The14th International Conference on QiR (Quality in Research)

Lombok
Indonesia

In conjunction with :

4th Asian Symposium on Material Processing (ASMP)

International Conference in Saving Energy in Refrigeration and Air Conditioning (ICSERA)

PROCEEDING

ISSN 1411-1284

ORGANIZED BY :

UNIVERSITAS INDONESIA
Veritas, Probitas, Iustitia

FACULTY OF ENGINEERING

CO HOSTED :

FACULTY OF ENGINEERING UNIVERSITAS MATARAM

STMIK LOMBOK

CONFERENCE ORGANIZER

Advisor
Prof. Prof. Dr. Ir. Dedi Priadi, DEA.,
Dr. Ir. Muhamad Asvial, M.Eng.
Ir. Hendri DS Budiono, M.Eng
Prof. Dr. Heri Hermansyah, S.T., M.Eng.
Jos Istiyanto, S.T., M.T., Ph.D.
Dr. Ir. Wiwik Rahayu,DEA.
Prof. Dr. Akhmad Herman Yuwono, M.Phil.Eng.,

Chairman
Dr. Fitri Yuli Zulkifli, S.T., M.Sc.
Vice Chairman
Dr. Nyoman Suwartha, ST., MT., MAgr.

International Advisory Board
Prof. Dr.-Ing. Axel Hunger University of Duisburg, Germany.
Prof. Chia-Fen Chi, National Taiwan University Science and Technology, Taiwan
Prof. Dr. Ir. Dedi Priadi, DEA, Universitas Indonesia, Indonesia
Prof. Josaphat Tetuko Sri Sumantyo, Chiba University, Japan
Prof. Koichi Ito,Chiba University, Japan.
Prof. Kozo Obara, Kagoshima University
Prof. Martin Betts, Griffith University, Australia
Prof. Michiharu Tabe, Shizuoka University, Japan
Prof. Tae-jo. Ko, Yeungnam University, South Korea

Steering Committee
Prof. Dr. Ir. Anne Zulfia Syahrial,, M.Sc. (UI)
Prof. Dr. Ir. Eko Tjipto Rahardjo, M.Sc. (UI)
Prof. Dr. Ir. Harinaldi, M.Eng. (UI)
Inaki Maulida Hakim, ST., MT (UI)
Prof. Dr. Ing. Ir. Misri Gozan, M.Tech. (UI)
Dr. Ir. Setyo Sarwanto Moersidik, DEA. (UI)
Ir. Sukisno, Msi (UI)
Yusron Saadi, ST., MSc., PhD. (UNRAM)
Dr. rer. nat. Teti Zubaidah, ST., MT. (UNRAM)
Hijrah Saputra, ST.,M.Sc (STMIK LOMBOK)

Technical Program Committee
Ir. Martha Leni Siregar, MSC. (UI)
Maya Arlini, ST., MT., MBA (UI)
Dr. Eny Kusrini, S.Si. (UI)
Dr. Mochamad Chalid, S.Si., M.Sc.Eng. (UI)
Dr. Ir. Purnomo Sidi Priambodo, M.Sc. (UI)
Rossa Turpuk G. S.Ars., M.Ars. (UI)
Sugeng Supriadi, S.T., M.S.Eng., Ph.D. (UI)
Dr. rer. nat. Agustino Zulys, S.Si., M.Sc. (UI)
Misbahuddin, ST., MT. (UNRAM)

Secretariat and Registration
Herra Astasusmini, SE

Treasurer
Evy Surpiningsih, S.Pd., MM
Nuri Nugraini, Amd

CONFERENCE ORGANIZER

Programme and Protocol
Tikka Anggraeni, M.Si.

Design and Documentation
Rengga Wibisono, S.Sos.
Widiya Prastiwi, S.Ikom.

Web and Information System
I Gde Dharma Nugraha, S.T., M.T.
Boma Anantasatya Adhi, ST., M.T.
Ruki Harwahyu, S.T., M.T., M.Eng.
Ardiansyah, ST., M.Eng.
Gunawan Heri Saputra, Amd

Exhibition and Sponsorship
Dr. Ir. Nahry., MT.
Dr. Adi Surjosatyo, M.Eng.
Dr. Muhammad Suryanegara
Dr. Badrul Munir, ST., MEng.Sc
Kemas Ridwan Kurniawan, ST., MSc., PhD.
Dr. Tania Surya Utami, S.T., M.T.
Ir. Erlinda Muslim, MEE.

Venue and Facilities
Jumiardi, S.Ars
Hadi Mulyadi

Meal
Anggie Dwiyana Putri, M.Si.

