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Bulletin of the Marine Geology <ejournal.p3gl@gmail.com>
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To: Dian Agus Widiarso <dianagus@lecturer.undip.ac.id>

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Bulletin of the Marine Geology <ejournal.p3gl@gmail.com>
Sat 8/14/2021 9:04 AM
To: Dian Agus Widiarso <dianagus@lecturer.undip.ac.id>
Cc: joni.widodo@esdm.go.id <joni.widodo@esdm.go.id>

1 attachments (46 KB)
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Bulletin of the Marine Geology (BoMG)
Dr. Dian Agus Widiarso:

We have reached a decision regarding your submission to BULLETIN OF THE MARINE GEOLOGY, "THE SEAWATER AND FRESHWATER INFLUENCE ON EXPANSIVITY BEHAVIORS OF CLAY MINERALS".

Our decision is: Revisions Required

Dr. Hananto Kurnio
Marine Geological Institute
hananto.kurnio@esdm.go.id

Reviewer A:

Marine Geological Institute of Indonesia
Jl. Dr. Djunjunan No.236, Bandung, Telp.+62-022-6032020, Fax. +62-022-6017887

THE SEAWATER AND FRESHWATER INFLUENCE ON EXPANSIVITY BEHAVIORS OF CLAY MINERALS

PENGARUH AIRLAUT DAN AIRTAWAR TERHADAP DAYA KEMBANG SUSUT MINERAL LEMPUNG

Dian Agus Widiarso[1], Nurakhmi Qadaryati[1], Wiyatno Haryanto[2]
[1]Department of Geological Engineering, Universitas Diponegoro, Jl. Prof. Soedharto, SH., Tembalang, Semarang, Indonesia
[2]Indonesian Society of Geotechical Engineering, Jakarta, Indonesia

dianagus@lecturer.undip.ac.id, nurakhmi@live.undip.ac.id, wiyatno.haryanto@gmail.com

ABSTRACT

Semarang City is characterized by an intercalating of loam-silt and clayey units. The behavior of the clay materials in terms of its expansivity changes in the volumetric parameter when it contacts the water. Some problems in the presence of tidal flooding appears when the seawater ingress to the shoreland that causes severe damage to infrastructures. This research attempts to reveal the influence of both seawater and freshwater on the expansivity behaviors of the clayey materials based on its mineral composition. Some tests are performed to observe the volumetric changes in the clay samples after being soaked in seawater and freshwater for twenty-four hours. The X-Ray Diffraction (XRD) tests are conducted on some selected samples by using the bulk method to determine the mineral composition of the samples. The ANOVA test is also introduced in the analysis to distinguish whether the certain mineral types and its composition influencing the clay expansivity behaviors at a confidence level of about ninety-five percent and alpha (α) of about five percent. The result of this research has proven that the presence of montmorilonite minerals is the most influencing factor on the clayey expansivity behaviors when immersed in seawater and freshwater than kaolinite and illite minerals.
Keywords: Clay minerals, montmorillonite, expansivity, seawater, freshwater, tidal flooding.

ABSTRAK

Kota Semarang tersusun dari satuan lanau dan lempung.. Mineral lempung memiliki sifat kembang susut dari segi volumenya ketika mengalami kontak dengan air. Peristiwa banjir pasang di perkotaan, menjadi masalah karena air laut menuju ke pantai dan daratan yang dapat merusak infrastruktur. Penelitian ini bertujuan untuk menunjukkan dampak yang ditimbulkan oleh air tawar maupun air laut terhadap kembang susut mineral lempung berdasarkan komposisi mineralnya. Uji perendaman (air tawar dan air laut) diaplikasikan pada sampel lempung di daerah penelitian untuk melihat perubahan volume yang terbentuk setelah perendaman selama dua puluh empat jam. Uji X-Ray Diffraction (XRD) dilakukan pada sampel pilihan untuk mengetahui komposisi mineral sampel tersebut. Uji ANOVA dengan tingkat kepercayaan 95% dan alpha (α) 5% diterapkan untuk mengetahui pengaruh tipe dan komposisi mineral lempung tertentu terhadap kembang susut yang terjadi. Penelitian ini berhasil membuktikan bahwa kehadiran Montmorilonit adalah faktor utama yang paling berkontribusi terhadap sifat kembang susut mineral lempung di daerah penelitian ketika direndam dengan air tawar dan air laut.
Kata Kunci: Mineral lempung, montmorilonit, kembang susut, air laut, air tawar, banjir pasarng

INTRODUCTION

In general, a clayey material is an important part of the soil, which mostly involves chemical weathering of rock-forming minerals and will change in some engineering behaviors when it contacts with seawater (Aksoy et.al, 2008). Some research on mineralogical and geotechnical approaches in coastal areas with a predominance of clay lithology has been performed widely in several countries (Veerasingam et.al, 2014) such as for a construction planning in Lianyungang – a region of China that requires some investigative data regarding the origin of rocks and some geotechnical studies of the clay minerals onsite (Liu et.al, 2011). The same case in the Changi project in Singapore took a place in Quaternary sediment composed of soft marine clay recognized as problematic soil for geotechnical engineering purposes (Bo et.al, 2015). The major decision in construction process involves the selection of suitable site with best soil conditions (Manimaran et.al, 2019).

Based on the geological setting, Semarang City is a part of the Holocene sediment which is composed of a river, flood-plain, swamp, tidal, and coastal deposits (Thanden et.al, 1996), characterized by intercalating of a dominant loam-silt and clay units and constitutes normally consolidated clays with a soft and very soft consistency (Widiarso et.al, 2019).

