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The Preliminary Study on The Effect of Coarse Particles Content on OMC and Maximum Dry Unit Weight: A Case of Aceh's Fill Materials

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Abstract - Empirical evidence suggests that the percentage of coarse fraction content on soil has an influence on the soil optimum moisture content (OMC) and soil maximum dry density (MDD). This phenomenon is used as a basis to examine the characteristics of Aceh's fill materials. The major objective of the present study is to determine the relationship between coarse-grained content and OMC and MDD of the Aceh's fill materials. This relationship is important in the justification of soil suitability as materials for engineering construction. Thirty (30) soil samples from various locations in the Province of Aceh have been collected and tested. The tests carried out include soil physical properties tests and standard compaction test. In the case of a relationship between soil coarse fraction content and soil OMC or MDD, two general findings have been deduced. The first finding of the present study shows that the soil OMC decreases when the content of coarse-grained particles in the soil increases. The later finding shows a positive correlation between coarse particles content and the soil MDD which the increase of the content of coarse-grained particles in the soil will increase the value of the soil's MDD. In conclusion, the coarse particles content affects the OMC and MDD of Aceh's fill materials.

Keywords: OMC; Maximum dry density; Compaction

Introduction

Das (1985; 2002) demonstrated that the optimum moisture content (OMC) of silty SAND (SM) is lower than the OMC of SILT (ML). Furthermore, the OMC of ML is less than the OMC of Silty CLAY (CL). In contrast, the maximum dry density (MDD) of SM is higher than the ML and the MDD of ML is higher than CL. Detailed of this phenomenon is illustrated in Figure 1. In other words, this illustration demonstrated that the lower OMC of soil results in higher their MDD (Ng *et al.*, 2015). The illustration, in Figure 1, also indicated that the soils with higher coarse particles content will have lower OMC and higher MDD than soils with low levels of coarse particles (Bowles, 1996; Craig, 1997; Holtz and Kovacs, 1981; Lambe and Whitman, 1979; Sowers, 1979; Whitlow, 1990; McCarthy, 2007).

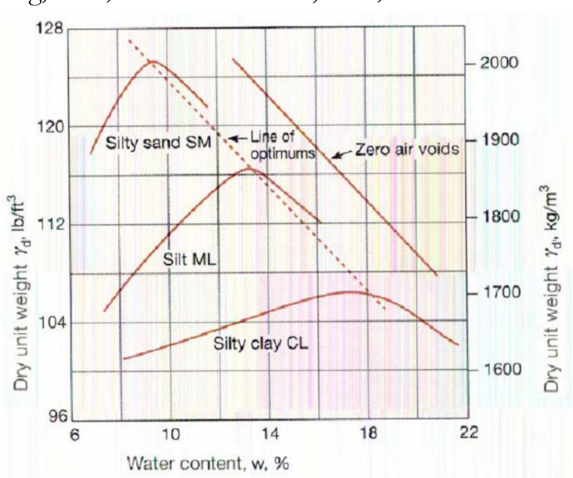

Figure 1. Relationship between OMC and MDD for three different soil types (Das, 1985; 2002)

Recently, the relationship between coarse particles content in soils and their OMC or MDD was investigated for different purposes by several researcher for example Bhat *et al.* (2015); Shirur and Hiremath (2014) and Alavi *et al.* (2009). Bhat *et al.* (2015) studied the relationship for investigating various compaction characteristics on granular soils. Shirur and Hiremath (2014) was indicating the relationship for suggesting a novel relationship to estimate soil California bearing ratio (CBR) from the physical proportion of soil. Alavi *et al.* (2009) was using the relationship for validating a new method using radial basis function (RBF) neutral networks to predict OMC and MDD of soils.

The characteristics as described above has attracted the author to study more in depth in the context of Aceh's fill material. The major aim of the present study

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is to determine the effect of coarse particles content on the Aceh's fill materials. The understanding of the influence of the existence of coarse particles in the OMC and MDD values in Aceh's fill material will be useful for various construction activities in Aceh Province.

In the present study soil physical properties and standard proctor tests were carried out on 30 soil samples taken from various locations in Aceh Province. The results of the tests are tabulated, compiled and analysed to obtain the relationship between the of coarse soil fraction content with their OMC and MDD. Effect of levels of the coarse fraction on the OMC and MDD of Aceh's fill material is presented in the present paper.