Conference Organizing Committee :
Faculty of Engineering Universitas Indonesia
Dekanat Building 3rd Floor Kampus UI, Depok 16424, Indonesia
Phone : +62-21- 7863503, Fax : +62-21 – 7270050
Email : qir@eng.ui.ac.id,
Website : http://qir.eng.ui.ac.id

www.eng.ui.ac.id

REVIEWER

Abdurrachman *Agency of the Assessment and Application of Technology* , Indonesia
Achmad Hery Fuad *Universitas Indonesia* , Indonesia
Achmad Munir *Institut Teknologi Bandung* , Indonesia
Adit Kurniawan *Institut Teknologi Bandung* , Indonesia
Adityo Abdi Nugroho *Universitas Indonesia* , Indonesia
Agus S. Pamitran *Universitas Indonesia* , Indonesia
Agus Setyo Muntohar *Universitas Muhammadiyah Yogyakarta* , Indonesia
Ahmad Fauzantoro *Agency of the Assessment and Application of Technology* , Indonesia
Ahmad Indra Siswantara *Universitas Indonesia* , Indonesia
Ahmad Munawar *Universitas Gadjah Mada* , Indonesia
Ajib Setyo Arifin *Graduate School of Science and Technology, Keio University* , Indonesia
Akhmad Herman Yuwono *Universitas Indonesia* , Indonesia
Akhmad Hidayatno *Universitas Indonesia* , Indonesia
Akmaluddin ST., M.Sc *Universitas Mataram* , Indonesia
Alfirano Alfirano *Universitas Sultan Ageng Tirtayasa* , Indonesia
Amalia Suzianti Universitas Indonesia, Indonesia
Anak Agung Putri Ratna *Universitas Indonesia* , Indonesia
Andi Rustandi *Universitas Indonesia*, Indonesia
Anne Zulfia Syahrial *Universitas Indonesia*, Indonesia
Ardiyansyah S. Yatim *Universitas Indonesia* , Indonesia
Arief Udhiarto *Universitas Indonesia*, Indonesia
Aries Subiantoro *Universitas Indonesia*, Indonesia
Ario Sunar Baskoro *Universitas Indonesia*, Indonesia
Astrida Fitri Nuryani *Universitas Brawijaya*, Indonesia
Ayomi Dita *Universitas Indonesia*, Indonesia
Azrar Hadi *Universitas Indonesia*, Indonesia
Badrul Munir *Universitas Indonesia*, Indonesia
Bagio Budiardjo *Universitas Indonesia*, Indonesia
Bambang Suharno *Universitas Indonesia*, Indonesia
Basari *Universitas Indonesia*, Indonesia
Boma Anantasatya Adhi *Universitas Indonesia*, Indonesia
Bondan T. Sofyan *Universitas Indonesia*, Indonesia
Budiarso M.Eng *Universitas Indonesia*, Indonesia
Catur Apriono *Universitas Indonesia*, Indonesia
Chairul Hudaya *Korea Institute of Science and Technology*, Indonesia
Chao-Lung Yang *National Taiwan University of Science and Technology*, Taiwan
Chi Chi National *Taiwan University of Science and Technology*, Taiwan
Cindy Rianti Priadi *Universitas Indonesia*, Indonesia
Danardono Agus Sumarsono *Universitas Indonesia* , Indonesia
Damrizal Damoerin *Universitas Indonesia* , Indonesia
Dave Mangindaan *Universitas Katolik Parahyangan* , Indonesia
Dedet Candra Riawan *Institut Teknologi Sepuluh November* , Indonesia
Deni Ferdian *Universitas Indonesia*, Indonesia
Dijan Supramono *Universitas Indonesia*, Indonesia
Dita Trisnawan *Universitas Indonesia*, Indonesia
Djoko M Hartono *Universitas Indonesia*, Indonesia
Docki Saraswati *Universitas Trisakti*, Indonesia
Dwita Sutjiningsih *Universitas Indonesia*, Indonesia
Edy Giri Rachman Putra *National Nuclear Energy Agency of Indonesia*, Indonesia
Eko Adhi Setiawan *Universitas Indonesia*, Indonesia
Eko Pradjoko *Universitas Mataram*, Indonesia
Eko Tjipto Rahardjo *Universitas Indonesia*, Indonesia
Ellen Sophie Tangkudung *Universitas Indonesia*, Indonesia
Elsa Krisanti *Universitas Indonesia*, Indonesia
Elyas Palantei *Universitas Indonesia*, Indonesia
Endang Widjajanti *Institut Sains dan Teknologi Nasional Jakarta*, Indonesia
Eny Kusrini *Universitas Indonesia*, Indonesia
Erika Buchari *Universitas Sriwijaya*, Indonesia
Essy Arijoeni *Universitas Indonesia*, Indonesia
Evawani Ellisa *Universitas Indonesia*, Indonesia
Evi Savitri Iriani *Ministry of Agriculture*, Indonesia
Faiz Husnayain *Universitas Indonesia*, Indonesia

