre.

Various design options for the different asphalt layers can be used within a lining system dependent upon the specific requirements of each project (high-risk projects, leak control, etc.).

1.1 Specification

Each project has its own specific design requirements and difficulties, such as exposure to UV radiation and persistent deformation of the substrate. However, a high-quality, multi-layered asphalt lining system can be designed to be extremely stable in the slope whilst being capable to withstand all climatic conditions and still remain durable and flexible.

Asphalt landfill lining systems in general have to perform to the following standards:

- Impermeability
- Durability
- Slope stability up to 1 :1.5
- Flexibility – accommodate up to 10 % settlements without losing its impermeability
- Nontoxic for environment

Equation 1 indicates that the most important requirement of a dense asphalt concrete lining system is its air void content – it must have an air void content ≤ 3.00 Vol.-% to ensure it is completely impermeable.

K – Value: Darcy < 1×10^{-13} cm/s [1]

In practice the air void content is the decisive criteria. It can be tested and calculated in laboratory, monitored both during the installation and after completion.

Atypical set of test results on a series of asphalt samples, with different variation of air void content and water pressures, are shown in Table 1:

Table 1: Relationship between Air Voids and Water Pressure

		calculated air void content in Vol.-%							
		5.04	4.92	4.88	4.80	4.32	3.28	3.00	2.24
water pressure	1 bar	-	+	+	+	+	+	+	+
	2 bar	-	-	-	+	+	+	+	+
	5 bar	-	-	-	-	+	+	+	+
	10 bar	-	-	-	-	-	+	+	+
	20 bar	-	-	-	-	-	+	+	+
						- permeable			
						+ impermeable			

Furthermore asphalt guarantees resistance against:

- Mechanical forces
- Chemical and Biological Resistant against fire and aging at temperatures over 50° C
- Vandalism

1.2 Quality

To achieve a high quality bituminous lining system you need to identify suitable raw materials to develop the project-specific asphalt mix for the various layers. The components for a bituminous barrier system are very similar to those for road asphalt.

The components are:

- crushed rock in various fractions
- crushed and natural sand
- filler
- bitumen
- additives (if required).

To achieve the optimum asphalt mix to meet the project-specific requirements, you have to correctly identify the right combination of the constituent elements of the mix to ensure the lining system will perform to the required standard.

Aggregates are selected by different criteria such as:

- hardness
- low water absorption
- resistance to frost
- good affinity to bitumen and shape.

It is very important to ensure the optimal grading of the different aggregates, bitumen and filler to guarantee impermeability. Crushed rock and crushed sand are needed for stability; natural sand is used for workability and bitumen for flexibility and plasticity.

The production of the asphalt mix is undertaken either on site via a mobile mixing plant or off-site by an existing asphalt mixing plant, depending upon the availability of asphalt production. The quality of the asphalt mix has to be monitored at all stages, during its design, production and whilst being installed. Quality monitoring is carried out continuously by experienced laboratories according to a predefined Quality Control Plan.

To achieve high quality asphalt lining system it is essential that the correct installation techniques are used by deploying specially designed machinery, experienced and highly skilled personal and attention to detail when forming joints that are impermeable.

1.3 Installation of Lining Systems

An asphaltic concrete barrier system has a layer composition of three (3) different types of bituminous material, which is usually placed on a gravel or drainage layer of crushed aggregate. The thickness of the drainage layer is usually between 200 mm and 500 mm. This layer acts as an efficient drainage system which prevents the build-up of water pressure underneath the asphalt layers.

The binder layer, with an air void content of 8% to 15 % is placed on top the drainage layer with a thickness of 60 mm to 100 mm. It serves as ventilation layer during the placing of the dense layer to relieve any vapour pressure in the way of steam, generated during the laying process and ensures with its stability a sufficient compaction of the dense layer.

The thickness of the dense layer depends on the demands of the project and on the standards required between 60 mm and 100 mm. To be impermeable it is necessary that the air void content is less than 3 % of its volume.

A thin layer of Mastic is then applied to the dense layer. Mastic consists of a mixture of filler and bitumen and protects the dense asphaltic against the ultraviolet radiation of the sun and seals any superficial voids.