Materials and Methods

Time and location

The collection and testing of the samples were carried out on four different occasions. Initially, from April to December 2005 several samples were collected and tested. Between February and March 2006, most of the samples were gained and tested, while in October 2009 only one sample was acquired. Finally, in early (March-April) 2012 the rest of the samples were obtained and examined.

The soil samples were taken from various locations in Aceh Province. The distribution of the samples is as follow: a sample from Simeulue District, 6 samples from Aceh Barat (West Aceh) District, 4 samples from Aceh Jaya District, 5 samples from Aceh Besar District, a sample from Banda Aceh District, 2 samples from Biruen District, 4 samples from Aceh Utara (North Aceh) District, a sample from Lhokseumawe District, 2 samples from Aceh Tenggara (Southeast Aceh) District, a sample from Subulussalam District and 3 samples from Aceh Selatan (South Aceh) District. These locations are indicated in red circle as shown in Figure 2.

Soil compaction

Soil compaction is a testing by compacting soil sample in several different moisture content from which the optimum moisture content and maximum dry unit weight of sample are deduced (Das, 1985; Bowles, 1996; Craig, 1997; Holtz and Kovacs, 1981; Lambe and Whitman, 1979; Sowers, 1979; Whitlow, 1990; STM D1557, 2009). The moisture content, where the maximum of dry unit weight soil conditions occurs, is called the optimum moisture content (OMC). The plotted compaction test into a graph that shows the relationship between soil dry unit weight and its moisture content is shown in Figure 3a. In the compaction process the volume of air in the void between the soil particles is reduced (Figure 3b). The decreasing of air volume in the soil will cause the increasing of soil modulus elasticity and soil strength. This compaction effort also results in the reduction of the changing of soil volume. Therefore, a compaction is crucial to prevent ground settlement.

In theory, Proctor (1933) in Bowles (1996), Craig (1997) and Das (1985) stated that the density of soil depends on soil type, the energy of compaction and moisture content. A certain type of soil will produce a specific compaction curve, therefore the compaction curve is different from one to another soil type as shown in Figure 1 above. Furthermore, compaction effort is also important in the compaction process (Jesmani *et al.*, 2008). The influence the compaction energy, which is represented as the number of blows on each layer, on the value of OMC and MDD of soil is illustrated in Figure 4. The figure shows that higher compaction energy applied to the sample results in the lower OMC and higher MDD.

Moisture content plays an important role during soil compaction (Das, 1985; Craig, 1994; Jesmani *et al.*, 2008; Ng *et al.*, 2015). Optimum moisture content (OMC) is required to obtain maximum soil density. Low moisture content causes the difficulty of compressing the soil particles as soil particles tend to separate themselves from one to another in this state. Excessive moisture content causes minimum interlocking or less contact between soil particles, therefore the particles will split up again after the confined compaction energy is released. This high moisture content also results in incompressibility of the soil layer. This description as aforementioned shows the importance of controlling the moisture content while compaction process is being carried out (Blotez *et al.*, 1998).

Procedure

The procedure includes soil sampling, testing of physical soil properties and soil compaction test. Descriptions of each stage are outlined below.

Soil sampling

The used soil samples in the present study were taken from various locations in the Province of Aceh. The samples were collected using a hoe. The disturbed soil sample was put into sacks and transported to the Soil Mechanics Laboratory, Faculty of Engineering, Syiah Kuala University (Unsyiah). Soil samples that have been transported to the laboratory were spread on trays and allowed to dry at room temperature for at least 24 hours. The air-dry soil was, then, crushed with a rubber mallet to break the clumps of soil into soil particles for sieving.