REVIEWER

Feri Yusivar *Universitas Indonesia*, Indonesia
Fitri Yuli Zulkifli *Universitas Indonesia*, Indonesia
Gabriel Sudarmini Boedi Andari *Universitas Indonesia*, Indonesia
Gamantyo Hendrantoro *Institut Teknologi Sepuluh November*, Indonesia
Gerry Liston *Universitas Indonesia*, Indonesia
Gunawan *Universitas Indonesia*, Indonesia
Gunawan Wibisono *Universitas Indonesia*, Indonesia
Hardianto Iridiastadi *Institut Teknologi Bandung* , Indonesia
Hartana *Universitas Mataram*, Indonesia
Heddy Rohandi Agah *Universitas Indonesia*, Indonesia
Henry Nasution *Universiti Teknologi Malaysia,* Malaysia
Herr Soeryantono *Universitas Indonesia*, Indonesia
Heru Purnomo *Universitas Indonesia*, Indonesia
Hugeng *Universitas Multimedia Nusantara*, Indonesia
I Made Kartika Diputra *Universitas Indonesia*, Indonesia
Ida Ayu Giriantari *Universitas Udayana*, Indonesia
Inaki Maulida Hakim *Universitas Indonesia*, Indonesia
Isti Surjandari *Universitas Indonesia*, Indonesia
Jachrizal Sumabrata *Universitas Indonesia*, Indonesia
Jauhar Fajrin *Universitas Mataram*, Indonesia
Johny Wahyuadi Soedarsono *Universitas Indonesia*, Indonesia
Kamarza Mulia *Universitas Indonesia*, Indonesia
Kazuyuki Saito *Japan Agency for Marine-Earth Science and Technology, Yokohama, Kanagawa*, Japan
Krairiksh Monai King Mongkuts *Institute of Technology Ladkrabang*, Thailand
Leksmono Suryo Putranto *Universitas Tarumanagara*, Indonesia
M. Dachyar *Universitas Indonesia*, Indonesia
Manik Mahachandra *Institut Teknologi Bandung*, Indonesia
Martha Leni Siregar *Universitas Indonesia*, Indonesia
Max Rudolf Muskananfola *Universitas Diponegoro*, Indonesia
Maya Arlini Puspasari *Universitas Indonesia*, Indonesia
Mazlina Esa *Universiti Teknologi Malaysia*, Malaysia
Mina Azhar Aziz *Oklahoma State University,* USA
Misri Gozan *Universitas Indonesia* , Indonesia
Mochamad Chalid *Universitas Indonesia*, Indonesia
Moh Abduh *Institut Teknologi Bandung*, Indonesia
Mohammed Ali Berawi *Universitas Indonesia*, Indonesia
Mudrik Alaydrus *Universitas Mercu Buana*, Indonesia
Muhamad Asvial *Universitas Indonesia*, Indonesia
Muhamad Sahlan *Universitas Indonesia*, Indonesia
Muhammad Agung Santoso *Universitas Indonesia*, Indonesia
Muhammad Agung Shamsuddin *Universitas Indonesia*, Indonesia
Muhammad Firdaus Syawalludin Lubis *Universitas Indonesia*, Indonesia
Muhammad Idrus Alhamid *Universitas Indonesia*, Indonesia
Muhammad Suryanegara *Universitas Indonesia*, Indonesia
Mulia Orientilize *Universitas Indonesia*, Indonesia
Myrna Ariati Mochtar *Universitas Indonesia*, Indonesia
Nahry Yusuf *Universitas Indonesia*, Indonesia
Naniek Utami Handayani *Universitas Diponegoro*, Indonesia
Niken Taufiqurrahmi *Universitas Surya*, Indonesia
Nji Raden Poespawati *Universitas Indonesia*, Indonesia
Nofrijon Sofyan *Universitas Indonesia*, Indonesia
Nyoman Suwartha *Universitas Indonesia* , Indonesia
Oki Setyandito *Universitas Mataram*, Indonesia
Paramita Atmodiwirjo *Universitas Indonesia*, Indonesia
Pijar Religia *Universitas Surya*, Indonesia
Prima Dewi Purnamasari *Universitas Indonesia*, Indonesia
Purnomo Sidi Priambodo *Universitas Indonesia*, Indonesia
Rahmat Nurcahyo *Universitas Indonesia* , Indonesia
Rahmayetty *Universitas Sultan Ageng Tirtayasa*, Indonesia
Ratno Nuryadi *Agency of the Assessment and Application of Technology*, Indonesia
Reini D. Wirahadikusumah *Institut Teknologi Bandung*, Indonesia
Retno Wigajatri Purnamaningsih *Universitas Indonesia*, Indonesia
Ridwan Gunawan *Universitas Indonesia*, Indonesia