The city is the capital of Central Java Province, located in a large coastal deposit area with some specific problematics such as a presence of tidal flooding in which the seawater ingresses frequently to the shoreland area in a high tide period (Wahyudi, 2007) that causes some serious damage in infrastructures and residential areas (Marfai and King, 2008; Muslim et.al, 2019). The quality of the circumference decreases due to influenced by the tidal flooding (Sulaksana et.al, 2019). One of the most important goals of disaster management teams is to protect the assets and infrastructures of the community in the event of accidents such as floods (Darani and Bashiri, 2018).

Based on the previous research conducted, it is explained the claystone which has a montmorillonite mineral composition of more than 72% when mixed with seawater may indicate a reduction in the expansivity of the clay material and less expansive when mixed with the freshwater (Elmashad and Ata, 2014). Other studies explained that the clay minerals such as kaolinite, chlorite, and mixing of other clay minerals have a lower reaction (low reactivity) than montmorillonite mineral when mixed with seawater (Aksoy et.al, 2008). Therefore, the authors intend to present the research on the influence of the seawater and freshwater on the expansivity behaviors of the clay materials based on certain minerals composition.

Clay Minerals Overview

Soil is defined as a constituent mineral with or without organic material left over from plants and fauna that are weathered, structured, and textured. It is useful as a construction material in various kinds of civil engineering works, besides that the land also functions as a support for the foundation of a building (Das, 2008). Based on the cohesivity, the soils can be distinguished as cohesive and non-cohesive soils, fine-grained or coarse-grained soils (Bowles, 2015).

The abundance of the clay minerals in the soils varies greatly, influenced by various things, including the type of origin rock, weathering, and the diagenesis process, which causes variations both vertically and laterally. The most influential factors that separate the different soil types are the particle size distribution (Kaream et,al, 2020). The clay materials with the particle size smaller than 0.002-mm can be distinguished into three subgroups of the clay minerals, referred to as kaolinite, illite, and montmorillonite (Dunn et.al, 1980).

Tidal Flood

The tidal flood is a flood that inundating the lowland areas in the coastal, including estuaries and deltas resulting in generating the salty/ brackish groundwater (Marfai, 2004). The underlying problem of tidal flooding affecting the shoreland and coastal area is caused by a lower ground level than the high tide level. Meanwhile, human beings' activities include excessive groundwater abstraction, dredging on the shipping lines, coastal reclamation, and others as some contributing factors of the tidal flooding. (Draw the tidal flood boundary on the location map to increase the sense of the problem-rev)

METHODS (AND MATERIALS)

The research takes a place in Semarang City, especially on the alluvium and flood plains as referring to the Geological Map of Magelang and Semarang, Java (Thanden et al., 1996). The soil mechanics laboratory tests are performed on some selected clay soil samples by soaking the samples in the seawater and freshwater for twenty-four hours while observing the changes in their volumetric parameters.

The X-Ray Diffraction (XRD) tests performed on the same selected samples using the bulk method to determine the minerals present in the sample that resulted in a mineral graph, then, is analyzed using the X-pert Highscore and Siroquant software. The software is used to obtain the quantitative data on the diffraction pattern of a sample; the results of this analysis are the types of minerals contained in the sample. ANOVA is tested for differences in the effect of mineral types and composition on the clay mineral expansivity. It also is used as an analytical tool to exercise the hypotheses by assessing whether any differences among the groups. The hypothesis testing is performed at the ninety-five percent confidence level and alpha (α) five percent.

Commented [F1]: •Provide an explanation of salt concentration in both fresh water and sea water.

RESULTS

Soaking Test

The freshwater and seawater used in the soaking tests have been analyzed in terms of chemical and physical properties in a laboratory prior to the soaking test to conditioning the same treatment on the samples. The soaking is performed on the four samples taken from the geotechnical drilling and undisturbed soil samples in Tambakharjo Semarang with the coordinate positions shown in Table 1.

Commented [F2]: •replace it with the sampling location map.

The drill holes and its undisturbed soil samples in-depth positions are BM01 in 60-meters depth, BM03 in 40-meters depth, BM04 in 30-meters depth, and BM05 in 30-meters depth. The soaking tests on some selected samples are performed for twenty-four hours in which the volumetric changes are recorded. The difference of the lithologic volume is a product of the reduction between a final volume and an initial volume.

Table 1. Coordinate position of the clay samples

No	Point	Drill hole depth (m)	Coordinate position	
			X	Y
1	BM01	60	431913.80	9230354.46
2	BM03	40	431098.58	9230366.47
3	BM04	30	431135.86	9229803.16
4	BM05	30	431200.18	9229890.96

Statistical Test of Soaking

The statistical test of the soaking is shown in Table 2, meanwhile, the result of the XRD (X-ray diffraction) analysis in the clay mineral compositions shown in Table 3.

