Quality Acceptance Testing of GCLs for Landfill Application

Kovacevic Zelic, B., University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Croatia

Kovacic, D., University of Zagreb, Faculty of Geotechnical Engineering, Varaždin, Croatia

Matesic, L., Geokon-Zagreb & University of Rijeka, Faculty of Civil Engineering, Croatia

Velickovic, B., Geokon-Zagreb, Croatia

Abstract

Approximately ten years ago remedial actions started at Jakusevec, the major unsanitary open dump in the vicinity of Zagreb. According to quality assurance testing program, mineral composition, swell index, fluid loss and water absorption capacity of GCLs bentonite component were determined. During remediation works three types of bentonites were tested prior to GCLs installation and it was proven that they meet the project requirement.

Yet a subsequent consideration initiated a series of new tests which have been performed on one type of bentonite immersed into the site specific leachate during different periods of time prior to testing. These results are described in the paper. From the present results it may be concluded that there is no significant influence of leachate to the bentonite behaviour in acceptance tests.

Introduction

Zagreb has been faced with the problem of waste management for years. There are a number of uncontrolled waste disposal sites located at the edges of the city. All of them are typical unsanitary open dumps. The major site is Jakusevec. The site has been used since 1965 for disposal of municipal, hospital and partly industrial waste.

Jakusevec is situated on the right bank of the Sava river in the south-east part of Zagreb. It occupies the area of about 800.000 m^2. The length of the site is approx. 3 km and the width varies from one hundred meters to several hundred meters.

The location of the site is extremely unfavourable as it intrudes into the city area. Besides, it is located in the area which most probably has the influence to the existing and future well fields used by municipal water distribution system. Therefore it has been decided to stop the disposal of the wastes on the site and to start the remedial actions. These should minimize its negative influence to the environment and particularly to the groundwater.

In order to immobilize permanently existing pollution in the zone where it is present today several options were discussed (Pletikapić, 1993). It has been decided to turn the existing dump site into a sanitary landfill of municipal waste of the city of Zagreb. It has been foreseen that the landfill will be in use until 2009. The remediation has been carried out in steps. Old waste had been restacked onto the prepared base ground which should prevent the contact of the waste with water-bearing sediments beneath the landfill (Nikolić et al. 2000). The area occupied by waste shall be finally reduced to 540.000 m^2.

According to the original design (IGH, 2000) the impervious barrier in the final cover was designed as 0.5 m thick clay layer. In the alternative design of final cover system (IGH, 2002) geosynthetic clay liner has been adopted instead of clay layer. Typical cross section of the sanitary landfill is shown on Fig. 1.

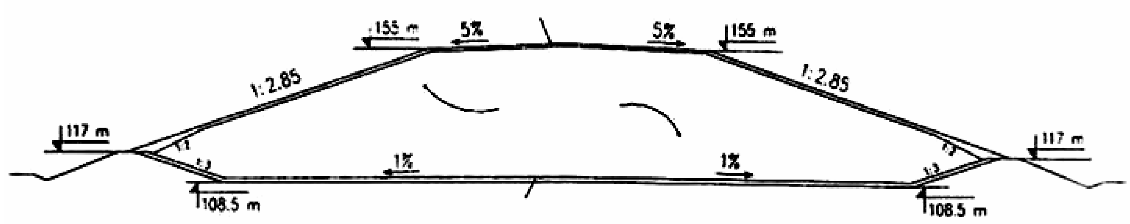

Figure 1: Typical cross section of the sanitary landfill Jakusevec.

The cover configurations for the top and side slopes are shown on Table 1, starting from the top layer and proceeding down.

Table 1: Cover configurations for sanitary landfill Jakusevec.

Top Portion of Cover (5% slope)	**Side Slopes of Cover (2.85H:1V)**
0.15 m thick topsoil	0.15 m thick topsoil
0.65 m thick frost protection layer	0.85 m thick frost protection layer
min. 10 mm thick geosynthetic water drain	min. 10 mm thick geosynthetic water drain
1 mm thick LLDP geomembrane	-
geosynthetic clay liner	*geosynthetic clay liner*
min. 10 mm thick geosynthetic gas vent layer	min. 10 mm thick geosynthetic gas vent layer
intermediate cover	intermediate cover

Quality Acceptance Testing Program

According to the project specifications and in line with ASTM D 6495 standard, quality acceptance testing program is envisaged for clay component of GCLs. The recommended tests, test methods and frequencies, together with the expected values are given in Table 2 (DGGT, 2002; von Maubeuge, 2002).