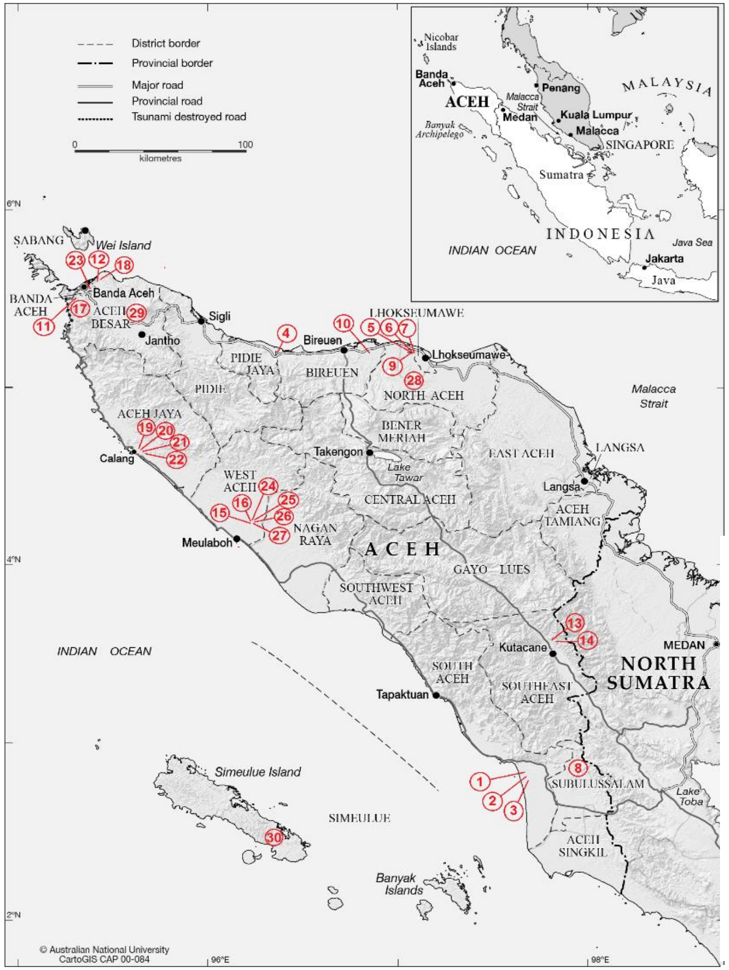

Figure 2. Location of samples (the base map is taken from ANU (2016)

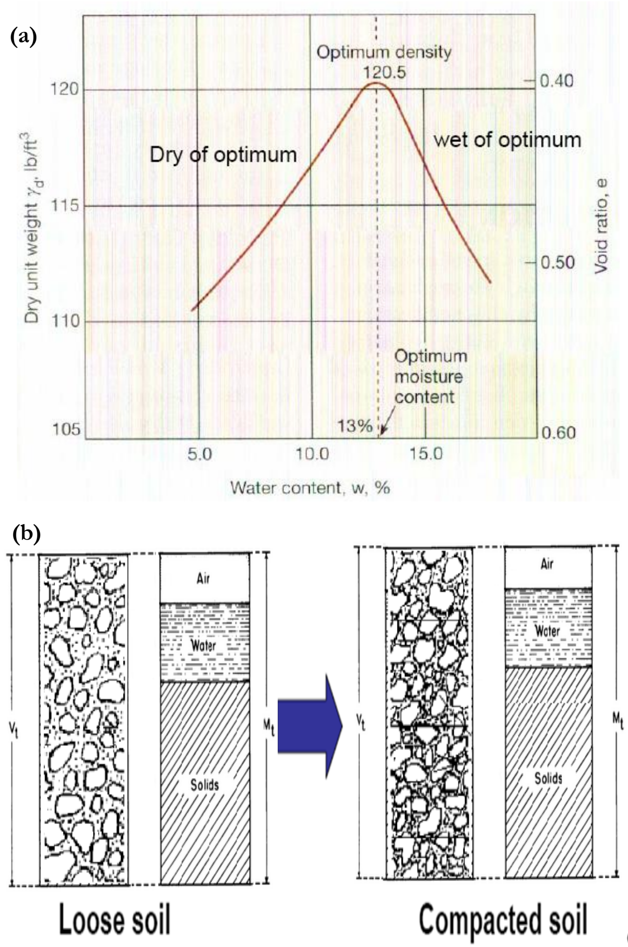

Figure 3. (a) Compaction curve (Das, 1985), (b) Effect of compaction on soil

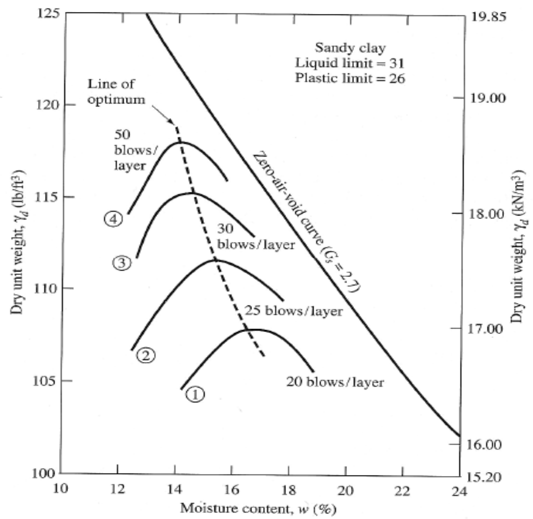

Figure 4. Compaction curve for four different types of compaction energy (Das, 1985)

Physical soil properties testing

Testing of the physical nature of the soil in the present study includes Atterberg limits and sieve analysis. The tests were carried out in accordance with the American Society for Testing and Materials (ASTM) standards. The result of testing is for soil classification, which in the present study the soil classification is based on the Unified Soil Classification System (USCS).