Table 2. Test parameters of soaking

No	Sample code (depth in m)	% of volume changes after soaking	
		Freshwater	Seawater
1	BM 01-1 (5.5-6)	158.40	0.00

2	BM 01-2 (11.5-12)	124.03	130.93
3	BM 01-3 (15.5-16)	140.83	119.47
4	BM 01-4 (23-24)	105.13	147.66
5	BM 01-5 (25-26)	501.09	563.72
6	BM 01-6 (31-32)	199.53	507.85
7	BM 01-7 (41-42)	112.12	121.28
8	BM 01-8 (51-52)	125.59	128.55
9	BM 01-9 (59-60)	119.64	112.33
10	BM 03-1 (5.5-6)	155.50	182.04
11	BM 03-2 (11.5-12)	167.35	142.22
12	BM 03-3 (15.5-16)	153.29	162.01
13	BM 03-3 (21-22)	129.90	135.31
14	BM 03-4 (25-26)	367.51	134.44
15	BM 03-5 (29-30)	127.05	137.99
16	BM 03-6 (39-40)	125.40	98.95
17	BM 04-1 (5.5-6)	129.10	155.50
18	BM 04-2 (11.5-12)	130.61	156.29
19	BM 04-3 (15.5-16)	122.57	151.52
20	BM 04-4 (21-22)	123.52	97.20
21	BM 04-5 (25-26)	149.31	1217.27
22	BM 04-6 (29-30)	585.28	626.11
23	BM 05-1 (5.5-6)	95.77	293.40
24	BM 05-2 (11.5-12)	-	-
25	BM 05-3 (15.5-16)	143.71	-
26	BM 05-4 (21-22)	393.47	228.15
27	BM 05-5 (25.5-26)	-	-
28	BM 05-6 (25-25.5)	-	-

DISCUSSIONS

Statistical Test on Soaking in Seawater

The independent variable in the statistical test with ANOVA is the mineral content in the sample referred to as kaolinite, montmorillonite, and illite. The value results show that the sample is broken and excluded in the calculation. The value of the significance coefficient (α) is determined at 0.05. The significance or probability column of the ANOVA test results show the level of significance in which the value is used as the cut-off of the model to determine whether the independent variable affects the dependent variable or not.

Commented [F3]: Is there any data of the initial soil moisture content before soaking process? so that the analysis of changes in volume data due to soaking wet is comparable to the initial conditions

Table 3. Percentage of identified mineral

No	Sample Code	Identified minerals (%)			
		(1)	(2)	(3)	(4)
1	BM 01-1	54.97	40.56	4.47	0
2	BM 01-2	57.33	35.09	7.58	0
3	BM 01-3	59.69	39.54	0	0.76
4	BM 01-4	42.35	48.53	9.12	0
5	BM 01-5	29.48	43.98	0	26.54
6	BM 01-6	28.47	40.95	0	30.58
7	BM 01-7	35.71	0	63.77	0.52
8	BM 01-8	40.48	13.42	33.55	12.54
9	BM 01-9	28.54	44.23	0	27.23
10	BM 03-1	47.26	20.15	31.70	0.89
11	BM 03-2	48.36	17.41	33.18	1.04
12	BM 03-3	47.98	22.34	28.34	1.35
13	BM 03-4	43.62	33.87	0	22.51
14	BM 03-5	27.03	0	60.36	12.61
15	BM 03-6	23.82	47.83	0	28.35
16	BM 03-7	28.06	44.60	0	27.34
17	BM 04-1	72.61	0	26.11	1.27
18	BM 04-2	64.78	28.85	0	6.37
19	BM 04-3	45.72	29.01	22.06	3.21
20	BM 04-4	50.19	49.05	0	0.76
21	BM 04-5	33.84	0	59.44	6.72
22	BM 04-6	28.04	38.10	0	33.86
23	BM 05-1	60.04	34.40	0	5.56
24	BM 05-2	48.12	25.29	24.71	1.88
25	BM 05-3	94.37	0	0	5.63
26	BM 05-4	59.62	0	0	40.38
27	BM 05-5	12.80	0	87.20	0
28	BM 05-6	63.55	35.81	0	0.65
Note :					
Quartz (1)			Illite (3)		
Kaolinite (2)			Montmorillonite (4)		

Based on Table 4, it shows that the sig value 0.024 is smaller than 0.05 (α), so the model passed and can be used to obtain the influence of the sample's mineral contents on the changes of the sample volume after soaked in seawater. The probability value (significance) is below 0.05 which means all independent variables influence the dependent variable and vice versa.

Tabel 4. ANOVA test result on soaking in seawater

Model	d_f	Mean square	F	Sig.
Regression	3	48961.1	3.897	0.024[b]
Residual	20	12563.6		
Total	23			

a. Dependent variable: after soaked in seawater
b. Predictors: (constant), montmorillonite, kaolinite, and illite.

After that, the value of F-count and F-table parameter is compared. The F-count is the F value resulted in the ANOVA table of about 3.897. The F-table is calculated by calculating the number of df (degree of freedom). The df of the multiple regression consists of the df1 and df2 with the following formula:

df1 = k – 1
df2 = n – k

under the following condition:
n = number of samples
k = number of independent variables
The soaking test in seawater has a value of k = 3 and a value of n = 25 so that the values of df1 = 2 and df2 = 22 are obtained. Based on the F distribution table at the 0.05 sig level, the F-table value is 3.4434 and smaller than the F-count 3.897, it can be concluded that all independent variables have an influence on the dependent variable. The test results of the coefficient value on the soaking in seawater is shown in Table 5. Column t in Table 5 shows the value of t per independent variable in which the value of t is the benchmark to see the influence of variable (partial) by comparing it with the t-table value. When the value of t-count is greater than the value of t-table then the variable has an influence. By calculating the number of df (degree of freedom), t-table is obtained with the following formula:

df = n – (k – 1)

under the following condition:
n = number of samples
k = number of independent variables

The calculation of df (degree of freedom) is = 25 – (3–1) = 23. Based on the t-table value for multiple regression df 23 at sig 0.05 is 1.71387. The t-count value of the montmorillonite mineral shows a value of 3.303 which is greater than the -ttable value, so the montmorillonite mineral has the most influence on the changes in sample volumetric when it soaked in seawater compared to kaolinite and illite minerals.
The sig column in Table 5 shows the significance level of each independent variable to determine whether the variables influence the dependent variable or not. The basis for the decision making is if the significance value is smaller than 0.05 (α) then the conclusion has an influence, if it is greater than 0.05 (α) then the conclusion has no influence at all. Based on the table, it is known that the sig value of the montmorillonite mineral shows a value of 0.005 (smaller than 0.05), so the montmorillonite mineral is the most influential in the changes of the volume sample compared to kaolinite and illite minerals when soaked in seawater.

