Landfill Construction in Asphalt

Landfill and waterproofing constructions in asphalt

A status report (1998)

1. INTRODUCTION

Asphalt concrete is an excellent waterproofing material and well established in hydraulic engineering for many decades.

In Germany the essential requirements for the waterproofing materials and the water proofing constructions are published by the Deutsche Gesellschaft für Erd- und Grundbau e.V. (German Association for Soil- and Groundworks) and is titled "Empfehlungen für die Ausführungen von Asphaltarbeiten im Wasserbau - EAAW" (Recommendations for Asphalt Works in Hydraulic Engineering).

As these recommendations were recently published and give a good overview on the application of the asphalt product in this area, the German experience is hereafter given as an illustrative example on how to apply asphalt in this area.[1]

Whereas the mix design for asphalt concrete for road constructions is focused on durability, stability and surface quality, the main point in hydraulic engineering is impermeability. In a fundamental study the water permeability of asphalt concrete under variable to hydraulic pressure has been tested as a function of the voids content. It could be shown that asphalt with a void content below 3 % by volume is impermeable even at high water pressures. This investigation is the basic of the EAAW in which is specified that construction methods with low or no voids have proved to be impermeable when the water absorption in the structures is =< 2.0 % by volume or the calculated void content is =< 3.0 by volume. The values must be found in the structure itself, not the specimen. For the mix design it is necessary to pre-select a low Marshall void content which accounts the special features of the site.

It must be noted that for dense asphalt concrete there is no water permeability k-value. Asphalt concrete with a calculated void content =< 3.0 % by volume is impermeable and the k-value could be compared to mineral sealing in hydraulic engineering, with a value of throughout 10-00.

The application of asphalt linings is not exclusively done in Germany, but also in other European countries. Several examples have been added for reference in the tables in the end.

2. LANDFILL CONSTRUCTIONS

Because of the good experiences in i.e. hydraulic engineering the next step was to use asphalt concrete for lining the bottom of landfill deposits for solid waste.

The German technical specifications for disposal of industrial wastes (TA Abfall) and domestic wastes (TA Siedlungsabfall) permit alternatives to the standard mineral and plastic lining system if an equivalence will be proved.

The standard is

2,5 mm plastic membrane

=>750 mm waterproofing layer with puddle clay, k-value =< 10-9

2,25 m "geological barrier" (aggregate mixture with clay), k-value =< 10-7 subsoil.

The questions of the equivalence of asphalt concrete linings had been discussed for some time by German technicians. In 1996 an Information Sheet on Asphalt Landfill Linings has been published by the German Association for Water and Agricultural Industries (DVWK) as a part of a series of Information Sheets on Hydraulic Works. Later during 1996 a general type approval was given for asphalt landfill lining systems by the German Institute for Construction Technology. This general type approval documents the above mentioned equivalence of asphalt landfill lining systems and explains all necessary measures.

2.1 Waterproof lining

The difference between asphalt in hydraulic engineering and in landfill lining is that in the former a small degree of permeability is allowable, whereas this cannot be tolerated in the latter, which needs to protect our ground water for centuries to come.
For this reason the Information Sheet envisages the laying of the lining in two layers, with staggered joints, intended to provide additional protection should one joint fail. This procedure is actually a retrograde step compared with present laying techniques for asphalt in hydraulic works. The former practice to lay the linings in several layers, gave rise to the possibility of blister formation between two dense layers, when laid in damp water.

Nowadays it is possible to get a higher degree of compaction when laying thick layers with modern screed, even in difficult areas like slopes. However the danger of blister formation is very low or appears to nil when a minimum layer thickness of 60 mm will be built.

Landfill lining mixes have to meet more stringent requirements relating to properties and quality assurance than asphalt road mixes. As far as linings for landfill slopes are concerned, the requirements will not differ much from those in hydraulic engineering, where they are already stringent. In addition to testing the density of the completed linings by means of the vacuum test, the non- destructive testing of density and thickness is envisaged with an isotope probe. The resistance to chemical attacks was already documented.

2.2 Lining substrate (base course)

Normally linings in hydraulic works are applied on a drainage layer, capable of conducting any possible seepage in a manner that does not endanger the structure. Such layers need to remain serviceable. In landfill constructions such a drainage system under the lining is undesirable because any localised cracks could be transformed into major failures through the cross-distribution of aggressive substances.

For this reason the asphalt base course (void content between 7 and 15 % by volume) was replaced by a more or less dense asphalt base with a void content of =< 5 % by volume (measured in the laid asphalt).