Compaction test

The present study adopted a standard proctor compaction test based on ASTM D-698. Equipment used in the standard proctor compaction work consists of mold, hammer (pounder) and extruder (a tool to remove the specimen). Testing was carried by dropping the hammer into the mold with soil sample inside. The hammer is dropped 25 times on each soil layer wherein for each mold on a standard proctor test is compacted in three layers. The excessive soil above the lip mold is leveled using a grader blade.

Obtained data for the compaction test are as follow: empty mold weight, bulk soil weight, the volume of the mold, and water content. Moisture content measurement is made after the compaction. Tree containers at the top, middle and bottom of the test specimen are taken for this moisture content measurement. The moisture content of the soil bulk density is obtained by averaging the obtained moisture content values of the three samples.

Results and Discussion

The results of the present study are USCS soil classification based on the physical soil properties and compaction test results. From both results, simple correlations for investigating the effect of soil coarse particles content on the values of its OMC and MDD are developed.

Soil classification

Soil classification results along with their visual descriptions of the present study are shown in Table 1. Ten of 30 soil samples in the present study are classified as the coarse-grained soil in the USCS Classification, whereas the rest (20 others) are categorised as fine-grained soil. USCS classification for fine-grained soil in the present study is shown in Figure 5. This fine-grained classification shows that the cohesive soils of the present study are mostly classified as clay to silt with low plasticity (CL and ML) and only a small proportion (3 of 20) of fine-grained soil samples of the present study are classified as high plasticity of clay (CH) or silt (MH) or organic clay (OH).

Grain size analysis, plasticity index (PI), liquid limit (LL), plastic limit (PL), OMC and MDD test results of the soil samples of the present study obtained from laboratory testing as described above are presented in Table 2. Several anomalies in the dry density results are found in samples from locations 4, 5, 9, 11, 15, 17, 23 and 25. Generally, soil dry density is within the range of 1.1 to 1.6 g/cm^3 (Hillel, 1980). The dry density of soil at Locations 4, 5, 11, 15, 17, 23 and 25 are higher than the common soil dry density (Table 2). The dry density of soil at location 9 is only 0.669 g/cm^3 which is much lower than the common dry density of soil. In the author opinion, this abnormality is the human error in the soil testing. The error may be caused by sampling handling and treatment error, apparatus reading error or apparatus handling error. Therefore, the author removes the affected samples for further analysis.

Effect of coarse-grained content

As described implicitly at the beginning of the present paper, correlations are developed to investigate the effect of the coarse fraction content in the soil characteristics. Only samples within the common dry density are used in this analysis. One of these correlations is to look at the effect of coarse particle concentration in soil OMC. The present study proposed the relationship between coarse-grained content and OMC as shown in Figure 6. This correlation indicates that the OMC value will decrease when the level of coarse soil particles is rising. Despite having relatively small coefficients of determination, the relationship between these two elements is in a good agreement others studies by Jesmani *et al.* (2008), Alavi *et al.* (2009), Alavi *et al.* (2010), Shirur and Hiremath (2014), Bhat *et al.* (2015) and Ren *et al.* (2015). In addition, Jesmani *et al.* (2008) found a positive correlation between OMC and clay content. The validation data of Alavi *et al.* (2009) shows similar results to the present study. The result of the present study is, also, in a good agreement with laboratory testing results by Shirur and Hiremath (2014) and Bhat *et al.* (2015) which suggested that the increasing of coarse-grained content will decrease the OMC of the soils. Ren *et al.* (2015) indicated that the OMC of CLAY soil is higher than SAND soil.