Tabel 5. Coefficient test result of soaked in seawater

Model	**t**	**Sig.**
(Constant)	1.503	0.148
Kaolinite	-0.375	0.712
Illite	0.568	0.576
Montmorillonite	3.303	0.004

Statistical Test on Soaking in Freshwater
The data is processed using multiple regression analysis methods with the dependent variable as the percentage of difference in the final volume of the sample after soaked in freshwater for twenty-four hours minus the initial volume of the sample. The ANOVA test resulted in the soaking in freshwater shown in Table 6 with the sig value of about 0.249.

Tabel 6. ANOVA test result on soaked in freshwater

Model	**d_f**	**Mean square**	**F**	**Sig.**

Regression	3	93014.1	1.484	0.249[b]
Residual	20	62688.1		
Total	23			

Dependent variable: after soaked in freshwater
Predictors: (Constant), montmorillonite, kaolinite, and illite

The value is greater than 0.05 (α), so the model does not pass and cannot be used to determine the influence of the sample's mineral content in the changes of the sample volume after being soaked in freshwater. The probability value (significance) is above 0.05 also means that not all independent variables have influence on the dependent variable and vice versa.

The soaking test in freshwater has a value of $k = 3$ and a value of $n = 24$, so that the values of $df1 = 2$ and $df2 = 21$ are obtained. Based on the F distribution table at the 0.05 sig level, the F-table value is 3.4468 and is greater than the F-count amounting to 1.484. It can be concluded that not all independent variables have an influence on the dependent variable.

Table 7 shows that no mineral element has a t value greater than 2.086, so there is no mineral element that has the most influence in the changes of sample volume when soaked in freshwater. In the sig column, there are no minerals that have a value of less than 0.05 (α), so there are no minerals that have the most influence in the changes in sample volume when soaked in freshwater.

The df value for the soaking test in freshwater is = 24–(3–1) = 20. Based on the t-table value for the multiple regression df 20 at sig 0.05 is 1.7247. The t-count value of the montmorillonite mineral shows a value of 1.837, so the montmorillonite mineral has the most influence in the changes of sample volume compared to the kaolinite and illite minerals when soaked in freshwater.

Based on a comparison of the ANOVA difference test for soaking of the clay minerals in seawater and freshwater, it is obtained that the F value is 3.897 with a sig of 0.024, while the results of soaking in freshwater, the F value is 1.464 with a sig 0.24. Hence, it suggested that seawater has a more significant influence on the expansion process of the clay minerals compared to freshwater.

Commented [F4]: •Add the discussion of why the volume change of monmorillonite is bigger in the sea water than in the fresh water

Table 7. Coefficient test result of soaked in freshwater

Model	t	Sig.
(Constant)	-0.012	0.990
Kaolinite	0.364	0.719
Illite	1.304	0.207
Montmorillonite	1.837	0.081

CONCLUSSIONS

The evidentiary results of this study indicate that the montmorillonite mineral element is the most influential in changing the volumetric expansivity of the sample when soaked in seawater and freshwater compared to kaolinite and illite minerals. The montmorillonite minerals give more influence in volumetric changes when the clay minerals are soaked in seawater than by soaking in freshwater. It provides a comparison of the previous research in which Elmashad and Ata (2014) explained that the results of laboratory experiments on the clay rocks that have a montmorillonite mineral composition of more than 72% when mixed with seawater indicate a reduction in the expansivity of the material and lower expansivity when mixed with freshwater. This study provides an understanding that it is also necessary to have good knowledge regarding the composition of clay minerals in the planning, especially when seated on the dominated by clay and affected by tidal flooding. Engineering geological planning not only looks at the physical properties of lithology but also needs to know the chemical properties of lithology.

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THE SEAWATER AND FRESHWATER INFLUENCE ON EXPANSIVITY BEHAVIORS OF CLAY MINERALS

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To: Mr. Joni Widodo <joni.widodo@esdm.go.id>

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Dear BOMG Editor's
I would like to confirm that I have submitted my revised paper with titled
The Seawater And Freshwater Influence On Expansivity Behaviors Of Clay Minerals
Thank you for kind attention and support
Best Regards,

Dian Agus Widiarso
Marine Geological Institute of Indonesia
Jl. Dr. Djunjunan No.236, Bandung, Telp.+62-022-6032020, Fax. +62-022-6017887

Response by Authors to Reviewer's Remarks/Comments

Title of paper : The Seawater And Freshwater Influence On Expansivity Behaviors Of Clay Minerals
Author's Dian Agus Widiarso , Nurakhmi Qadaryati, and Wiyatno Haryanto

Reviewer_A's Comments	**Authors Response**
Provide an explanation of salt concentration in both fresh water and sea water.	The results of the chemical analysis of water samples have been shown in this paper
Replace it with the sampling location map.	The coordinate positions are replaced with the sampling location map
Is there any data of the initial soil moisture content before soaking process? so that the analysis of changes in volume data due to soaking wet is comparable to the initial conditions	The authors appreciate the comments from the reviewer A. Statistical tests were carried out by looking at changes in the sample volume before and after soaking without taking into account the soil water content
Add the discussion of why the volume change of monmorillonite is bigger in the sea water than in the fresh water	An explanation why the volume change of montmorillonite is greater in seawater than in fresh water has been added to the discussion

The authors appreciate the valuable comments from the Reviewers.