REVIEWER

Riezqa Andhika *Yeungnam University*, Korea
Rike Yudianti *Indonesian Institute of Sciences*, Indonesia
Rini Riastuti *Universitas Indonesia*, Indonesia
Riri Fitri Sari *Universitas Indonesia*, , Indonesia
Rizal Munadi *Universitas Syiah Kuala* , Indonesia
Rizki Reynaldo *Universitas Indonesia*, Indonesia
Rochmadi *Universitas Gajah Mada*, Indonesia
Rony Seto Wibowo *Institut Teknologi Sepuluh Nopember*, Indonesia
Rossa Turpuk Gabe *Universitas Indonesia*, Indonesia
Rudy Setiabudy *Universitas Indonesia*, Indonesia
Ruki Harwahyu *Universitas Indonesia*, Indonesia
Said Zulamraini *Universitas Riau*, Indonesia
Sajjad Haider *King Saud University,* Saudi Arabia
Sasono Rahardjo *Agency of the Assessment and Application of Technology*, Indonesia
Sigit Pranowo Hadiwardoyo *Universitas Indonesia*, Indonesia
Siswa Setyahadi *Agency of the Assessment and Application of Technology* , Indonesia
Siti Aminah *Universitas Indonesia* , Indonesia
Siti Murniningsih *Universitas Indonesia*, Indonesia
Slamet *Universitas Indonesia*, Indonesia
Sotya Astutiningsih *Universitas Indonesia*, Indonesia
Sri Harjanto *Universitas Indonesia*, Indonesia
Sugeng Supriadi *Universitas Indonesia*, Indonesia
Sunaryo *Universitas Indonesia*, Indonesia
Sutrasno Kartohardjono *Universitas Indonesia*, Indonesia
Syahril A. Rachim *Universitas Indonesia*, Indonesia
Tania Surya Utami *Universitas Indonesia*, Indonesia
Teti Zubaidah *Universitas Mataram,* , Indonesia
Tiena Gustina Amran *Universitas Trisakti*, Indonesia
Toha Saleh *Universitas Indonesia*, Indonesia
Tommy Ilyas *Universitas Indonesia*, Indonesia
Tri Tjahjono *Universitas Indonesia*, Indonesia
Triatno Judho Hardjoko *Universitas Indonesia*, Indonesia
Wahyuaji Np *Universitas Indonesia*, Indonesia
Wayan Mustika *Universitas Gadjah Mada*, Indonesia
Wen Chien Le *National Taiwan University* Taiwan
Widjojo Adi Prakoso *Universitas Indonesia*, Indonesia
Widodo Wahyu Purwanto *Universitas Indonesia* , Indonesia
Yalun Arifin *Universitas Surya*, Indonesia
Yandi Andri Yatmo *Universitas Indonesia*, Indonesia
Yanuar M.Sc., M.Eng. *Universitas Indonesia*, Indonesia
Yohandri Azwir *Universitas Negeri Padang*, Indonesia
Yudan Whulanza *Universitas Indonesia*, Indonesia
Yusuf Latief Universitas Indonesia, Indonesia
Yuswan Muharam *Universitas Indonesia*, Indonesia

Table of Contents

Physico-Hydro-Mechanical Properties of a Commercial Bentonite in Indonesia

Yulian Firmana Arifin[1,a], Umi Baroroh Lili Utami[2,b], and Tom Schanz[3,c]

[1]Faculty of Engineering, University of Lambung Mangkurat, Indonesia

[2]Faculty of Mathematics and Natural Science, University of Lambung Mangkurat, Indonesia

[3]Chair and Professor for Foundation Engineering, Soil & Rock Mechanics, Ruhr-Universitaet Bochum, Germany

[a]yulianfirmana@yahoo.com, [b]liliutami@yahoo.com, [c]tom.schanz@rub.de

Keywords: Bentonite; Barrier; Water retention; Hydro-mechanical properties; Chilled-mirror hygrometer technique

Abstract. This paper presents the physico-hydro-mechanical properties of a commercial bentonite in Indonesia related to the possibility of its use as a barrier in the waste repository. Physical properties include specific gravity, Atterberg limits, grain distribution, and compaction. Methods used to determine physical properties followed ASTM standards procedures. X-ray diffraction (XRD) and Environmental Scanning Electron Microscopy Test (ESEM) were also utilized in order to investigate the mineral content and microscopic level of the bentonite, respectively. The hydraulics properties of the bentonite (i.e., permeability and water retention) were obtained from permeability test and chilled-mirror hygrometer test, respectively. The mechanical property of the material includes the shear strength which was determined by using direct shear tests, respectively. The results are compared to other bentonites that have been widely used in the world.

Introduction

Bentonite is a highly plastic clay which contains large quantity of montmorillonite (or smectites) and expands when it is in contact with water in liquid form or in vapor form. In Indonesia, bentonite is often used in slurry form to solve problems in the construction of borings or excavating trenches in water-saturated soils. In fact, bentonite is now widely used as a barrier in domestic or hazardous waste repository. The bentonite or mixtures of bentonite with other materials such as sand and clay is compacted to reach a certain density. In the field, this material is directly incontact with waste, water and/or leachate. These lead to extend the characterisation of bentonite not only the consistency but also its hydro-mechanical properties.

This paper presents the physico-hydro-mechanical properties of a commercial bentonite in Indonesia related to the possibility of its use as a barrier in the waste repository.