The second correlation is shown in Figure 7. The correlation shows the influence levels of soil coarse particles on the soil MDD. The increase of the content of coarse-grained particles in the soil will increase the value of the soil MDD. The relationship between coarse-grained content and MDD also has been indicated by Worku and Shiferaw (2004), Jesmani *et al.* (2008), Alavi *et al.* (2009), Alavi *et al.* (2010), Shirur and Hiremath (2014), Bhat *et al.* (2015) and Ren *et al.* (2015). The coarse particle content in Worku and Shiferaw (2004) was represented using the coefficient of uniformity (CU). Alavi *et al.* (2009; 2010) shown similar results to the present study in their validation data. Laboratory testing results by Shirur and Hiremath (2014) and Bhat *et al.* (2015) show in a good agreement with the present study

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which suggested that the increasing of coarse-grained content will increase the MDD of the soils. Ren *et al.* (2015) indicated that the MDD of SAND soil is higher than CLAY soil.

Table 1. Soil samples data for USCS classification and visual description of the present study

No	% retained #200	Plasticity index %	Liquid limit %	Visual description	Location in Aceh, Indonesia
1	59	15	51	Organic clayey SILT	Aceh Selatan
2	39	5	44	Clayey SILT with some organic matters & sand	Aceh Selatan
3	48	5	33	SILT with a little organic matters	Aceh Selatan
4	60	7	29	Clayey sandy GRAVEL	Bireun
5	65	3	21	Silty SAND	Lhokseumawe
6	80	3	22	Silty SAND	Lhokseumawe
7	83	2	27	Clayey SAND	Lhokseumawe
8	46	4	34	Silty SAND with some gravel???	Subulussalam
9	35	10	51	Clayey SILT with some sand	Lhokseumawe
10	52	3	30	Sandy SILT with some gravel	Biruen
11	72	18	37	Clayey GRAVEL	Aceh Besar
12	41	17	45	Clayey SILT with some sand	Aceh Besar
13	48	9	30	Clayey SILT	Aceh Tenggara
14	12	12	34	Clayey SILT	Aceh Tenggara
15	41	25	40	Clayey SILT	Aceh Barat
16	41	17	40	Clayey SILT	Aceh Barat
17	33	6	30	CLAY with rock fragments	Aceh Besar
18	45	18	50	Silty CLAY with rock fragments	Aceh Besar
19	45	14	41	Silty CLAY	Aceh Jaya
20	48	16	42	CLAY with rock fragments	Aceh Jaya
21	12	28	61	Clayey SILT	Aceh Jaya
22	15	28	58	Clayey SILT	Aceh Jaya
23	43	24	47	Sandy SILT	Banda Aceh
24	91	19	35	Silty SAND	Aceh Barat
25	14	20	40	Clayey SILT	Aceh Barat
26	13	19	39	Clayey SILT	Aceh Barat
27	49	11	33	CLAY	Aceh Barat
28	34	18	40	Clayey SILT	Aceh Utara
29	35	10	51	???	Aceh Besar
30	29	22	43	Clayey SILT with some sand	Simeulue