2.3 Support for the asphalt base

The requirement for the asphalt base support depends of the value of the deformation modulus Ev2. With Ev2 =< 45 MN/m2 an additional unbound base is required with the goal to get a deformations modulus Ev2 >= 45 MN/m2. This deformation modulus is required to ensure a satisfied compaction of the asphalt base. The German Institute for Construction Technology has given a construction permit for a combination of an asphalt and mineral lining.

This is intended to be equivalent to the standard combination lining of the specifications TA Abfall und TA Siedlungsabfall. Since asphalt layers are much thicker than the standard plastic membranes, the thickness of the mineral layer can be reduced.

2.4 Requirements

1. Structural design:

	drainage layer (unbound)
2 x 60 mm	waterproof lining, asphalt concrete 0/11
>= 80 mm	lining substrate, asphalt concrete 0/16
2 x 200 mm	mineral lining, aggregate mixture with puddle clay, k-value =< 10^{-9} modulus of deformation E_{v2} >= 45 MN/m^2
	subsoil, modulus of deformation E_{v2} >= 45 MN/m^2

2. Asphalt concrete:

waterproof lining 0/11	lining substrate 0/16	
mineral aggregates	high quality chipping, crushed sand with constant filler rate, washed natural sand, fines; $CaCO_3$ - content < 50 Mass.-% (not for fines)	
fines (< 0,09 mm) Mass.-% chipping (> 2,0 mm) Mass.-% oversize Mass.-%	12 - 16 40 - 55 =< 8,0 (>11 mm)	9 - 14 50 - 65 =< 8,0 (>16 mm)

binder content in mixture Mass.-%	B 65 or B 80 (PmB not applied)	
	6,5 - 7,5	5,2 - 6,5
void content • Marshall specimen, 2 x 25 compaction strikes Vol.-% • in structure Vol.-%	=< 2,0 =< 3,0	=< 3,0 =< 5,0

3. WATERPROOFING CONSTRUCTIONS

Normally the theme of waterproofing construction should have been described at first because it is the basic for the asphalt landfill lining systems. That means basically if a void of an asphalt concrete layer measured in the structure is lower than 3.0 % by volume, the layer is impermeable. In chapter 1 this context has been explained.

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asphalt concrete		0/5, 0/8, 0/11	0/16, 0/22, 0/32
binder		B 65, B 80 (B 200, B 45)	
binder content in mixture	Mass.-%	6,5 - 10,0	5,0 - 8,0
fines (< 0,09 mm)	Mass.-%	>= 10,0	>= 5,0
gravel, chippings or gravel and chippings (> 2,0 mm)	Mass.-%	20 - 50	40 - 60
water absorption in structure	Vol.-%	=< 2,0	
calculated void content in structure	Vol.-%	=< 3,0	

The maximum particle size can be selected as a function of layer thickness. Though no traffic loading needs to be considered, it is nevertheless essential that joints are watertight. For this reason mixes with lower maximum particle size in proportion to layer thickness are to be preferred. The mortar ratio should not to be too low and the ratio of voids filled with binder should be more than 90 %

3.1 Mix design

The Marshall specimen are the mix design basic of asphalt waterproof layers. In order to take account of varying site conditions, particularly the differing gradients of the slopes, the number of blows and the temperature of the asphalt are varied in the laboratory mix design procedure. In practice when rolling steep slopes only a part of the roller weight bears on the slope when rolling steep slopes.

In addition the stability on the slope and the impermeability in the event of deformation and settlement need to be determined. These tests are made with the mix which has been selected. For testing the stability on the slope a specimen, 200 x 300 mm, is prepared in laboratory. The specimen thickness is the same like the material that will be laid. The density of the specimen should correspond to the Marshall specimen density. The stability is tested in a chamber heated to 60 °C or 70 °C, with the specimen placed on a slope having the required gradient. The flow of the asphalt is measured.

The working life of an asphalt lining must be guaranteed also when settlement occurs in the subsoil or on the dam base. The asphalt lining must be able to take up such settlement without loss of impermeability. A special test according to van Asbeck verifies this important property.

Besides the impermeability requirements the immunity to chemical or solvent attack is demanded especially for landfill linings for both domestic and special waste.

3.2 Test methods

In the Netherlands a European wide inventory was made to determine what test method was available to determine whether an asphalt is impermeable. The following criteria were used:

* the test should be applicable both in the laboratory prepared specimen as well as on cores drilled from the landfill,

* the test should be applicable on specimen of different height,

* during the test, the pressure should be raised to speed up the testing process.