Samples of Na-Bentonite were obtained for testing directly from the landfill Jakusevec in a granular form.

Table 2: CQA testing summary for clay component of GCLs.

Bentonite Properties	Test Method	Test Frequency(*)	Expected Value (1)	Expected Value (2)	Manufacturer Specification
Swell Index	ASTM D5890	10.000 m^2	≥ 20 ml	> 24 ml	24 ml
Fluid Loss	ASTM D5891		≤ 18 ml	< 18 ml	-
Water Adsorption Capacity	DIN 18132		≥ 450 %	> 600 %	-
Mass per unit area	ASTM D5993		≥ 4500 g/m^2	> 3500 g/m^2 (#)	4800 g/m^2

(*)ASTM D 6495 Suggested frequency for a typical 50.000 m^2 project.
(1) DGGT, 2002
(2) von Maubeuge, 2002
(#) at 10% moisture content

In order to evaluate the influence of leachate from the landfill Jakusevec on the clay component of GCLs, three series of tests were conducted comprising four tests mentioned in Table 1. The first series (baseline testing, series I) of tests were performed on as-received samples of bentonite and with the use of distilled water as a test fluid. In other two series (series II and III), bentonite samples were immersed (Fig. 2) - for one and seven days, respectively, into the site-specific liquid i.e. real leachate collected from the leachate retention basin of a municipal solid waste disposal site Jakusevec. Following the conditioning period, the leachate was carefully decanted and bentonite samples were dried. The same tests were conducted again by the use of distilled water.

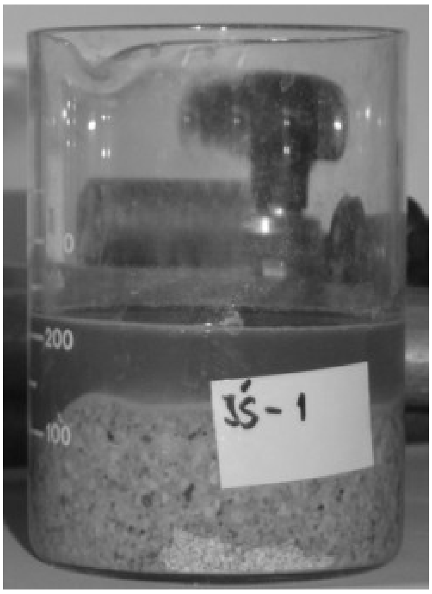

Figure 2: Bentonite sample immersed into leachate.

The chemical composition of the leachate at the landfill Jakusevec has been continuously monitored since Autumn 2000. Table 3 shows the data from the annual report for the year 2004 (ECOINA, 2005a) together with the data obtained in March 2005 (ECOINA, 2005b), i.e. in the period when the leachate sample was collected for use in the present testing.

Table 3: Chemical composition of leachate at the landfill Jakusevec.

Parameter	**January – December, 2004**		**March, 2005**
	Minimum	**Maximum**	
Temperature [°C]	3,6	24,1	8,15
pH	7,71	7,96	7,83
Electroconductivity [μS/cm]	9950	11970	7760
Sodium Na^+ [mg/l]	951,84	1232,83	871,27
Potassium K^+ [mg/l]	515,7	938,0	413,74
Calcium Ca^{2+} [mg/l]	13,0	546,0	81,6
Magnesium Mg^{2+} [mg/l]	83,8	229,0	117,4
Ammonium NH_4 [mg/l]	383,8	606,75	190,41
COD[a] [mg/l]	1040	1520	955
BOD[b] [mg/l]	156	728	120
SM[c] [mg/l]	4908	6052	4724
Total oil [mg/l]	2,66	6,79	2,71
Mineral oils [mg/l]	0,08	0,67	0,26

[a]COD chemical oxygen demand
[b]BOD biological oxygen demand
[c]SM suspended matter

Laboratory Test Results

XRD Analysis

Mineral composition has been determined by X-ray powder diffraction (XRD). XRD patterns were taken using Philips diffractometer with graphite monochromator, CuKa radiation (U=40kV, I=35mA) and proportional counter. Diffraction pattern of original untreated sample was recorded as well as the patterns of sample treated with glycerol, ethylene glycol and heated 2 hours at 600˚C. Diffraction pattern of insoluble residue following dilution with 18 % hydrochloric acid is recorded due to more reliable definition of mineral content. The particle fraction less than 2 μm are separated by sedimentation and analysed with the same methods as mentioned above for the original sample. The identification of clay minerals was generally based on the methods outlined by Brown (1961), Brindley and Brown (1980), and Moore and Reynolds (1997).