THE SEAWATER AND FRESHWATER INFLUENCE ON EXPANSIVITY BEHAVIORS OF CLAY MINERALS

PENGARUH AIRLAUT DAN AIRTAWAR TERHADAP DAYA KEMBANG SUSUT MINERAL LEMPUNG

Dian Agus Widiarso[1], Nurakhmi Qadaryati[1], Wiyatno Haryanto[2]

[1]Department of Geological Engineering, Universitas Diponegoro, Jl. Prof. Soedharto, SH., Tembalang, Semarang, Indonesia

[2]Indonesian Society of Geotechical Engineering, Jakarta, Indonesia

dianagus@lecturer.undip.ac.id, nurakhmi@live.undip.ac.id, wiyatno.haryanto@gmail.com

ABSTRACT

Semarang City is characterized by an intercalating of loam-silt and clayey units. The behavior of the clay materials in terms of its expansivity changes in the volumetric parameter when it contacts the water. Some problems in the presence of tidal flooding appears when the seawater ingress to the shoreland that causes severe damage to infrastructures. This research attempts to reveal the influence of both seawater and freshwater on the expansivity behaviors of the clayey materials based on its mineral composition. Some tests are performed to observe the volumetric changes in the clay samples after being soaked in seawater and freshwater for twenty-four hours. The X-Ray Diffraction (XRD) tests are conducted on some selected samples by using the bulk method to determine the mineral composition of the samples. The ANOVA test is also introduced in the analysis to distinguish whether the certain mineral types and its composition influencing the clay expansivity behaviors at a confidence level of about ninety-five percent and alpha (α) of about five percent. The result of this research has proven that the presence of montmorilonite minerals is the most influencing factor on the clayey expansivity behaviors when immersed in seawater and freshwater than kaolinite and illite minerals.

Keywords: Clay minerals, montmorillonite, expansivity, seawater, freshwater, tidal flooding.

ABSTRAK

Kota Semarang tersusun dari satuan lanau dan lempung.. Mineral lempung memiliki sifat kembang susut dari segi volumenya ketika mengalami kontak dengan air. Peristiwa banjir pasang di perkotaan, menjadi masalah karena air laut menuju ke pantai dan daratan yang dapat merusak infrastruktur. Penelitian ini bertujuan untuk menunjukkan dampak yang ditimbulkan oleh air tawar maupun air laut terhadap kembang susut mineral lempung berdasarkan komposisi mineralnya. Uji perendaman (air tawar dan air laut) diaplikasikan pada sampel lempung di daerah penelitian untuk melihat perubahan volume yang terbentuk setelah perendaman selama dua puluh empat jam. Uji X-Ray Diffraction (XRD) dilakukan pada sampel pilihan untuk mengetahui komposisi mineral sampel tersebut. Uji ANOVA dengan tingkat kepercayaan 95% dan alpha (α) 5% diterapkan untuk mengetahui pengaruh tipe dan komposisi mineral lempung tertentu terhadap kembang susut yang terjadi. Penelitian ini berhasil membuktikan bahwa kehadiran Montmorilonit adalah faktor utama yang paling berkontribusi terhadap sifat kembang susut mineral lempung di daerah penelitian ketika direndam dengan air tawar dan air laut.

Kata Kunci: Mineral lempung, montmorilonit, kembang susut, air laut, air tawar, banjir pasang

INTRODUCTION

In general, a clayey material is an important part of the soil, which mostly involves chemical weathering of rock-forming minerals and will change in some engineering behaviors when it contacts with seawater (Aksoy et.al, 2008). Some research on mineralogical and geotechnical approaches in coastal areas with a predominance of clay lithology has been performed widely in several countries (Veerasingam et.al, 2014) such as for a construction planning in Lianyungang – a region of China that requires some investigative data regarding the origin of rocks and some geotechnical studies of the clay minerals onsite (Liu et.al, 2011). The same case in the Changi project in Singapore took a place in Quaternary sediment composed of soft marine clay recognized as problematic soil for geotechnical engineering purposes (Bo et.al, 2015). The major decision in construction process involves the selection of suitable site with best soil conditions (Manimaran et.al, 2019).

Based on the geological setting, Semarang City is a part of the Holocene sediment which is composed of a river, flood-plain, swamp, tidal, and coastal deposits (Thanden et.al, 1996), characterized by intercalating of a dominant loam-silt and clay units and constitutes normally consolidated clays with a soft and very soft consistency (Widiarso et.al, 2019).

The city is the capital of Central Java Province, located in a large coastal deposit area with some specific problematics such as a presence of tidal flooding in which the seawater ingresses frequently to the shoreland area in a high tide period (Wahyudi, 2007) that causes some serious damage in infrastructures and residential areas (Marfai and King, 2008; Muslim et.al, 2019). The quality of the circumference decreases due to influenced by the tidal flooding (Sulaksana et.al, 2019). One of the most important goals of disaster management teams is to protect the assets and infrastructures of the community in the event of accidents such as floods (Darani and Bashiri, 2018).

Based on the previous research conducted, it is explained the claystone which has a montmorillonite mineral composition of more than 72% when mixed with seawater may indicate a reduction in the expansivity of the clay material and less expansive when mixed with the freshwater (Elmashad and Ata, 2014). Other studies explained that the clay minerals such as kaolinite, chlorite, and mixing of other clay minerals have a lower reaction (low reactivity) than montmorillonite mineral when mixed with seawater (Aksoy et.al, 2008). Therefore, the authors intend to present the research on the influence of the seawater and freshwater on the expansivity behaviors of the clay materials based on certain minerals composition.