1.4 Technology

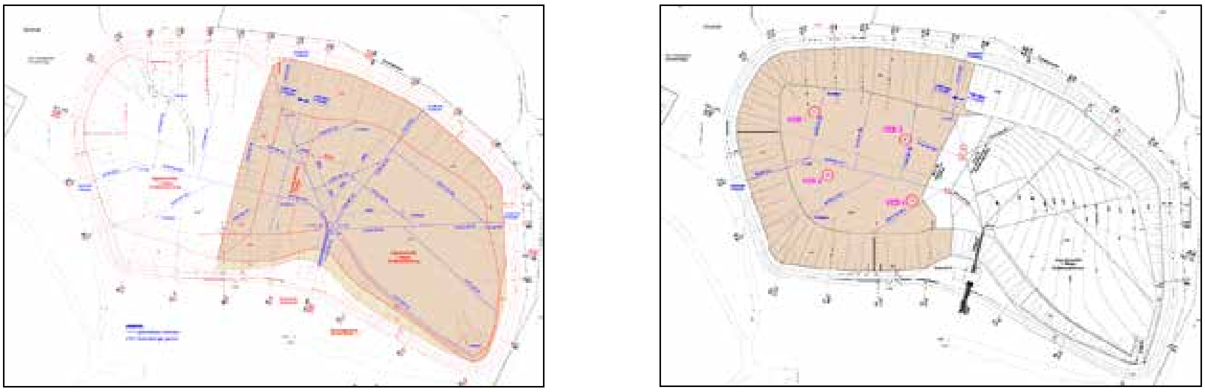
Very quick and efficient installation of the lining system is a major advantage of the bituminous sealing systems. With modern equipment and mixing-plants an installation capacity of 5'000 m² a day can be achieved, even on slopes as steep as 1:1.5 is possible.

Installation is carried out with specially equipment developed to work on slopes. These include slope-pavers, dumpers, rollers and associated winches. This is particularly advantageous for projects in regions with extreme climatic conditions and a short construction period is of great importance.

2. CASE STUDY: CHOLWALD LANDFILL

The Cholwald Landfill is situated in Central Switzerland and stores incinerator ash, sewage sludge and contaminated soil. The landfill cell constructed comprises an area of 30,000 m^2 with a maximum slope length of 35 m and was completed in less than four (4) months. Three (3) cells had previously been constructed using geomembrane and clay. The initial design for the fourth cell also utilised a geomembrane but the hydraulic risk assessment, in conjunction with a reduced construction period, much steeper slopes and significant cost savings, convinced the client to line the cell in dense asphalt.

Moreover, the Client had to build the landfill cell in two phases, the first in 2012 and the second in 2013. The reason for this was due to the way the earthworks had to be carried out. The advantage to the Client was that he could store material in Phase 1 whilst Phase 2 was constructed.



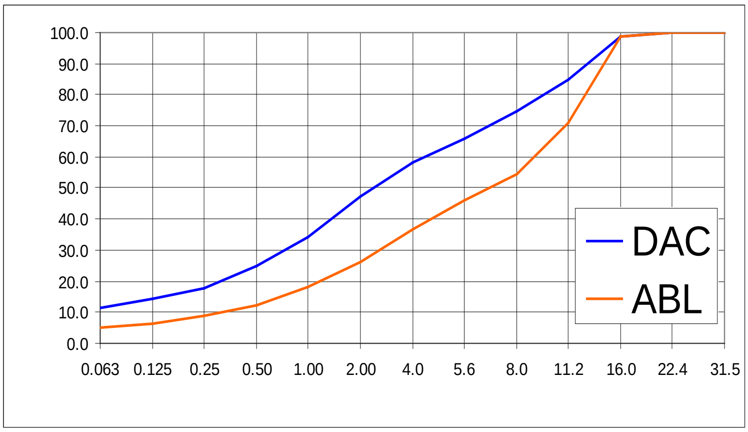
a) Phase 1 in 2012 b) Phase 2 in 2013

Figure 1: Cholwald Landfill – Phased Construction

1.5 Pilot Survey

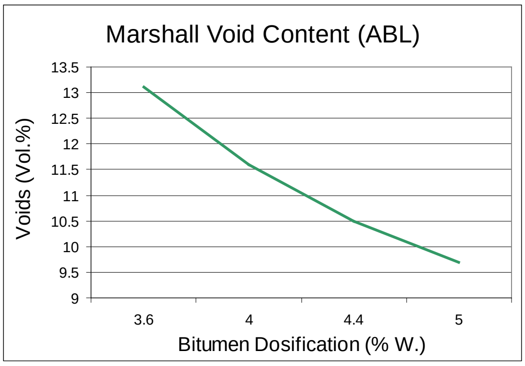
Prior to the construction, the WALO Laboratory had to identify the optimum asphalt mixes (Asphaltic Binder Layer (ABL), Dense Asphalt Concrete (DAC) and Mastic), as shown in Table 2: to meet the project specific requirements. For this purpose the rock and bitumen samples were obtained from the mixing plant to be used and were tested for their constituent properties. When the laboratory investigations were complete, different trial mixes were produced for the different materials (ABL, DAC and Mastic) in order that the correct mixes for each material could be identified in terms of its bitumen content and aggregate grading as shown in Tables 3 and 4.

