The Use of Asphaltites in the Landfill Layer

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Abstract: The waste materials emerged in developing cities should be disposed without damage to environment. Landfills must properly be designed and well managed. Recently, some waste materials were began to be used with clay in landfill layer design. This process was positive effects on environment by means of recycling, regains to economy and reducing environmental pollutions. In this study, asphaltite dust was added at ratio of 5%, 10% and 15% to mixture of 90% kaolinite and 10% bentonite by weight. Geotechnic, physical and chemical experiments were carried out on the samples. The experiment results were in acceptable limits with the literature, United States Environmental Protection Agency and the Turkish solid waste regulations. As a result, the asphaltite can be used as an additive material in landfills.

Introduction

In recent years, as a result of condensation of the world's population in cities and increasing consumption, the waste management (collection, transport, processing, waste treatment, recycling or disposal of waste materials) is becoming a serious problem. The increasing of production and consumption results in the increase of amount of waste. In the developing countries, distinct rules of waste disposing is initiated to prevent the environment pollution. However, many technologies are developed for the recycling of wastes, many of then cannot be recycled by the economical and technological points of view. The collected wastes can be burned and/or composted by newly developed technologies, however, a final amount of trashes must be stored for the last removal procedure.

In the regular landfill areas, highly polluted garbage water leaks and reaches to the bottom layer. This leakage water can diffuse to ground and surface water. For avoiding this diffusion, clay layers are supposed to be constructed as a bottom liner. The waste materials should be covered to isolate from surrounding environment and humans and to prevent leakage of rain water to landfill. Some properties are required for this impermeable clay barriers; ie; resistance to environmental effects, lower permeability, higher ductility to prevent crack formation, chemical stability, prevention capability of contaminants by diffusion of similar mechanism (Taşpolat, 2006).

In the landfill layers, utilization of suitable materials and possibly waste mixture material are important to block the heavy metal diffusion in garbage water. By this way, the waste materials, such as fly ash, would be gained to economy.

Several researchers have studied the usage potential of fly ash in the clay layer as a hydraulic barrier. In these studies, it is seen that the fly ash can be used for leakages having alkalin character (Edil and Berthouex, 1990; Palmer et al, 2000; Prashanth et al, 2001; Kalkan and Akbulut, 2004). Zeolite-Bentonite mixture was also used as an altenative material. In these mixtures, the proportion of bentonite to zeolite between 0,05 to 0,20 was obtained as a suitable mixtures. The cation exchange capacity and lower permeability values of the zeolite and bentonite have shown that it could be used in clay layers (Kayabalı et al, 1997; Tuncan et al, 2003; Kaya and Durukan, 2003).

Besides natural materials, the petroleum based geomembranes can also be used widely as a hydraulic barrier. The using of impermeable geomenbranes have been allowing to build thinner clay layer. In this case, the thin layer should be carefully applied in order to prevent the tearing and puncturing.

In this study, usability of asphaltite dust in the impermeable layer was investigated. For this reason, three mixture of soil to asphaltite dust (the proportions were 5,10,15% dust to dry soil by weight) have been prepared. The following tests are carried out on the samples taken from the mixtures: Index properties of the specimens were determined by liquid limit test, plastic limit test, shrinkage test, sieve test, hydrometer test and buoyancy analysis tests. Mechanical properties of the specimens were determined by standard proctor test, permeability test, unconfined compression test and UU triaxial test. Finally, physicochemical properties such as pH, EC, CEC were determined by chemical tests.

Materials And Method

Materials

Na Bentonite Clay

Bentonite is a colloidal aluminium hydrosilicate. The volume of bentonite can rise 10 to 30 times by the addition of water. It has a swelling characteristic till 200°C. This property loses completely over 600°C. The vertical permeability of bentonite clay is $4,09x10^{-10}$ cm/s and the lateral swelling pressure of bentonite clay is 4,48 kg/cm^2 (Mining Special Expert commission 2001). The bentonite clay used in this study is Na-Bentonite. It was supplied from the Karakaya Bentonite factory, Ankara (Tuerkey). Some physicochemical and geotechnic parameters of Na Bentonite clay were shown in table 2.1, the amount of total metal is shown in table 2.2, the results of chemical analysis determined by the X-Ray Flourans Elemental analysis are shown in table 2.3 (Koyuncu 1998).