Clay Minerals Overview

Soil is defined as a constituent mineral with or without organic material left over from plants and fauna that are weathered, structured, and textured. It is useful as a construction material in various kinds of civil engineering works, besides that the land also functions as a support for the foundation of a building (Das, 2008). Based on the cohesivity, the soils can be distinguished as cohesive and non-cohesive soils, fine-grained or coarse-grained soils (Bowles, 2015).

The abundance of the clay minerals in the soils varies greatly, influenced by various things, including the type of origin rock, weathering, and the diagenesis process, which causes variations both vertically and laterally. The most influential factors that separate the different soil types are the particle size distribution (Kaream et,al, 2020). The clay materials with the particle size smaller than 0.002-mm can be distinguished into three subgroups of the clay minerals, referred to as kaolinite, illite, and montmorillonite (Dunn et.al, 1980).

Tidal Flood

The tidal flood is a flood that inundating the lowland areas in the coastal, including estuaries and deltas resulting in generating the salty/ brackish groundwater (Marfai, 2004). The underlying problem of tidal flooding affecting the shoreland and coastal area is caused by a lower ground level than the high tide level. Meanwhile, human beings' activities include excessive groundwater abstraction, dredging on the shipping lines, coastal reclamation, and others as some contributing factors of the tidal flooding.

METHODS (AND MATERIALS)

The research takes a place in Semarang City, especially on the alluvium and flood plains as referring to the Geological Map of Magelang and Semarang, Java (Thanden et al., 1996). The soil mechanics laboratory tests are performed on some selected clay soil samples by soaking the samples in the seawater and freshwater for twenty-four hours while observing the changes in their volumetric parameters. The results of chemical analysis of water sample shown in Table 1

Table 1. The results of chemical analysis of water sample

Type of Water	Indicators (mg/L)					
	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	SO_4^{2-}
Seawater	315	749,5	248,5	7293,5	13393,9	246,5
Freshwater	25,4	6,4	6	19,1	14,4	1

The X-Ray Diffraction (XRD) tests performed on the same selected samples using the bulk method to determine the minerals present in the sample that resulted in a mineral graph, then, is analyzed using the X-pert Highscore and Siroquant software. The software is used to obtain the quantitative data on the diffraction pattern of a sample; the results of this analysis are the types of minerals contained in the sample. ANOVA is tested for differences in the effect of mineral types and composition on the clay mineral expansivity. It also is used as an analytical tool to exercise the hypotheses by assessing whether any differences among the groups. The hypothesis testing is performed at the ninety-five percent confidence level and alpha (α) five percent.

RESULTS

Soaking Test

The freshwater and seawater used in the soaking tests have been analyzed in terms of chemical and physical properties in a laboratory prior to the soaking test to conditioning the same treatment on the samples.

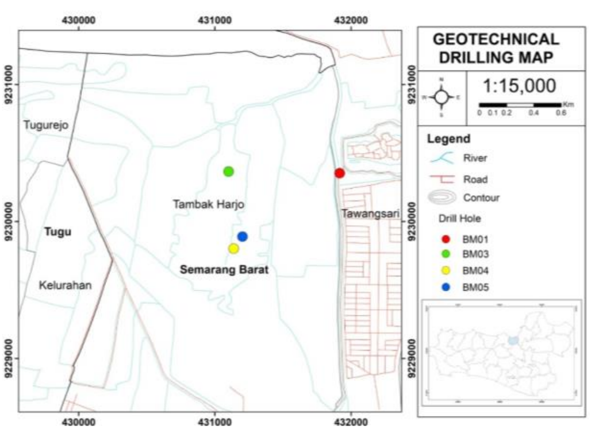

Figure 1. Geotechnical Drilling Map

The soaking is performed on the four samples taken from the geotechnical drilling and undisturbed soil samples in Tambakharjo Semarang with the geotechnical drilling locations shown in Figure 1.

The drill holes and its undisturbed soil samples in-depth positions are BM01 in 60-meters depth, BM03 in 40-meters depth, BM04 in 30-meters depth, and BM05 in 30-meters depth. The soaking tests on some selected samples are performed for twenty-four hours in which the volumetric changes are recorded. The difference of the lithologic volume is a product of the reduction between a final volume and an initial volume.

Statistical Test of Soaking

The statistical test of the soaking is shown in Table 2, meanwhile, the result of the XRD (X-ray diffraction) analysis in the clay mineral compositions shown in Table 3.

Table 2. Test parameters of soaking

No	Sample code (depth in m)	% of volume changesafter soaking	
		Freshwater	Seawater
1	BM 01-1 (5.5-6)	158.40	0.00
2	BM 01-2 (11.5-12)	124.03	130.93
3	BM 01-3 (15.5-16)	140.83	119.47
4	BM 01-4 (23-24)	105.13	147.66
5	BM 01-5 (25-26)	501.09	563.72
6	BM 01-6 (31-32)	199.53	507.85
7	BM 01-7 (41-42)	112.12	121.28
8	BM 01-8 (51-52)	125.59	128.55
9	BM 01-9 (59-60)	119.64	112.33
10	BM 03-1 (5.5-6)	155.50	182.04
11	BM 03-2 (11.5-12)	167.35	142.22
12	BM 03-3 (15.5-16)	153.29	162.01
13	BM 03-3 (21-22)	129.90	135.31
14	BM 03-4 (25-26)	367.51	134.44
15	BM 03-5 (29-30)	127.05	137.99
16	BM 03-6 (39-40)	125.40	98.95
17	BM 04-1 (5.5-6)	129.10	155.50
18	BM 04-2 (11.5-12)	130.61	156.29
19	BM 04-3 (15.5-16)	122.57	151.52
20	BM 04-4 (21-22)	123.52	97.20
21	BM 04-5 (25-26)	149.31	1217.27
22	BM 04-6 (29-30)	585.28	626.11
23	BM 05-1 (5.5-6)	95.77	293.40
25	BM 05-3 (15.5-16)	143.71	-
26	BM 05-4 (21-22)	393.47	228.15