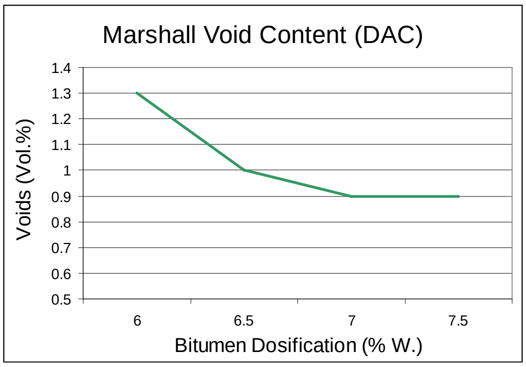
Table 2: Optimum Grading Design for both ABL and DAC



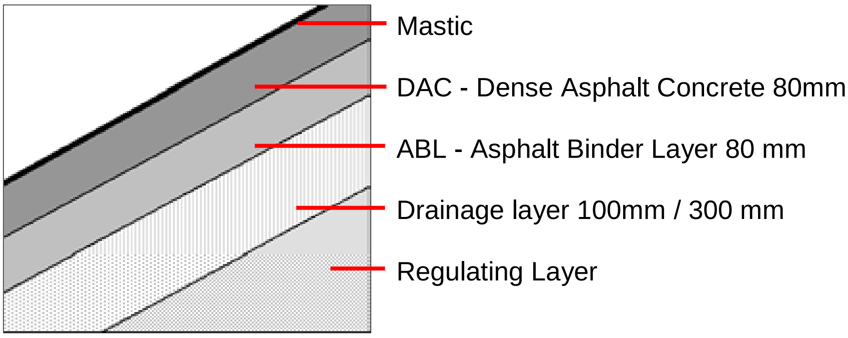
Tests in the Marshall body are indicative of the best bitumen dosage.

Table 3 & 4: Marshall Testing to Determine Optimum Design to Achieve the Correct Air Voids





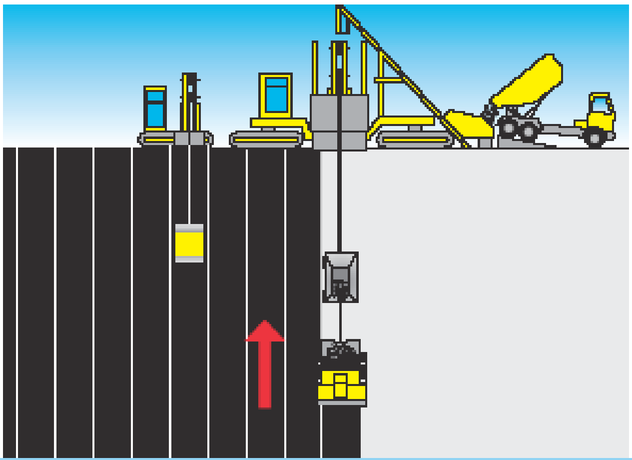
Upon completion of the laboratory investigations a suitable design was identified and a fourth cell was constructed consisting of a 100 mm regulating layer (0/30 gravel) in the slopes, a 300 mm drainage layer (0/45 gravel) in the base, a 80 mm controlled bituminous drainage layer; a 80 mm layer of dense asphalt and a Mastic sealing coat.

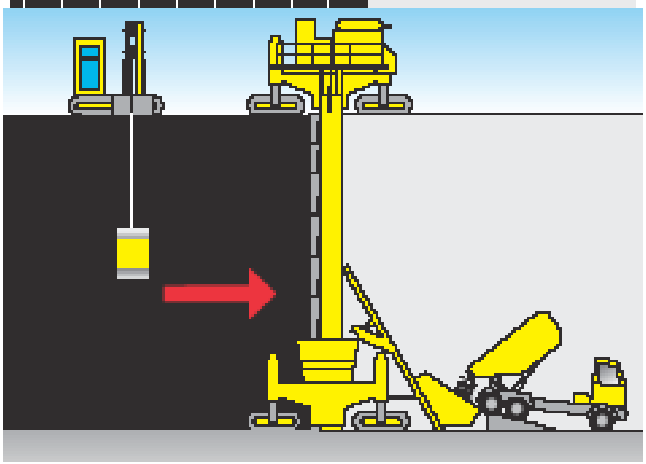


Figures 2 and 3: Construction Details of Asphaltic Layers Used at Cholwald Landfill and DAC in the Slope

1.6 Installation ABL and DAC

Figures 4 and 5 show the two different laying methods can be used for placing asphalt on slopes; a horizontal system, and the more common, a vertical system. For both types of asphalt laying the machinery used is highly specialist and is individually designed and built in the contractor's workshops.