Mineral composition reported in Table 4 indicates that the sample contains about 75% of clay minerals with majority of the minerals being smectite.

Table 4: The results of semi-quantitative X-ray analysis.
(made by Mrs. M. Covic and Mr. N. Tadej, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb)

Mineral type	**Mass ratio [%]**
Smectite*	≤ 75
Quartz	5-10
Plagioclase	≤ 5
Potassium-feldspar	?
Cristobalite	≥ 5
Calcite	≤ 5
Goethite	?

? Uncertain presence of mineral due to small amount or mutual covering of diffraction lines.

* Smectite amorphous component, which content is < 10 %, is included.

Diffraction pattern of original sample (series I), as well as the patterns of samples exposed to the action of leachate (series II and III) are shown on the Fig. 3. The diffraction patterns indicate shift in position of basal diffraction lines to the higher angles. Reason for changing of basal spacing (Table 5) is exchange of primary interlayer cations with inorganic and organic chemical compounds from the leachate.

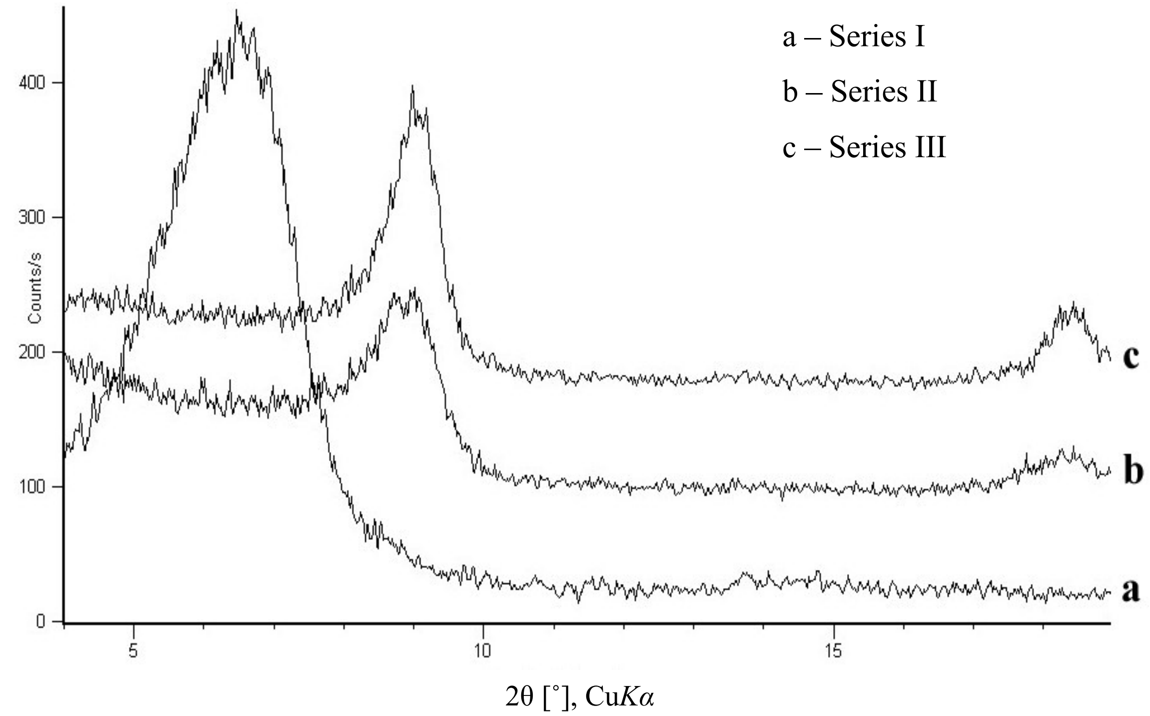

Figure 3: XRD patterns of bentonite.

Table 5: Basal spacings.

Test series	Spacing [Å]
Series I	13.8
Series II	10.0
Series III	9.8

Index Tests

Three types of index tests were performed on the bentonite samples i.e. Water Adsorption Capacity (DIN 18132), Fluid Loss (ASTM 5891), and Swell Index (ASTM 5890).