DISCUSSIONS

Statistical Test on Soaking in Seawater

The independent variables in the statistical test with ANOVA were the mineral content in the sample, which was referred to as kaolinite, montmorillonite, and illite. Statistical tests were carried out by looking at changes in the sample volume before and after soaking without taking into account the soil water content. The value of the coefficient of significance (α) is determined at 0.05. The significance or probability column of the ANOVA test results shows the level of significance where the value is used as a cut-off model to determine whether the independent variable affects the dependent variable or not.

Table 3. Percentage of identified mineral

No	Sample Code	Identified minerals (%)			
		(1)	(2)	(3)	(4)
1	BM 01-1	54.97	40.56	4.47	0
2	BM 01-2	57.33	35.09	7.58	0
3	BM 01-3	59.69	39.54	0	0.76
4	BM 01-4	42.35	48.53	9.12	0
5	BM 01-5	29.48	43.98	0	26.54
6	BM 01-6	28.47	40.95	0	30.58
7	BM 01-7	35.71	0	63.77	0.52
8	BM 01-8	40.48	13.42	33.55	12.54
9	BM 01-9	28.54	44.23	0	27.23
10	BM 03-1	47.26	20.15	31.70	0.89
11	BM 03-2	48.36	17.41	33.18	1.04
12	BM 03-3	47.98	22.34	28.34	1.35
13	BM 03-4	43.62	33.87	0	22.51
14	BM 03-5	27.03	0	60.36	12.61
15	BM 03-6	23.82	47.83	0	28.35
16	BM 03-7	28.06	44.60	0	27.34
17	BM 04-1	72.61	0	26.11	1.27
18	BM 04-2	64.78	28.85	0	6.37
19	BM 04-3	45.72	29.01	22.06	3.21
20	BM 04-4	50.19	49.05	0	0.76
21	BM 04-5	33.84	0	59.44	6.72
22	BM 04-6	28.04	38.10	0	33.86
23	BM 05-1	60.04	34.40	0	5.56
24	BM 05-2	48.12	25.29	24.71	1.88
25	BM 05-3	94.37	0	0	5.63
26	BM 05-4	59.62	0	0	40.38
27	BM 05-5	12.80	0	87.20	0
28	BM 05-6	63.55	35.81	0	0.65
Quartz (1)			Illite (3)		
Kaolinite (2)			Montmorillonite (4)		

Based on Table 4, it shows that the sig value 0.024 is smaller than 0.05 (α), so the model passed and can be used to obtain the influence of the sample's mineral contents on the changes of the sample volume after soaked in seawater. The probability value (significance) is below 0.05 which means all independent variables influence the dependent variable and vice versa.

Tabel 4. ANOVA test result on soaking in seawater

Model	df	Mean square	F	Sig.
Regression	3	48961.1	3.897	0.024[b]
Residual	20	12563.6		
Total	23			

a. Dependent variable: after soaked in seawater
b. Predictors: (constant), montmorillonite, kaolinite, and illite.

After that, the value of F-count and F-table parameter is compared. The F-count is the F value resulted in the ANOVA table of about 3.897. The F-table is calculated by calculating the number of df (degree of freedom). The df of the multiple regression consists of the df1 and df2 with the following formula:

$df1 = k – 1$
$df2 = n – k$

under the following condition:
n = number of samples
k = number of independent variables
The soaking test in seawater has a value of k = 3 and a value of n = 25 so that the values of df1 = 2 and df2 = 22 are obtained. Based on the F distribution table at the 0.05 sig level, the F-table value is 3.4434 and smaller than the F-count 3.897, it can be concluded that all independent variables have an influence on the dependent variable. The test results of the coefficient value on the soaking in seawater is shown in Table 5. Column t in Table 5 shows the value of t per independent variable in which the value of t is the benchmark to see the influence of variable (partial) by comparing it with the t-table value. When the value of t-count is greater than the value of t-table then the variable has an influence. By calculating the number of df (degree of freedom), t-table is obtained with the following formula:

$df = n – (k – 1)$

under the following condition:
n = number of samples
k = number of independent variables

The calculation of df (degree of freedom) is = 25 – (3–1) = 23. Based on the t-table value for multiple regression df 23 at sig 0.05 is 1.71387. The t-count value of the montmorillonite mineral shows a value of 3.303 which is greater than the -ttable value, so the montmorillonite mineral has the most influence on the changes in sample volumetric when it soaked in seawater compared to kaolinite and illite minerals.
The sig column in Table 5 shows the significance level of each independent variable to determine whether the variables influence the dependent variable or not. The basis for the decision making is if the significance value is smaller than 0.05 (α) then the conclusion has an influence, if it is greater than 0.05 (α) then the conclusion has no influence at all. Based on the table, it is known that the sig value of the montmorillonite mineral shows a value of 0.005 (smaller than 0.05), so the montmorillonite mineral is the most influential in the changes of the volume sample compared to kaolinite and illite minerals when soaked in seawater.

