



Review article

A probabilistic approach for the assessment of the influence of the dielectric constant of pore fluids on the liquid limit of smectite and kaolinite



Giovanni Spagnoli^{a,*}, Asuri Sridharan^b, Pierpaolo Oreste^c, Lucio Di Matteo^d

^a BASF Construction Solutions GmbH, Dr.-Albert-Frank-Straße 32, 83308 Trostberg, Germany

^b Indian National Science Academy, New Delhi, Formerly at Indian Institute of Science, Bangalore, India

^c Department of Environmental, Land and Infrastructural Engineering, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 Torino, Italy

^d Department of Physics and Geology, University of Perugia, Via A. Pascoli snc, 06123 Perugia, Italy

ARTICLE INFO

Keywords:

Kaolinite

Smectite

Liquid limit

Organic pore fluids

Probabilistic analysis

ABSTRACT

Liquid limit (LL) is defined as a limiting water content separating the viscous liquid state and plastic state of soil consistency. LL of clays, being a basic physico-chemical property, plays a role in environmental geotechnical engineering practice. Since it is well-known that kaolinite and smectite behave quite differently from each other from the geotechnical point of view, ninety-one data regarding smectite (Na and Ca) and kaolinite mixed with organic pore fluids having different dielectric constant (ϵ) values have been carefully analyzed. Data confirm that for a decreasing ϵ value of the pore fluid a decrease in LL is observed for the smectitic clays, with different magnitude depending on the main ion, whereas for kaolinitic clays this decreasing ϵ causes an increase in attractive forces causing flocculation and increase in LL values. A probabilistic approach has been performed to assess the robustness of the regression functions. For smectitic and kaolinitic clays the mathematical dependency of LL with ϵ is validated by the probabilistic analysis.

1. Introduction

Engineering properties of fine-grained soils are largely influenced by the chemistry of the pore fluids (e.g. Sridharan and Venkatappa Rao, 1975; Sridharan et al., 1988; Schmitz et al., 2004; Bergaya et al., 2006; Spagnoli et al., 2010, 2012; Olgun and Yildiz, 2010; Sridharan, 2014; Di Matteo et al., 2016). Understanding this behavior is very important for assessing the variation of the geotechnical properties for contaminated sites (e.g. Graham et al., 2001; Singh et al., 2008; Di Matteo et al., 2011). According to Sridharan (2014) the geotechnical modifications of the fine-grained soils are due to “the charge deficiency on the surfaces and edges of the clay platelets and the associated electrical attractive and repulsive forces”, which is regulated by the soil clay mineralogy. Many researches focused on the behavior of kaolinitic and smectitic clays (e.g. Mesri and Olson, 1971; Kaya and Fang, 2005; Di Matteo et al., 2011; Spagnoli and Sridharan, 2012) as these two clays behave quite differently from each other from the geotechnical point of view under any given set of physico-chemical environment (Sridharan, 2014).

Atterberg limits are basic geotechnical tests, which are performed on fine-grained soils to assess the water content at which the plastic state is separated from liquid state (liquid limit, here abbreviated as LL), water content at which the semi-solid state separates from the

plastic state (plastic limit, here abbreviated as PL) and the index of plasticity (IP), which is range of the plastic state in terms of water content. As clays are colloids, their physical and chemical properties change if the pore fluid is different than water and this, in turn, reflects on the mechanical behavior of the fine-grained geo-materials. The model used to explain the variation of the Atterberg limits is attributed to the diffuse double layer (DDL) which is compressed, if the dielectric constant of the pore fluids decreases or the ionic strength of the pore fluids increases, causing coagulation (e.g. Bowders and Daniel, 1987; Mitchell, 1993). However, the mechanisms governing LL of kaolinitic and montmorillonitic soils are not the same (Sridharan and Venkatappa Rao, 1973, 1975; Sridharan et al., 1986, 1988; Sridharan, 2014). Normally, the data available in the literature refer to hydraulic conductivity (e.g. Anderson et al., 1985; Anandarajah, 2003; Lee et al., 2005), compressibility variation (e.g. Sridharan and Venkatappa Rao, 1973; Meegoda and Ratnaweera, 1994; Di Maio, 1996) or shearing strength variation (e.g. Sridharan and Venkatappa Rao, 1979, Olson, 1974; Spagnoli et al., 2011), where mostly mixed clays are used, or when pure clays are employed, data about the change of Atterberg limits with different pore fluids are not discussed. This research tries to summarize the effects of the different organic pore fluids on the liquid limit (LL) of clayey soils primarily containing

* Corresponding author.

E-mail address: giovanni.spagnoli@basf.com (G. Spagnoli).