Kaolinite Clay

Kaolinite clay is a product of a type of rock which contains a great amount of feldspar. Kaolinite consists of silica and aluminium layers. The thickness of layers are 7.2 Å, the length of layers are between1000 and 20000 Å and the specific surface area is (SSA) 15 m^2/g.

The clay used in this study is obtained from the Bilecik district. The clay is produced by a three step procedure; first excavation from clay ores, then cleaning from fine sand by water washing and, finally crashing below 40 μm At the end of washing, groups of clay and shale are completely decomposed. The 80 % of this clay consist of kaolinite mineral.

Some physicochemical and geotechnical parameters of the kaolinite clay are shown in table 2.1, the amounts of total metal are shown in table 2.2 the results of chemical analysis determined by the X-Ray Flourans Elemental analysis are shown in table 2.3(Koyuncu 1998).

Asphaltite

Asphaltite, one of the primary energy sources, was assumed that it is a fossil fuel. While amount of oxygen is 3-44% in turba, lignite and coal, it is thought that asphaltite materials have formed as a result of oil transformation, duo to its amount of oxygen (2%).

During transformation, asphaltite comes out after natural asphalt its color is bright black or matt black. Its hardness varies between 2 and 3, specific gravity varies 1.03 and 1.20 and its thermal value varies between 10 and 23 Mj/kg. It contains 10 to 55% constant carbon, 0 to 2% oxygen and from a driblet to 5% mineral material. It melts between 120-135°C and solubility of asphaltite in carbon sulphide is between 45% and 100% (Nakoman 1997).

Other physicochemical and geotechnical parameters, the amount of total metal, the results of chemical analysis determined by the X-Ray Flourans Elemental analysis are given in tables 2.1, 2.2 and 2.3 respectively (Koyuncu 1998).

At the beginning; the asphaltites were used in production of dye and some chemical materials. After 1920, they has been also used for production of asphalt. Lately, it is used in production of synthetic petroleum. In addition, it is used in production of ammonia after gasifying. Asphaltite materials are also important because of valuable minerals (nickel, molybdenum, vanadium, titanium and uranium) in its contents. Asphaltites can also be used in production of energy by direct burning (Atlaş et al, 1994a). In figure 2.1, asphaltite coal and waste of asphaltite dust used in energy sector are shown.

Additions	pH	CEC	EC	SM	NSA	GSW	UVW	Grain Size Distribution (%)

		(meq/100g)	(mS/cm)	(%)	(%)		(gr/l)	Sand	Silt	clay	Cu	Cc
Na-Bentonite	9.50	90.22	2.69	12.7	6.82	2.76	0.94	2	46	52	40	0.8
Kaolinite	4.86	25.93	0.15	0.1	7.36	2.64	0.59	11	26	63	170	1.7
Asphaltite	8.37	4.73	0.14	0.54	1.61	2.66	0.34	----	----	----	----	----
CEC:Cation Exchange Capacity, EC:Electrical Contuctivity,WC:Water Content, OSA:Organic Substance Amount, GSG:Grain Specific gravity,UVW:Unit Volume Weight												

Table 2.1: Some physicochemical properties of materials used in the study.

Additions	Al	As	Cu	Zn	Fe	Cd	Ca	Co	Pb	Cr	Mg	Mn	Mo	Ni	Na	K
Na-Bentonite	90262	<5	81	71	10724	<0.5	12134	21	91	9	6815	2419	92	7	16920	2558
Kaolinite	123750	<5	280	52	7550	<0.5	770	22	136	405	1230	870	10	280	3000	6000
Asphaltite	671	<5	66	35	1650	<0.5	27761	22	63	6	6034	258	73	88	5022	579

Table.2.2: Total metal amounts of materials (mg/kg).