Material Used and Method

The material used is widely used bentonite in Indonesia. Although it has long been used for example in the drilling process, the physical, chemical, mechanical, and hydraulics properties of the bentonite has not been published yet.

The methods used to obtain the physical, chemical, mechanical, and hydraulic are related to the use of the bentonite as a barrier material. Specific gravity, the limits of Atterberg, grain size distribution, and compaction tests have been performed based on ASTM D854, ASTM D4318-93, ASTM D422-63 and ASTM D698 [1], respectively. Cation exchange capacity was determined by using saturation method with $BaCl_2$. X-ray diffraction (XRD) method was used to determined mineral content of the bentonite. Bentonite hydraulic properties (i.e., permeability and water retention behavior) were obtained by using the ASTM D 5856-95 method [1] and the chilled mirror hygrometer technique, respectively. Chilled-mirror hygrometer technique has been used to determine total suction of soils [2]. The chilled-mirror hygrometer is known as the most accurate technique for measuring the relative humidity [3, 4]. Mechanical property was conducted using direct shear ASTM D 3080 [1]. In the permeability and direct shear strength tests, the samples were prepared and tested at optimum moisture content and maximum dry density based on Proctor compaction test results.

Result and Disscussion

Table 1 summarizes the physico-chemical properties of bentonite performed using ASTM standards (i.e., specific gravity, Atterberg limits, grain size distribution, and compaction), and saturation method (i.e., CEC). As shown in Table 1, the bentonite has specific gravity of 2.78, liquid limit of 140%, and plastic limit of 55%. The plasticity index calculated from the liquid and plastic limits is 85%. Based on grain size distribution result, the bentonite contains 100% fine grain with 70% clay content. The maximum dry density and optimum water content of the bentonite resulted from Proctor compaction are 1.2 Mg/m^3 and 23%, respectively. The bentonite has CEC of 26.8 meq/100g.

Table 1. Summary of the bentonite characteristics used in this study

Properties	Value
Specific gravity	2.78
Liquid limit (%)	140
Plastic limit (%)	55
Plasticity index (%)	85
Clay content (%)	70
Fine content (%)	100
Maximum dry density (Mg/m^3)	1.2
Optimum water content (%)	23
Cation exchange capacity (meq/100g)	26.8

Fig. 1 shows XRD result of bentonite. The figure reveals presence of montmorillonite in the bentonite and other minerals such as illite and quartz.

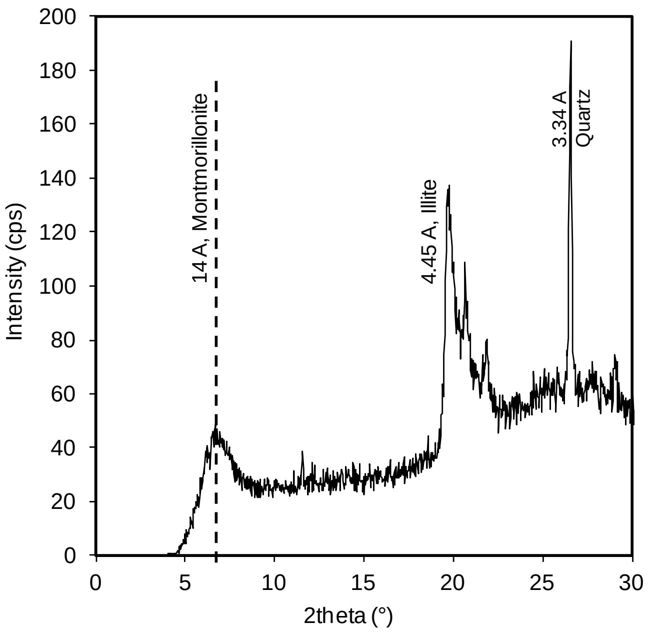
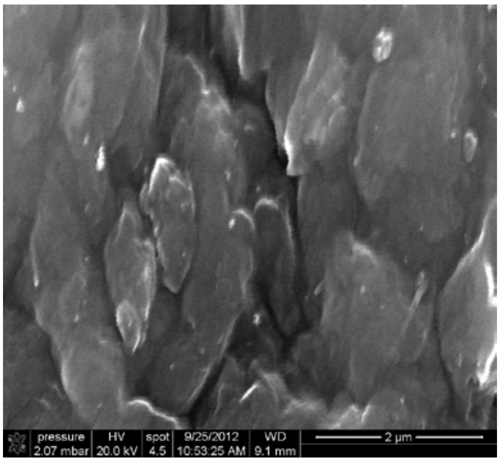
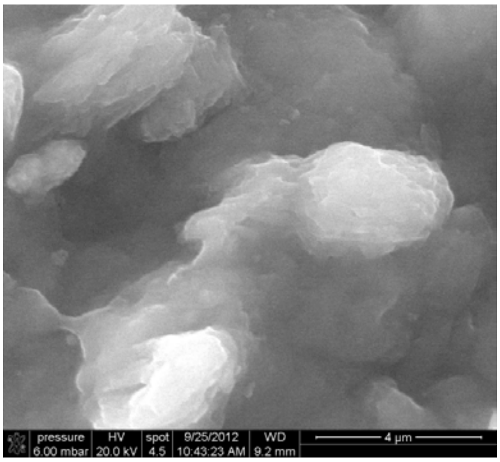