It was decided that ISO-DIN 7031, originally designed to test the penetration of water into cement concrete is the most appropriate test. The procedure was slightly modified. The water pressure was raised to 1 mbar over 72 hours. In the Netherlands it was also found that mixtures with 3% voids could be classified as water impermeable.

[1] "Asphalt für Deponieabdichtungen". Deutsches Asphalt Institute, Berlin 1996.

Tab. 1 ASPHALT WASTE DISPOSAL SITES IN GERMANY (BUILT)

	TYPE	LOCATION	CONSTRUCTION	BUILT	SIZE
1	Waste Disposal	Gochsheim near Schweinfurt	Surface Sealing 40 mm 0/11 mm AC 70 mm 3/35 mm PA 30 mm ACBC	1973	70.000 m^2
2	Waste Disposal	Bornhausen in Gandersheim	10 mm MA 6+8=140 mm ACBC	1974	10.000 mm^2
3	Waste Disposal	Bürring (With Bayer AG)	30 mm AC+MA 120 mm 0/32 mm ACBC	1977	20.000 m^2
4	Waste Disposal	Oberndorf-Bochingen	70-180 mm ACBC voids 2 Vol.-% UBC	1979/80 1985/86 1991	20.000 m^2
5	Silt Disposal	Großlappen near München	10 mm MA 40 mm AC 180 mm 0/32 mm ACBC	1980/83	175.000 m^2
6	Controlled Disposal	Kriftel, Hessen with Fa. Hoechst AG	>200 mm UBC 750 mm AC+MA 40 mm AC 80 mm PA 200 mm UBC	1986	6.000 m^2
7	Temp. Disposal	Berlin	40 mm MA 250 mm B 35 Concrete 310 mm UBC	1990	3.800 m^2
8	Temp. Waste Disposal Site	St. Martin Kreis Schwandorf	70 mm 0/11 mm AC 100 mm 0/16 mm PA with control drains 70 mm 0/11 mm AC >250 mm ACBC	1991	16.000 m^2
9	Silt Disposal Bokel near Elmshorn/ Holstein	St. Martin Kreis Schwandorf	40 mm 0/11 mm AC 40 mm 0/16 mm AC 150 mm 0/32 mm ACBC 300 mm UBC 300 mm Sand 2,5 mm PE-HD Geotextile	1993	10.000 m^2
10	Process Waste Disposal Sugar Factory	Könnern Halle/Saale	60 mm 0/11 mm AC 60 mm 0/16 mm AC 150 mm 0/32 mm UBC 350 mm 0/32 mm Base	1991/93	5.350 m^2
11	Waste Disposal with Controlled Sealing	Walddorf	200 mm Crushed Sand 0/8 mm on 1200 g/m^2 Geotextile 2,5 mm PE-HD Geotextile 750 mm UBC Control Drains: 60 mm PA with PmB 45A 50 mm 0/16 mm AC 100 mm (Pmb) 0/32 mm AC 300 mm 0/45 till 0/56 mm ACBC	1992/93	11.000 m^2
12	Waste Disposal	Bochingen/ Rottweil	60 mm 0/16 mm AC membrane PmB 45 A, 1,5		50.000 m^2

			kg/m^2 60 mm 0/16 mm AC 150 mm ACBC		
13	Waste Disposal	Talheim, Tuttlingen	60 mm 0/16 mm AC membrane PmB 45 A, 1,5 kg/m^2 60 mm 0/16 mm AC		27.000 m^2
14	Disposal Extension	Hanberg Enzkreis	60 mm 0/16 mm AC membrane PmB 45 A, 1,5 kg/m^2 60 mm 0/16 mm AC	1995	44.000 m^2
15	Waste Disposal	Rechenbachtal Zweibrücken	60 mm 0/16 mm AC 60 mm 0/16 mm AC 80 mm 0/32 mm ACBC	1995	76.000 m^2
16	Waste Disposal	Haslach Ortenaukreis	60 mm 0/16 mm AC 60 mm 0/16 mm AC 100 mm 0/32 mm ACBC	1994/95	20.000 m^2
				TOTAL	560.000 m^2

1. AC = Asphalt Concrete
2. PA = Porous Asphalt
3. BC = Base Course
4. MA = Mastic Asphalt
5. UBC = Unbound Base Course

Tab. 2

ASPHALT WASTE DISPOSAL SITES IN GERMANY (TO BE BUILD)