Additions	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_3	K_2O	Na_2O	SO_3	Cl	Mn_2O_3	HL	CO_2	DW
Na-Bentonite	59.49	18.06	4.14	3.72	2.42	0.11	0.91	2.50	0.10	0.003	----	8.02	1.31	----
Kaolinite	51.52	32.00	1.75	0.20	0.20	-	0.50	0.09	-	0.004	0.04	9.60	1.03	----
Asphaltite	58.05	0.60	0.33	0.70	34.79	0.00	0.00	0.03	0.04	0.000	----	5.32	4.84	----
HL:Heating loss,DW:Dependent Water														

Table 2.3: Chemical compound determined by X-Ray elemantal analysis of materials used in the study

Figure 2.1:. Asphaltite coal and waste asphaltite dust used in energy production

Experimental Study

Impermeable clay layer was prepared by 90% kaolinite and 10% bentonite mixture by dry weight This mixture was named as control specimen - 90K+10B. Then, the asphaltite dust was added to the mixture at ratio of 5%, 10% and 15%. Specimens were prepared with compaction in a standard proctor mold by using optimum water contents for every mixture.

The sharpened brass pipe whose diameter is 38mm and height is 203mm was used for taking specimens from the compaction mold. From the pipe, the specimens with 37 mm diameter and 74 mm height were obtained. Several experiments are carried out on these samples to determine the geotechnical, physical, physicochemical properties and, environmental impacts.

Geotechnical Properties

The ASTM D854-2000 test was used for the determination of specific gravity. For consistency limits, BS 1377 Part 2: 1990: 4.3 and 5.4 were applied for the liquid limit test and plastic limit tests respectively. For the liquid limit test, the cone penetrometer method was utilized. The shrinkage limit test was applied according to the ASTM D427 1998 standard. The grain size distribution was also determined according to the ASTM standards.

Generally, the soil classification study is carried out as a last geotechnical examination. For this purpose, there are two standards, namely; USCS (Unified Soil Classification System) and AASHTO (American Association of State Highway and Transportation Office).In this study the both method are utilized for determination of soil class. The soil classification, specific gravity and consistency limits are given in table 2.4. The curves of grain size distribution were also given in figure 2.2.

PARAMETERS	USCS	AASHTO	Specific Gravity	Consistency Limits (%)			
				Liquid limit	Plastic limit	Shrinkage limit	Plasticity index
Control(90K10B)	CH	A-7-5(9)	2,64	50,97	32,38	1,75%	18,59
90K10B +5% Asp.	CH	A-7-5(12)	2,63	50,44	32,40	1,42%	23,66
90K10B +10% Asp.	CH-CL	A-7-5(10)	2,59	50,26	32,62	1,25%	26,11
90K10B +15% Asp.	CL	A-7-5(9)	2,55	49,01	32,80	1,35%	30,45

Table 2.4: Soil classifications of the mixtures, specific gravity and consistency limit values.

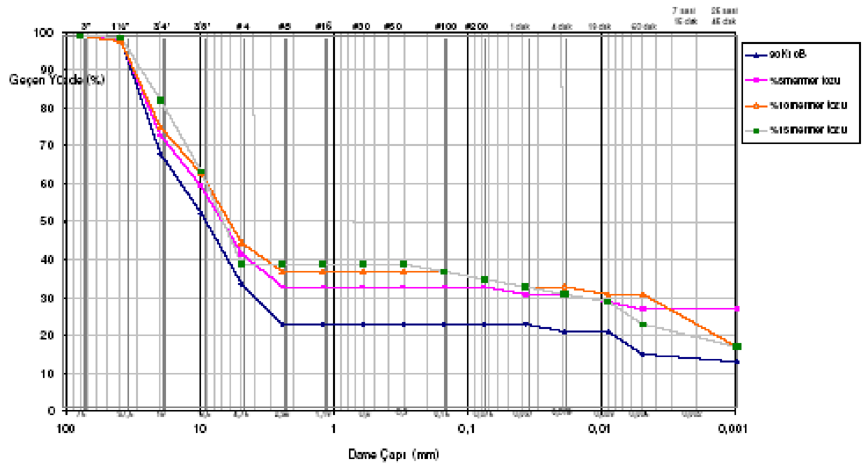

Figure 2.2: Grain size distrubution curves

Mechanical Properties

In this study the standard proctor test was applied to the mixtures by using ASTM D 698-78 and the relation between water contents and dry unit volume weight was observed. The other mechanical test in this study is permeability. "Saturated Hydraulic Conductivity, Saturated Leachate Conductivity, and Intrinsic Permeability", indicated in USEPA Method 9100 (1986) was used in this test. The results of tests are shown in table 2.5 The triaxial UU test was done under 100 kPa and 200 kPa surrounding pressure in accordance with method suggested in Turkish Standard No1900. The unconfined compression test was also used in triaxial UU test method but the only difference is the absence of cell pressure. The results of triaxial UU test and the unconfined compression test are shown in figure 2.3 and 2.4 respectively.