Fig. 1. XRD result of the bentonite

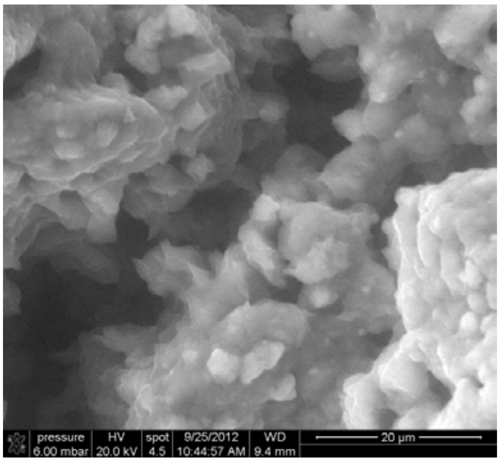
Environmental scanning electron microscopy (ESEM) was used to study the microscopic bentonite. Tests were carried out in the Laboratory of Chemistry at Ruhr-Universitaet Bochum, Germany. Microscopic structure is important for further investigation when the bentonite is compacted or mixed with other materials such as sand, cement, polymer [5], etc. Fig. 2 shows photos of bentonite obtained by using ESEM with magnification of 5000-50000 times. The photos show that the bentonite is composed of fine particles with a size less than 4μm (Figs. 2a and 2b). The particles form a larger structure called aggregates (Figs. 2c and 2d). The presence of particles and aggregates of different sizes produces different sizes pores (i.e., space between them) [6, 7].



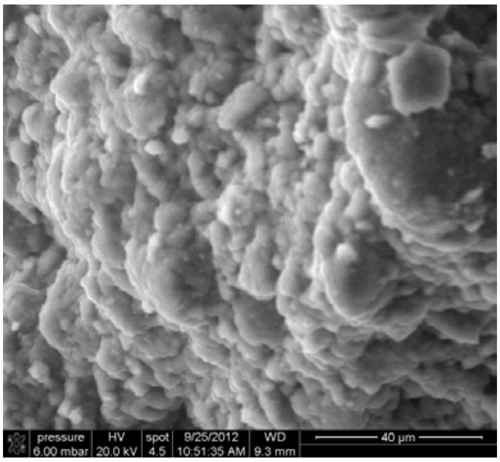
(a)



(b)



(c)



(d)

Fig. 2. ESEM photos of the bentonite

Table 2 summarizes the physico-chemical data of bentonite obtained in this study and collected from literatures for different types of bentonite. All bentonites presented in Table 2 are commercial bentonite from different countries such as Germany, India, Spain, USA, Japan, and China. Based on Unified Soil Classification System (USCS), all soils in Table 2 are highly plastic clays.

As shown in Table 2, the specific gravity of the bentonite is close to that of other bentonites. The Liquid limit and Plasticity index are less than that of other bentonites except FEBEX. The plastic limit is close to plastic limit of Calsigel, FEBEX, and MX80. For CEC, the bentonite used in this study has the lowest value. However, the physical and mechanical properties of montmorillonite soils such as liquid limit and swelling potential were not influenced by the total CEC of the soils other than only by the amount of exchangeable sodium cation in the CEC [8].

There is no unique relationship observed from data in Table 2. This is due to the variation of the physico-chemical properties and mineralogy of the bentonite. Two important parameters that influence behavior of the bentonite (i.e., montmorillonite content and specific surface area) are not available and will be performed in the next investigation.

Table 2. Bentonite characteristics used in the world

Properties	Bentonite (in this study)	Calsigel [2]	Indian Bentonite [2]	FEBEX [9]	MX80 [10]	Kunigel [11]	GMZ [12]
Specific gravity	2.78	2.8	2.85	2.7	2.76	2.79	2.71
Liquid limit (%)	140	180	400	102	411±10	473.9	276
Plastic limit (%)	55	56	34	53	47	26.6	37
Plasticity Index	85	124	366	49	364±10	447.3	239
Montmorillonite content (%)	-	50-60‡	-	92	75	48	
Clay content (%)	70	40	83	68	77.6	64.8	60
Fine content (%)	100	100	100	92	92.6	-	98
Total S_s (m^2/g)	-	500	400	725	562	388.8	420
CEC (meq/100g)	26.8	49	62	102	73	76	68
Country	Indonesia	Germany	India	Spain	USA	Japan	China

Shear Strength of Bentonite

Direct shear test was performed on the sample at maximum dry density and optimum water content as shown in Table 1. The mechanical properties tested herein involved the determination of shear strength parameters (i.e., cohesion (c') and internal friction angle (ϕ')). The values of cohesion (c) and internal friction angle (ϕ) are 30 kPa and 20^o, respectively. The result shows typical values of shear strength of clay soil. Comparison with other bentonite cannot be done due to lack of data of shear strength similar to that done here.