Tabel 5. Coefficient test result of soaked in seawater

Model	**t**	**Sig.**
(Constant)	1.503	0.148
Kaolinite	-0.375	0.712
Illite	0.568	0.576
Montmorillonite	3.303	0.004

Statistical Test on Soaking in Freshwater
The data is processed using multiple regression analysis methods with the dependent variable as the percentage of difference in the final volume of the sample after soaked in freshwater for twenty-four hours minus the initial volume of the sample. The ANOVA test resulted in the soaking in freshwater shown in Table 6 with the sig value of about 0.249.

Tabel 6. ANOVA test result on soaked in freshwater

Model	**df**	**Mean square**	**F**	**Sig.**

Regression	3	93014.1	1.484	0.249b
Residual	20	62688.1		
Total	23			

Dependent variable: after soaked in freshwater
Predictors: (Constant), montmorillonite, kaolinite, and illite

The value is greater than 0.05 (α), so the model does not pass and cannot be used to determine the influence of the sample's mineral content in the changes of the sample volume after being soaked in freshwater. The probability value (significance) is above 0.05 also means that not all independent variables have influence on the dependent variable and vice versa.
The soaking test in freshwater has a value of k = 3 and a value of n = 24, so that the values of df1 = 2 and df2 = 21 are obtained. Based on the F distribution table at the 0.05 sig level, the F-table value is 3.4468 and is greater than the F-count amounting to 1.484. It can be concluded that not all independent variables have an influence on the dependent variable.
Table 7 shows that no mineral element has a t value greater than 2.086, so there is no mineral element that has the most influence in the changes of sample volume when soaked in freshwater. In the sig column, there are no minerals that have a value of less than 0.05 (α), so there are no minerals that have the most influence in the changes in sample volume when soaked in freshwater.

Table 7. Coefficient test result of soaked in freshwater

Model	t	Sig.
(Constant)	-0.012	0.990
Kaolinite	0.364	0.719
Illite	1.304	0.207
Montmorillonite	1.837	0.081

The df value for the soaking test in freshwater is = 24–(3–1) = 20. Based on the t-table value for the multiple regression df 20 at sig 0.05 is 1.7247. The t-count value of the montmorillonite mineral shows a value of 1.837, so the montmorillonite mineral has the most influence in the changes of sample volume compared to the kaolinite and illite minerals when soaked in freshwater.
Based on a comparison of the ANOVA difference test for soaking of the clay minerals in seawater and freshwater, it is obtained that the F value is 3.897 with a sig of 0.024, while the results of soaking in freshwater, the F value is 1.464 with a sig 0.24. Hence, it suggested that seawater has a more significant influence on the expansion process of the clay minerals compared to freshwater.
Montmorillonite is a mineral formed by two sheets of silica and one sheet of aluminium. The octahedral sheet is located between two silica sheets with the ends of the tetrahedra mixed with the hydroxyl of the octahedral sheet to form a single layer of aluminum by magnesium. Due to the weak Van der Waals bonding forces (bonds due to changes in the number of electrons at any time in one part of the atomic nucleus) between the ends of the silica sheet and there is a lack of negative charge in the octahedral sheet, water (H_2O) and moving ions can enter and separate the layers. This causes high swelling properties. The higher ionic content in seawater compared to ion levels in fresh water causes the swelling properties of montmorillonite minerals to develop higher when exposed to seawater than when exposed to fresh water.

CONCLUSSIONS

The evidentiary results of this study indicate that the montmorillonite mineral element is the most influential in changing the volumetric expansivity of the sample when soaked in seawater and freshwater compared to kaolinite and illite minerals. The montmorillonite minerals give more influence in volumetric changes when the clay minerals are soaked in seawater than by soaking in freshwater. It provides a comparison of the previous research in which Elmashad and Ata (2014) explained that the results of laboratory experiments on the clay rocks that have a montmorillonite mineral composition of more than 72% when mixed with seawater indicate a reduction in the expansivity of the material and lower expansivity when mixed with freshwater. This study provides an understanding that it is also necessary to have good knowledge regarding the composition of clay minerals in the planning, especially when seated on the dominated by clay and affected by tidal flooding. Engineering geological planning not only looks at the physical properties of lithology but also needs to know the chemical properties of lithology.

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Authors

Name	Dian Agus Widiarso
Affiliation	Departemen Teknik Geologi, Fakultas Teknik, Universitas Diponegoro
Country	Indonesia
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Title and Abstract

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Abstract	Semarang City is characterized by an intercalating of loam-silt and clayey units. The behavior of the clay materials in terms of its expansivity changes in the volumetric parameter when it contacts the water. Some problems in the presence of tidal flooding appears when the seawater ingress to the shoreland that causes severe damage to infrastructures. This research attempts to reveal the influence of both seawater and freshwater on the expansivity behaviors of the clayey materials based on its mineral composition. Some tests are performed to observe the volumetric changes in the clay samples after being soaked in seawater and freshwater for twenty-four hours. The X-Ray Diffraction (XRD) tests are conducted on some selected samples by using the bulk method to determine the mineral composition of the samples. The ANOVA test is also introduced in the analysis to distinguish whether the certain mineral types and its composition influencing the clay expansivity behaviors at a confidence level of about ninety-five percent and alpha (α) of about five percent. The result of this research has proven that the presence of montmorilonite minerals is the most influencing factor on the clayey expansivity behaviors when immersed in seawater and freshwater than kaolinite and illite minerals.

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#713 Review

SUMMARY **REVIEW** EDITING

Submission

Authors	Dian Agus Widiarso
Title	THE SEAWATER AND FRESHWATER INFLUENCE ON EXPANSIVITY BEHAVIORS OF CLAY MINERALS
Section	Articles
Editor	Joni Widodo

Peer Review

Round 1

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