PARAMETERS	The result of compaction opt. water content%	Permeability m/s
Control(90K10B)	22,72	1.2 x 10^{9}
90K10B +5% Asf.	22,61	1.4 x 10^{9}
90K10B +10% Asf.	22,46	1.5 x 10^{9}
90K10B +15% Asf.	22,35	1.8 x 10^{9}

Table 2.5: Optimum water contents and permeability results

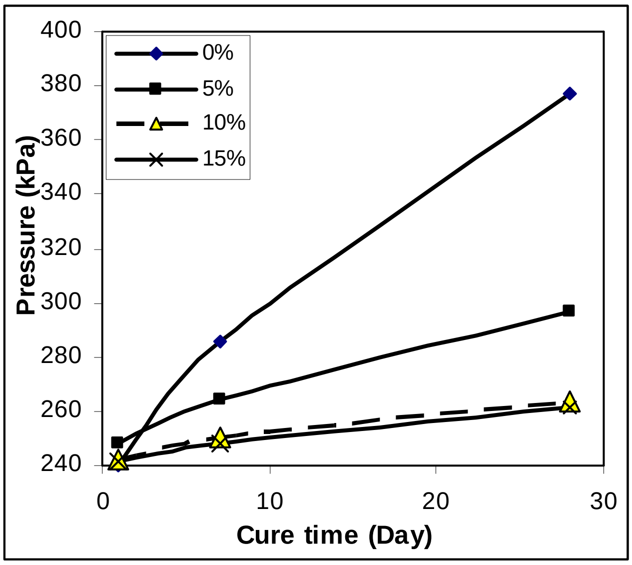

Figure 2.3: Strenght vs cure time in triaxial UU test.

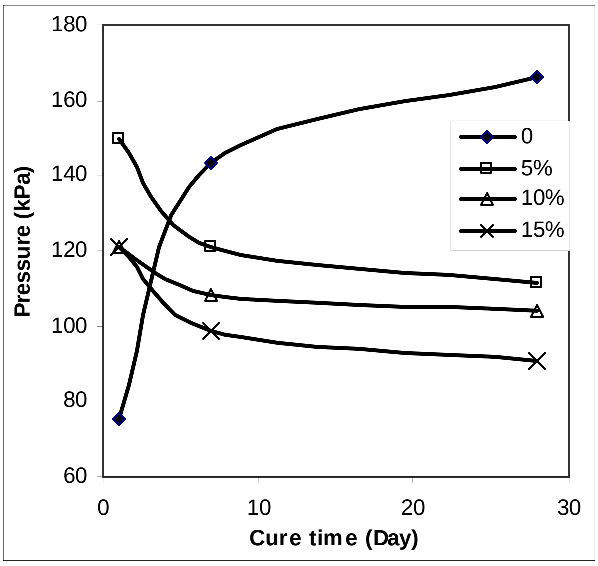

Figure 2.4: Strenght vs cure time in unconfined compression test.

Physicochemical Properties

Physicochemical properties of materials are also extremely important for permeability. Therefore, pH, cation exchange capacity (CEC), electrical conductivity (EC) and the amount of organic material are also studied for the conclusion at usability of the studied material.

U.S. EPA Method 9045 (1986) was used for of pH test. For comparison, pH values of the same mixtures were remeasured one day later. This measurement is similar to the technique suggested by Jackson(1958). The sodium saturation method was used for CEC. EC of specimens were determined by sinking electrode into the mixture (Wilcox1946; Karakouzian et al. 1996). The amount of organic material in the mixture was determined by dry-burn method (Standard Methods 1993, Horneck et al.1989).

The results are shown in table 2.6. Leachate test is done for the physicochemical results and it is shown in table 2.7.

Materialas	pH	EC (mS/cm)	CEC (meq/100g)	O.E.M (%)
Control(90K10B)	8,9	1171	13,44	0,1
90K10B +5% Asp.	8,2	1420	16,33	7,9
90K10B +10% Asp.	8,2	1674	17,90	9,9
90K10B +15% Asp.	7,9	1765	17,18	10

Table 2.6: Physicochemical properties of the mixtures.