Hydraulic Properties of Bentonite

The hydraulic property of bentonite that is very important pertaining to its use as barrier is coefficient of permeability. Permeability test was conducted on samples at maximum dry density of 1.2 Mg/m^3 and optimum water content of 23%. The coefficient of permeability obtained is 1.90×10^{-8}cm/s or 1.90×10^{-10}m/sec.

Comparison of permeability is made by plotting the coefficient of permeability value versus dry density of sample. Fig. 3 shows permeability of bentonite used in this study and several compacted bentonite obtained from literature plotted in semi-log scale as a function of bentonite dry density. According to the figure, the permeability of the bentonite used is relatively higher than that of other bentonites. The low permeability of other bentonites may be attributed the high percentage of monmorillonite. More data of the bentonite based material are required to give better comparison.

Besides permeability, the relationship between the water content and the negative pore water pressure (or suction) also plays important role in hydraulics behavior. The relationship also called water retention curve shows the bentonite ability to hold water by increasing or decreasing of suction. In this study, the negative pore water pressure is determined using a chilled-mirror hygrometer technique called AQUALAB. The tests were conducted at the Soil Mechanics Laboratory, Ruhr-Universitaet Bochum, Germany. Fig. 4 shows the relationship curve between water content and suction of bentonite used in this study compared with bentonites that are commonly used in the world i.e., MX80 (USA) and Calcigel (Germany). As shown in the picture, the curve of the bentonite used is placed in between that of Calcigel and MX80. It shows that the ability of bentonite used in this study to retain water is higher than that of Calsigel that is proposed to be a sealing material for high level waste in Germany.

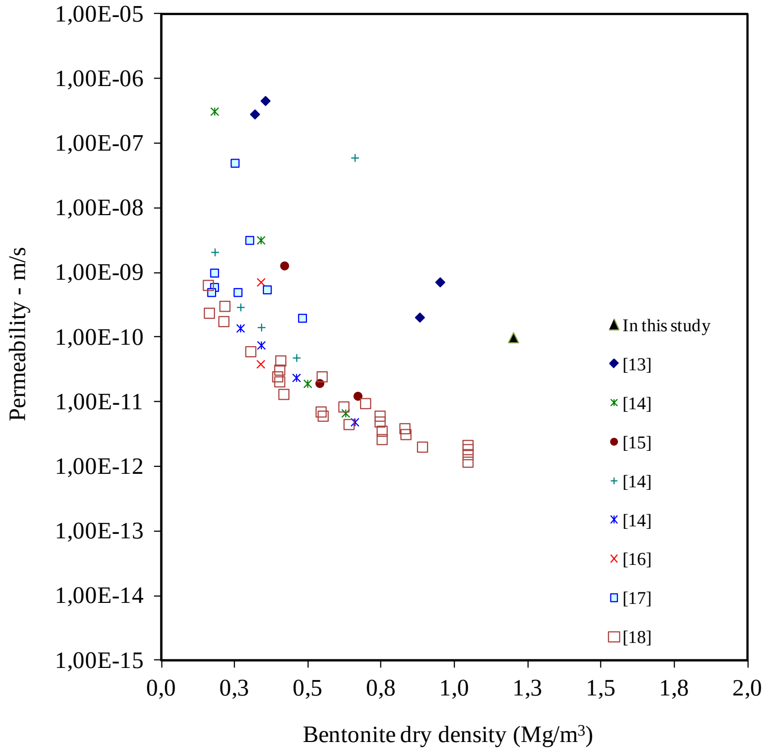


Fig. 3. Permeability of compacted bentonite as a function of bentonite dry density