Table 1
Data used for the Atterberg limits prediction for kaolinitic and smectitic clays mixed with organic pore fluids.

Smectite							
Reference	< 2 μm (%)	Pore fluid	Dielectric constant (ϵ)	LL (%)	PL (%)	IP (%)	Cation (only for smectite)
Andrews et al. (1967)	–	Water	80.37	506	55	451	Assumed Na ^a
		Dimethyl sulfoxide	48.90	140	80	60	Assumed Na ^a
Sridharan and Venkatappa Rao (1973, 1975)	–	Water	80.37	306	–	–	Na
		Hexane	1.89	34.6	–	–	Na
		Carbontetrachloride	2.28	86.7	–	–	Na
		Ethylacetate	6.02	57.1	–	–	Na
		Acetone	20.70	56.9	–	–	Na
		Ethanol	24.30	55.5	–	–	Na
		Methanol	32.63	59.5	–	–	Na
Acar and Olivieri (1989)	90 (Na) 12 (Ca)	Water	80.37	425	–	–	Na
		Ethyle Glycol	38.60	110	–	–	Na
		Nitrobenzene	35.74	78	–	–	Na
		Acetone	20.70	67	–	–	Na
		Phenol	13.13	62	–	–	Na
		Aniline	6.90	58	–	–	Na
		Xylene	2.50	46	–	–	Na
		Ethanol	24.30	64	–	–	Na
		Water	80.37	88	–	–	Ca
		Ethyle Glycol	38.60	78	–	–	Ca
		Nitrobenzene	35.74	80	–	–	Ca
		Acetone	20.70	77	–	–	Ca
		Phenol	13.13	65	–	–	Ca
		Aniline	6.90	50	–	–	Ca
		Xylene	2.50	54	–	–	Ca
		Ethanol	24.30	62	–	–	Ca
Gleason et al. (1997)	–	Water	80.37	603	567	36	Na
		Water/Methanol 50:50	56.99	328	100	228	Na
		Methanol	32.63	60	46	14	Na
		Water	80.37	124	567	98	Ca
		Water/Methanol 50:50	56.99	85	28	57	Ca
Spagnoli et al. (2010)	85	Water	80.37	455	70	385	Na
		Water/Ethanol 75:25	66.35	200	59	141	Na
		Water/Ethanol 50:50	52.33	127	52	75	Na
		Water/Ethanol 25:75	38.31	89	0	89	Na
Jang and Santamarina (2016)	–	Water	80.37	276	–	–	Assumed Na ^a
		Kerosene	1.80	39	–	–	Assumed Na ^a
New data set	60	Water	80.37	143.5	62	81.5	Ca
		Water/Ethanol 75:25	66.35	120	53	67	Ca
		Water/Ethanol 50:50	52.33	99	48	51	Ca
		Water/Ethanol 25:75	38.31	78	42	36	Ca
		Ethanol	24.30	74	43	31	Ca

Kaolinite							
Reference	< 2 μm (%)	Pore fluid	Dielectric constant (ϵ)	LL (%)	PL (%)	IP (%)	
Andrews et al. (1967)	–	Water	80.37		62	33	29
		Dimethyl sulfoxide	48.90		105	20	85
Sridharan and Venkatappa Rao (1973, 1975)	–	Water	80.37		49	–	–
		Hexane	1.89		140	–	–
		Carbontetrachloride	2.28		67.5	–	–
		Ethylacetate	6.02		61.4	–	–
		Acetone	20.70		57.4	–	–
		Ethanol	24.30		57.4	–	–
		Methanol	32.63		50.8	–	–
Meegoda and Ratnaweera (1994)	84	Water	80.37		48	36	12
		Water/Propanol 87.5:12.5	72.83		56	28	28
		Water/Propanol 75:25	65.30		64	27	37
		Water/Propanol 50:50	50.23		68	28	40
Foreman and Daniel (1986)	98	Water	80.37		54	31	23
		Methanol	32.63		74	45	29
		Heptan	2.00		116	–	–
Bowders and Daniel (1987)	–	Water	80.37		58	34	24
		Water/Methanol 80:20	71.02		60	32	28
		Water/Methanol 60:40	61.67		60	31	29
		Water/Methanol 40:60	52.32		59	32	27
		Water/Methanol 20:80	42.97		58	33	25
		Methanol	32.63		74	45	29
		Heptane	2.00		82	–	–
		TCE	2.30		158	–	–

(continued on next page)

Download English Version:

<https://daneshyari.com/en/article/5468588>

Download Persian Version:

<https://daneshyari.com/article/5468588>

[Daneshyari.com](https://daneshyari.com)