Water adsorption test results (Fig. 4 and Table 6) are almost the same for series I and II (530-590%; 545-590%) and slightly lower for the series III (485-510%). Based on these results, one can conclude that under the short-term immersion into the leachate (1-7 days), the changes of water adsorption capacity can be neglected. According to CQA testing programme (Table 2) all samples satisfy acceptance criteria by DGGT, 2002 but they do not satisfy alternative acceptance criteria by von Maubeuge, 2002.

The question remains whether present duration of sample exposure to the liquid is sufficient, and whether the duration of the test (24 hours) is long enough in order to achieve adsorption capacity of the sample. The shape of the curves points clearly to the conclusion that adsorption capacity was not achieved in all series of tests. Only few samples in series III (J-3.1C and J-3.1D) show trend of process completion (approximation by straight line). According to Egloffstein (1995) the rate of adsorption process, particularly in the beginning, is essentially different for Ca- and Na-bentonite. While Ca-bentonite completely adsorbs water very quickly within initial period of 15-30 minutes, the process of water adsorption for Na-bentonites can last up to several days.

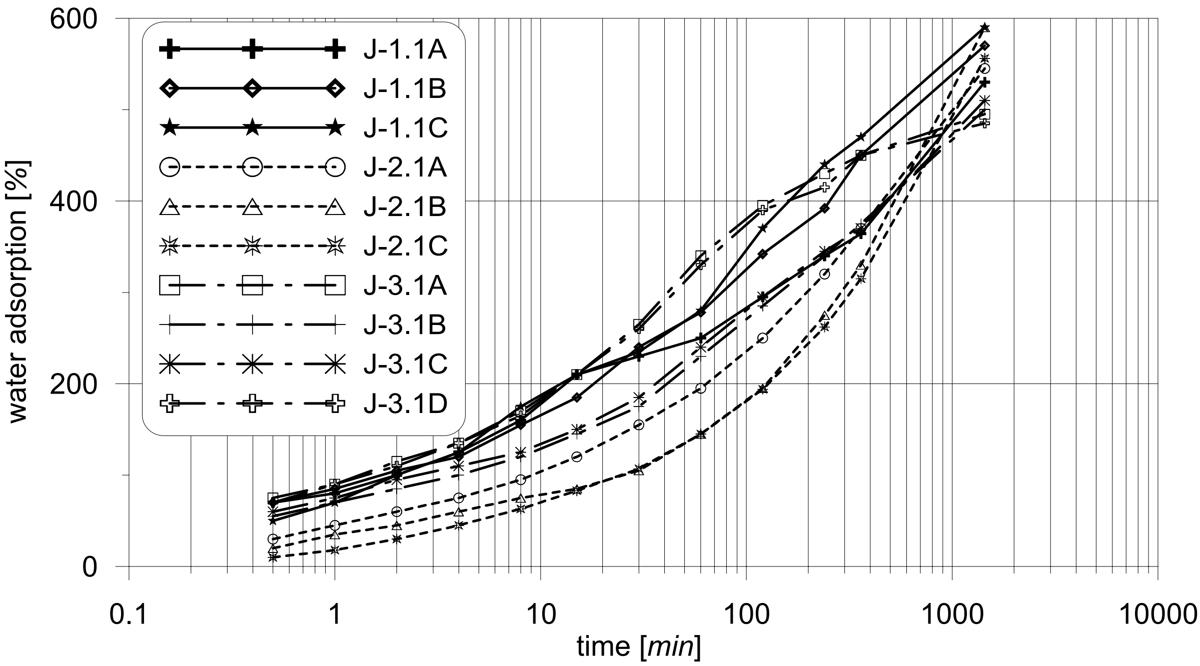

Figure 4: Water adsorption capacity.

Table 6: Water adsorption capacity after 24 hours.

	Sample no.	Water adsorption capacity [%]	
		Values	**Range**
Series I	J-1.1A	530	530 - 590
	J-1.1B	570	
	J-1.1C	590	
Series II	J-2.1A	545	545 - 590
	J-2.1B	590	
	J-2.1C	556	
Series III	J-3.1A	495	485 - 510
	J-3.1B	500	
	J-3.1C	510	
	J-3.1D	485	

Fluid loss test results (Table 7) and free swell test results (Table 8) yield no significant difference in values obtained with as-received samples in comparison with samples immersed into site specific leachate. These results seem to be contradictory to the indication obtained in XRD analysis where basal spacing reduction was observed (Table 5).

Table 7: Fluid loss [ml].

Sample no.	**Series I**	**Series II**	**Series III**
1	12	14	14
2	12	14	14
3	14	-	-

Table 8: Free swell [ml/2g].