Materials	Cu (ppm)	Zn (ppm)	Ni (ppm)	Pb (ppm)
Control(90K10B)	22,25	20,50	20,00	21,25
90K10B +5% Asp.	0.25	0,25	0,00	0,00
90K10B +10% Asp.	0,25	0,25	0,00	0,00
90K10B +15% Asp.	0,25	0,25	0,00	0,00

Table 2.7: Results of the leachate experiment of the mixtures.

The properties belong to environmental conditions

The effect of environmental conditions is another factor on the permeability of mixtures In order to determine thesebehavoir; freezing and thawing strength was determined according to "Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures" indicated in ASTM D560-82 (1985) and results are given in table 2.8.

Materials	Initial water contents (%)	The number of cycle	Grain loss (%)
Control(90K10B)	25	12	17,6
90K10B +5% Asf.	25	12	19,9
90K10B +10% Asf.	25	12	23,8
90K10B +15% Asf.	25	12	25,2

Table 2.8: Freezing-Thawing experiment results of asphaltite powder mixtures.

Discussion

Plasticity index values of all specimens used in this study are between 16 and 19. These values are appropriate to $I_p < 50$ criterion determined for landfill layers studied by Daniel and Wu,1993. It is observed that the materials are CH and CL class according to USCS. However a variation was observed from higher (CH) plasticity clay to lower plasticity clay (CL) as the amount of asphaltite in the mixtures has increased. This shows that CH, CL and MH type of soil can be used in landfill layers.

It was declared that the acceptable maximum volume shrinkage ratio was 4% for landfill layers (Daniel and Wu, 1993, Kleppe and Olson, 1984). Volume shrinkage ratios is measured between 1,25%-1,75% in this study. On the other hand, the specific gravity measured for samples is 2,55 at minimum and 2.63 at maximum. These values are between 2,5-2,7 ranges observed in previous studies (Yong-Weidth, 1985, Benson 1994).

The optimum water content values of the samples are around 22%. The solid waste regulations is declared that the optimum water contents must be between 20 and 40%. When the amount of dissolved salt in water in soil increases, EC also increases. The maximum EC obtained is 1765 mS/cm. In previous studies, it is declared that EC<4000 mS/cm is a reasonable value (Tuncan et al,1996). When the salt in the soil is dissolved in water, it causes an increase in the permeability. The permeability values of samples are between $1{,}2\times10^{-9}$ and $1{,}8\times10^{-9}$ m/s. The highest permeability value indicated by USEPA is 10^{-8} m/s. On the other hand, the amount of organic material in the mixture has increased as the amount of asphaltite from 0,1% to 7,9% increased. Organic material increase makes increasing influence on permeability. It was confirmed by test results.

On examining CEC behavior of samples, it was seen that it has increased from 13,44% to 17,90%. Higher CEC value will reduce heavy metal pollution in leakage water. Furthermore, higher CEC means higher potential of expansion which is another criterion of permeability. The results of Leachate test were shown that the asphaltite dust added mixtures was absorbed Cu, Pb, Zn and Ni excellently. As can be seen from table 2.7, these values are reduced from 22,25 ppm to 0,25 and 0.

The unconfined compression test and triaxial test results of the samples were shown that asphaltite has no positive influence on strength values. Depending on cure time and amount of additives, some decline was seen in strength values. Finally, after freezing and thawing test consisting of totally 12 cycles, it was seen that grain loss has increased with asphaltite increase. It has increased from 17.6% to 25,2% at the end of 12 cycles. It can be declared that the grain losses can make negative influence to the strength values of layers.

Conclusions

It was determined that the usage of asphaltite dust has reasonable criteria as additive materials in the kaolinite-bentonite mixture landfill layers as the results are comparable with criteria in the literature and Turkish solid waste municipial regulations. The usage of asphaltite will also influence the environment by means of recycle of waste material.

In future, studies with asphaltite dust, it is suggested that increasing addition ratio, considering solutions in order to see heat effects, repetition experiments at low and high temperature, researching mixtures which will be composed with only kaolinite or only natural clays.

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