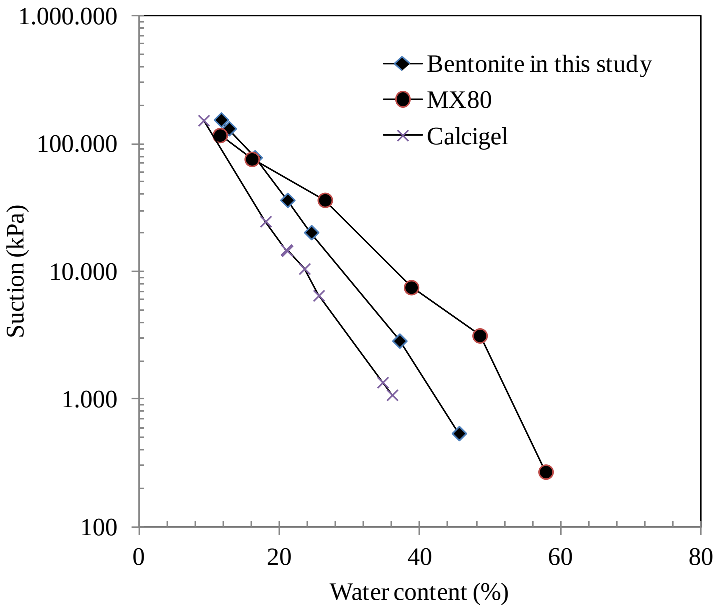


Fig. 4. Water retention curves of bentonite

Conclusion

A study on the physico-hydro-mechanical properties of a commercial bentonite in Indonesia has been presented. The results obtained show that: (1) Bentonite is used has a specific gravity of 2.78 with initial moisture content of 14.94%. Liquid limit, plastic limit, and plasticity index are 140%, 55%, and 85%, respectively. Presence of montmorillonite was confirmed in XRD result; (2) Bentonite has cation exchange capacity of 26.8 meq/100g. Compared to bentonite commonly used in the world, the value is small but it is still much higher than that of clays generally; (3) From the hydraulic properties, the permeability of the compacted bentonite at maximum density is 1.9×10^{-10} m/sec. In addition, the bentonite is also able to retain water with a very large capacity and comparable to bentonites that are currently widely used in Europe and America. The shear strength parameters (i.e., cohesion and internal friction angle) obtained at the same condition as permeability test are 30 kPa and 20^{o}, respectively.

References

[1]. ASTM, Annual Book of Standards. Volumes 04.08 and 04.09, Soil and rock, ASTM International. West Conshohocken. PA, (1997)
[2]. Y.F. Arifin dan T. Schanz, Osmotic suction of highly plastic clays, Actageotechnica, 4(3) (2009) 177-194.
[3]. Leong E.C., Tripathy S., and Rahardjo R., Total suction measurement of unsaturated soils with a device using the chilled-mirror dew-point technique. Géotechnique, 53(2) (2003) 173-182
[4]. S.S Agus . and T. Schanz, Comparison of four methods for measuring total suction. Vadose Zone Journal. Special section: Soil Water Sensing. Soil Science Society of America, 4(4), (2005) 1087-1095.
[5]. Trisoplast, Trisoplast mineral liners. Documentation Trisoplast®, Netherland, (2004)
[6]. Gens and E.E. Alonso, A Framework for the behaviour of unsaturated expansive (1992)
[7]. R.N. Yong, Soil suction and soil-water potentials in swelling clays in engineered clay barriers. Engineering Geology, Elsevier, 54 (1999) 3-13.
[8]. Sridharan, Engineering behaviour of clays: Influence of mineralogy. Chemo-Mechanical Coupling in Clays; from Nano-Scale to Engineering Applications (Eds. Di Miao, Hueckel and Lloret). Swets & Zeitlinger. Lisse. (2002) 3-27.
[9]. ENRESA, FEBEX project—full-scale engineered barriers experiment for a deep geological repository for high level radioactive waste in crystalline host rock. Final Report, Publicatión Técnica 1/2000, Empresa Nacional de Residuos Radiactivos SA (ENRESA), Madrid, Spain (2000)
[10]. S. Tripathy, T. Schanz, and A. Sridharan, Swelling pressures of compacted bentonites from diffuse double layer theory. Canadian Geotechnical Journal, 41 (2004) 437-450.
[11]. H. Komine and N. Ogata, New equations for swelling characteristics of bentonite-based buffer material. Canadian Geotechnical Journal, 40 (2003) 460-475
[12]. Y. Weimin, T. Schanz, Q. Lixin, J. Wang, and Y. F. Arifin, Characteristics of swelling pressure of densely compacted Gaomiaozi bentonite GMZ01 Chinese Journal of Rock Mechanics and Engineering 26(2) (2007) 3861-3865
[13]. P. Sitz, Materialuntersuchungen für Mehr- komponensysteme auf Ton/Bentonite Basis für Dichtung und Lastabtrag mit hohem Rückhaltvermögen für den langzeitsicheren Verschluβ von UTD und Endlagern im Salinar. Abschluβbericht, TU Bergkakademie Freiberg, Germany (1997)
[14]. T.C. Kenny, W.A. van Veen, M.A. Swallow, and M.A. Sungaila, Hydraulic conductivity of compacted bentonite-sand mixture. Canadian geitechnical journal, 29 (1992)364-374.
[15]. S. Hansbo, and C. Olsson, Geotechnical properties of sodium-bentonite, type volclay. Internal report.Chalmers University of Technology, Gothenburg, Sweden. (In Swedish) (1973)
[16]. M.D. Haug, and L.C. Wong, Impact of molding water content on hydraulic conductivity of compacted sand-bentonite. Canadian Geotechnical Journal, 29 (1992)253-362.
[17]. G. Sällfors, and A. Högsta, Determination of hydraulic conductivity of sand-bentonite mixtures for engineering purposes. Geotechnical and Geological Engineering 20 (2002) 65-80.
[18]. H. Komine, Simplified evaluation on hydraulic conductivities of sand-bentonite mixture backfill. Applied Clay Science 26 (2004) 13-19.