Sample no.	Series I	Series II	Series III
1	34	35	35
2	33	34	34
3	34	35	34

Discussion and conclusion

It could be concluded that present test results are only partially satisfactory. The authors are of the opinion that it could be explained by three main reasons: drying temperature for sample preparation, duration of tests and duration of sample exposure to leachate.

According to standard specification for swell index testing bentonite sample should be dried at 105°C. Similarly bentonite samples for fluid loss testing were dried at the same temperature. However bentonite samples for water adsorption testing were dried at 60°C (Egloffstein, 1995). This difference may cause unexpected results for free swell and fluid loss tests.

Duration of swell index test and water adsorption test is limited to 24 hours. But water adsorption test curves presented in this paper indicate that adsorption process was not completed. This statement is supported by findings of Egloffstein (1995). On the other side Shackelford et al. (2000), using results of Lin (1998), concluded that swelling process may not be complete after 24 hours. Therefore it is reasonable to assume that both test duration should be extended beyond 24 hours.

Bentonite samples were exposed to the action of leachate for a relatively short period of time (up to 7 days). Some changes have been noticed only in the water adsorption test results, but no significant changes occurred in swelling test results and in fluid loss test results. It may be concluded that longer sample immersion in leachate could cause more significant changes in all acceptance test results. Namely in that case a chemical equilibrium could be established (Shackelford et al., 2000).

The above mentioned observation leads to the conclusion that further research is needed in order to clarify the influence of drying temperature, duration of tests and duration of leachate action to the behaviour of bentonite sample in acceptance tests.

Acknowledgement

The authors would like to recognize Dr. Z. Milanovic and Mr. G. Pogledic (ZGOS, Company for Bulky Waste Management, Zagreb) for making available records on leachate collection at Jakusevec landfill. Also, thanks to Mr. B. Drnjevic (IGH - Civil Engineering Institute of Croatia, Zagreb) for providing information from Jakusevec design documentation.

References

1. Brindley, G. W., Brown, G. (1980). “Crystal structures of clay minerals and their X-ray identification”. Miner. Soc., London, 495 pp.
2. Brown, G. (1961). “The X-ray identification and crystal structures of clay minerals”. Miner. Soc., London, 544 pp.
3. DGGT: Empfelungen zur Anwendung geosynthetischer Tondichtungsbahnen EAG-GTD, Ernst & Sohn, 2002.
4. ECOINA (2005a). Monitoring of the surface waters and leachate and waters from the Sava river – Annual report for the year 2004.
5. ECOINA (2005b). Monitoring of the surface waters and leachate and waters from the Sava river – Report no: 17/2005.
6. Egloffstein, T. (1995). “Properties and test methods to assess bentonite used in geosynthetic clay liners”. *Geosynthetic Clay Liners, Proceed. Int. Symp., Nuremberg, Germany, 14-15 April 1994,* Koerner, Gartung & Zanzinger (eds), A. A. Balkema, Brookfield, 51-72.
7. IGH (2000). Jakusevec-Prudinec dumpsite remediation, Civil Engineering Institute of Croatia, Zagreb, Design No. 2400-2-240027.
8. IGH (2002). Jakusevec-Prudinec dumpsite remediation, Civil Engineering Institute of Croatia, Zagreb, Design No. 2400-2-240101.
9. Moore, D. M. and Reynolds, R. C. (1997). “X-Ray Diffraction and the Identification and Analysis of Clay Minerals”. Oxford University Press, 378 pp.
10. Nikolić, S., Pletikapić, Z. (2000). “Solution of Sealing Baseground of Remediated part of Jakusevec Dump Site applied on Experimental Field”. *VIth International Symposium waste Management* - Zagreb 2000, 457-473 (in Croatian).
11. Pletikapić, Z. (1993). “Alternative Solutions for Closing and Improving the Jakusevec Garbage Dump”. *Građevinar* 45 (1993) 12, 743-749 (in Croatian).
12. Shackelford, C. D., Benson, C., Katsumi, T., Edil, T. B., Lin, L. (2000). “Evaluating the hydraulic conductivity of GCLs permeated with non-standard liquids”. *Geotextiles & Geomembranes* 18, 133-161.
13. von Maubeuge, K. P. (2002). “Investigation of bentonite required for geosynthetic clay barriers”. *Clay Geosynthetic Barriers, Proceed. Int. Symp., Nuremberg, Germany, 16-17 April 2002,* Zanzinger, Koerner& Gartung (eds), Swets & Zeitlinger, Lisse, 155-163.