Figures 4 and 5: Vertical Placing System and Horizontal Placing System

The horizontal system is used when a uniform slope length allows constant forward movement of the asphalt finisher.

For Cholwald Landfill the vertical system was used due to the variances in the slope lengths on site. The vertical lining system consists of a main winch unit for the finisher and for the first roller; a finisher and a charging dumper to feed the finisher. A separate roller winch and two special slope rollers complete the laying group.

With the vertical system the asphalt is laid from the bottom of slope to the top, lane by lane. The asphalt is supplied by wagon into a hopper on the crest and from the hopper into a feed dumper which delivers the hot mix to the finisher. When the crest of the slope is reached, the whole system is moved across one lane width and the cycle is then repeated.

Figure 6: Finishing Phase 2 - Joint between Phases 1 and 2

The laying output of this vertical lining system is high. When conditions permit it is possible to lay more than 1'000 tonnes of material in a day. Such outputs enable very short construction periods to be achieved.

1.7 Joints

All placing methods produce joints between the different lanes of laid material and from "day-joints" constructed at the end of each working day. The joints between the different lanes laid "hot on hot" do not need to be reworked. Joints between different days, or in this case years, have to be reheated by infrared-heaters and then recompacted with gas-heated electrical vibro tampers. This method guaranties a continuous and homogenous asphalt membrane at every joint.

Figures 9 - Joint Preparation

Figures 10 - Joint Re-Heating

Figures 11 - Joint Re-Compaction

To connect the new asphalt laid in 2013 to the existing asphalt laid in 2012 the joint only had to be cleaned so that the paver could install the next lane to the old joint.

After all the works were completed the landfill was absolutely impermeable, including the joints between Phase 1 and Phase 2, and the joints to the existing concrete structures. The laid material was drill cored and tested for its impermeability (as shown in Figure 13) and all joints were vacuum tested at 20 m intervals (shown in Figure 13), as determined by the Construction Quality Assurance Plan (CQA).

One significant technical advantage of a bituminous lining system is that it is possible to connect a new lining system to the existing lining system, with very little effort.

1.8 Mastic

After finishing the joint-treatment a thin layer of Mastic was applied on the dense asphalt. The Mastic layer serves as a protective layer" against ultra-violet radiation and closes any superficial pores. It is laid by a special Mastic finisher. The dense asphalt sealing must be absolute dry and clean before placing the Mastic coat. It is laid in lanes of 2 m wide at a rate of 1.5 kg/ m2 to 2.5 kg/m^2, giving a Mastic layer of some 1.5 mm to 2.5 mm thick.

Figures 10 - Placing Mastic in the Slopes

Figures 11 - Placing Mastic in the Slopes

In general a Mastic comprises of approximately 1/3 bitumen and 2/3 filler. The Mastic is pre-mixed in a conventional mixing plant and then transported, heated up and mixed in special mastic cookers similar to those for mastic-asphalt. The Mastic is liquid when placed at a temperature of 200 °C - 220 °C. (Control parameter is a ring-and-ball value > 75 °C.).

1.9 Quality Control

Throughout the mix design stage, material production and installation (including the formation of the joints),a comprehensive set of records are maintained in the form of CQA documentation for the project and a final CQA report is produced and presented to the Client. This documentation includes for:

- Investigations of the raw materials
- Mix analysis
- Drill core studies
- Vacuum tests

The testing of the DAC included the following testing:

- Particle size distribution of the coarse and fine aggregates to BS EN 933-1 and fillers to BS EN 933-10.
- Flakiness index of coarse aggregates to BS EN 933-3.
- Particle density of coarse and fine aggregates to BS EN 1097-6.
- Water absorption of coarse and fine aggregates to BS EN 1097-6.
- Magnesium sulphate soundness of coarse and fine aggregates to BS EN 1367-2.
- Adhesion to bitumen to coarse aggregates to AASHTO – T182.
- Penetration of bitumen to BS EN1426.
- Softening point of bitumen to BS EN 1427.
- Marshall test to BS EN 12697-34 on DAC layer mix and asphalt binder layer to determine air voids in compacted mix. Test to be carried out with 2 x 10, 2 x 20, and 2 x 30 blows.
- Specific gravity (maximum density) of mixes to BS EN 12697-5 on DAC layer mix and asphaltic binder layer mix.
- Bulk density of mixes to BS EN 12697-6 on DAC layer mix and asphaltic binder mix.
- Swelling test on both DAC layer and asphalt binder layer in water at room temperature for 28 days.
- Hydraulic conductivity of the design mix for both DAC layer and asphalt binder layer.