TYPE	LOCATION	SIZE	
1	Waste Disposal	Außernzell, in Deggendorf	21.000 m^2
2	Waste Disposal	Radeburger Straße Grube 2, Dresden	100.000 m^2
3	Waste Disposal	"Am Grubenrand" Landkreis Darmstadt-Dieburg	160.000 m^2
4	Waste Disposal	"Litzholz II" Alb-Donau-Kreis	ca. 85.000 m^2
5	Waste Disposal	Ringgenbach, in Sigmaringen	ca. 104.000 m^2
		TOTAL	ca. 560.000 mm^2

Tab. 3

ASPHALT WASTE DISPOSAL SITES IN SWITZERLAND (BUILT)

NAME	BUILD	SIZE m^2	LENGTH OF SLOPE > 15 m
Chalen-Süessplätz	1979	6.000	
Elbisgraben 1	1982	14.000	X
Riet 1	1983	12.000	

Steinigand	1985	10.000	
Elbisgraben 2.1	1985	18.500	X
Eglisau	1986	15.000	X
Riet 2	1986	10.000	
Lufingen	1987	14.000	
Elbisgraben 2.2	1987	20.000	X
Steinigand 2B	1988	14.000	
Elbisgraben 4	1989	26.000	X
Türliacher	1989	30.000	
Riet 3	1990	8.000	
Valle Motta 0	1990	23.000	X
Kniebreche	1990	2.000	
Buchserberg	1990	13.000	X
Alznach	1991	10.000	X
Eielen	1992	15.000	
Gamsenried	1992	30.000	
Kniebreche 2	1992	1.000	
Türliacher 2	1992	25.000	X
Montey, Ciba-Geigy	1992	7.000	
Pflumm	1992	10.000	X
Valle Motta 1	1993	25.000	X
Teuftal	1993	3.200	
Lienz	1993	12.000	
Türliacher 1b, Teil 2	1993	15.000	X
Châtillon	1994	20.000	X
Lufingen 2	1994	7.000	
Collombey	1994	8.200	X
St. Ursanne	1994	1.500	
Wissenbüel	1994	9.500	X
Flawil	1994/95	37.000	X
Total		473.900	

Tab. 4

ASPHALT WASTE DISPOSAL SITES IN THE NETHERLANDS

LOCATION	BUILT	CONSTRUCTION
TOP Moerdijk	1990	Temporary disposal of heavily poluted soil

60 mm mastic asphalt

60 mm dense asphalt concrete

250 mm secondary raw material: unbound base

600 mm sand with control drains

2 mm HDPE membrane

Hydraulic applications of hot mix asphalt in the Netherlands have a history that goes back to round 1930, when in first experiments revetments of canals were protected with impervious asphalt. Later, after World War II, asphalt has been widely applied in coastal protection.

The first application of bottom protection dates from 1957 when an industrial landfill was lined with 20.000 m2 of asphaltic concrete. In general the application of asphalt in linings is more or less restricted to reservoirs for industrial waste. Several examples of constructions for temporary storage are known for hazardous waste. In these type of landfill pits hazardous waste is stored before being processed to be cleaned or handled in an other way. Constructions may consist of dense asphaltic concrete, in some cases in combination with a second impervious geo-membrane.

In the period '80 - '90 several landfills for domestic and industrial waste have been lined with reinforced bituminous membranes. This type of membranes consists of a prefabricated membrane of modified bitumen on a fabric or non woven. The membranes are 3 - 5 mm thick and produced in 4 - 5 m width. In situ the strips are overlapped and sealed with hot bitumen.

A special application of mastic as a lining for a landfill is the so called C2 Deponie near Rotterdam harbour. This facility has been constructed as a permanent storage for extremely hazardous waste. The total construction has the shape of a hall, approximately 350 m long, 60 m wide and 40 m high. The walls are made of concrete and lined with polymer membranes. The bottom of the hall is lined with a multiple impervious layer of asphalt mastic. The top of the building has a movable roof.

According to official regulations of the Ministry of Environment for bottom and top lining of landfills for domestic waste still only polymer membranes in combination with sand/bentonite are accepted.

Tab. 5

ASPHALT WASTE DISPOSAL SITES IN THE UK

LOCATION	BUILT	SIZE mm^2	CONSTRUCTION
Huddersfield	1994/5	43.000	domestic and industrial waste

200 mm granular drainage layer

70 mm stabilizing binder

85 mm dense asphalt concrete

Tab. 6

ASPHALT WASTE DISPOSAL SITES IN FINLAND

LOCATION	BUILT	
Helsinki	1990	Temporary