All aggregates and fillers in the DAC layer and the ABLhad to conform to the requirements of BS EN 13043 when tested in accordance with:

- BS EN 932. General properties (including sampling);
- BS EN 933, Geometrical properties (size and shape);
- BS EN 1097, Physical properties (strength and surface characteristics);
- BS EN 1367, Thermal and weathering properties (durability).

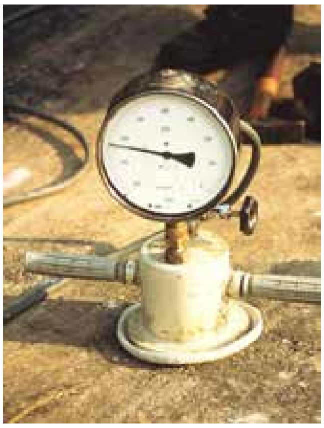
On completing the compaction of each panel of the DAC liner, the following regime of compliance testing was carried out by the CQA Engineer and repaired by the Contractor to confirm that the plant and techniques have achieved a level of compaction established during the Field Trial to be necessary to obtain the specified hydraulic conductivity:

- Temperature of material when laid and being rolled.
- Air voids measurement using nuclear density gauge.
- Vacuum testing of all joints.
- Core sample taken for air voids and hydraulic conductivity measurement.
- Depth profiling to predetermined markers.

Compliance testing was carried out at the following nominal grid spacing's:

Temperature measurement	20 m
Nuclear Density Gauge (NDG)	20 m
Vacuum measurement	20 m length of joint
Core samples for air voids	1 per 15 NDG
Hydraulic conductivity (laboratory)	80 m

Figures 12 - Drill Cores Taken for Testing Impermeability and Vacuum Testing Joints



Figures 13 - Drill Cores Taken for Testing Impermeability and Vacuum Testing Joints

3. CONCLUSION

The Cholwald Landfill project was completed on time and within budget. The success of the project was due to the identification of the optimum design mixes for the various asphaltic layers to achieve the desired performance and the specialised knowledge, skills, craftsmanship, laying techniques and equipment deployed.

Quality was maintained throughout the project and was supported by the extensive and comprehensive CQA regime used.

By using a DAC liner for the fourth cell at Cholwald Landfill the Client was able to take advantage of some of the inherent advantages of DAC over other more conventional lining systems used before, in that a DAC linier is:-

- Much quicker to construct, taking weeks instead of months to complete.
- Not affected by inclement weather whilst being laid or afterwards, giving the landfill operator a quicker response time for starting his landfill operations.
- A much thinner lining system to construct, with the total thickness generally averaging approximately 340 mm. (including drainage layer, binder layer, and the DAC layer) a saving of a metre or more of void space against most other lining systems.
- Strong and constructed to provide hydraulic permeability results of ≤ 1 x 10-13 m/s, tested up to 10 bar (100 m) head of water pressure.
- Constructed using an extensive CQA procedure and all results can be re-tested throughout the construction period and afterwards without destroying the integrity of the lining material.
- Extremely flexible, allowing sufficient flexibility to accommodate a differential settlement of the underlying formation amounting up to 1 in 10 without showing any signs of stress fracture or cracking.
- Nontoxic - It does not contain mobile toxic compounds that may pollute the ground or surface water.
- Completely stability when placed on slopes of up to 1:1:5 (34°) under all conditions of waste and leachate cover.
- Capable of being laid on steep slopes - the increased steepness of slopes provides extra void space for the waste product.
- Unaffected by vandalism and all natural weather conditions that may be experienced before covering with waste.
- Capable of having rubber tyred construction plant and vehicles run on the surface without fear of damaging the lining system.
- Strong enough to support landfill material, daily cover material and capping material without thinning or deforming.
- Strong enough such that it cannot be punctured and is resistant to mechanical forces resulting from the impact of drainage materials and landfill materials.
- Unaffected by leachate and gases normally found in landfills.