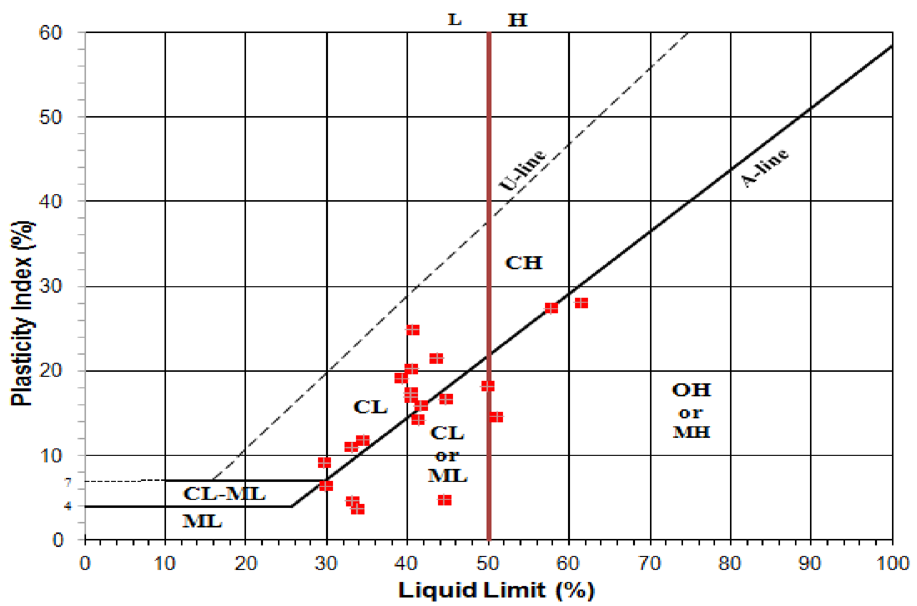

Figure 5. USCS Classification of fine grained soils in the present study

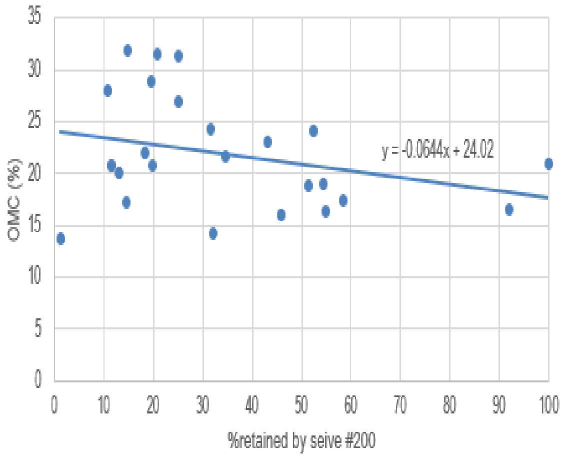

Figure 6. Effect of coarse particle content on the value of soil OMC

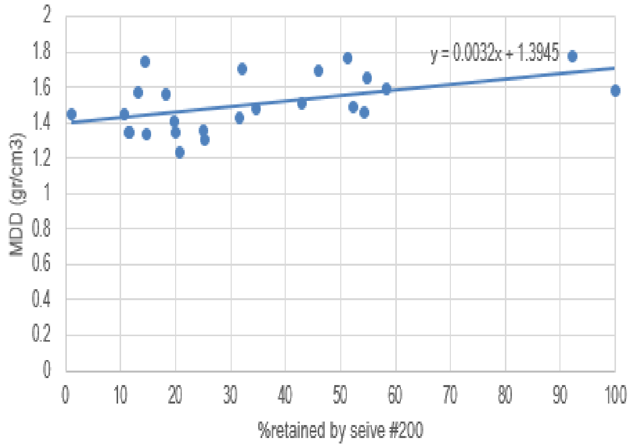

Figure 7. Effect of coarse particle concentration on the value of soil MDD

Table 2. Plastic limit, OMC and MDD soil in the present study

No	% retained					PI	LL	PL	OMC	MDD	Location in Aceh, Indonesia
	#10	#20	#40	#60	#200	%	%	%	%	gr/cm³	
1	0	0	0.13	0.28	1.22	14.69	50.85	36.16	13.7	1.452	Aceh Selatan
2	0	7.73	12.63	22.33	34.7	4.84	44.4	39.56	21.7	1.477	Aceh Selatan
3	3	4.58	6.25	9.65	19.67	4.72	32.99	28.27	28.8	1.405	Aceh Selatan
4	67.6	75.05	79.55	81.37	84.92	6.97	28.52	21.55	14.2	1.87	Bireun
5	14.1	27.24	41.83	53.65	67.47	3.25	20.53	17.28	12.8	1.873	Lhokseumawe
6	3.18	7.33	14.51	21.93	54.94	2.5	22.32	19.82	16.3	1.651	Lhokseumawe
7	8.73	15.98	25.98	38.85	58.44	1.92	26.57	24.65	17.4	1.597	Lhokseumawe
8	8.33	9.1	24.82	35.73	45.97	3.76	33.63	29.87	16.1	1.695	Subulussalam
9	0	16.67	33.33	50	100	9.77	51	41.23	24.1	0.669	Lhokseumawe
10	10.3	11.19	11.9	13.02	52.4	2.53	29.69	27.16	24	1.485	Biruen
11	73.2	80.31	84.92	88.49	92.04	18.18	37.34	19.16	16.4	1.776	Aceh Besar
12	7.48	12.9	16.33	20.07	30.93	16.72	44.58	27.86	29.8	1.09	Aceh Besar
13	0	0.43	0.7	1	19.92	9.21	29.57	20.36	20.7	1.351	Aceh Tenggara
14	0	0.13	0.65	1.78	11.617	11.95	34.38	22.43	20.7	1.351	Aceh Tenggara
15	0	0.45	1.2	2.07	32.02	24.92	40.43	15.51	14.1	1.704	Aceh Barat
16	0	0.48	1.17	3.42	31.7	16.99	40.28	23.29	24.4	1.431	Aceh Barat
17	3.97	15.48	22.55	27.37	44.78	6.49	29.68	23.19	13.8	1.867	Aceh Besar
18	3.47	6.25	9.9	14.58	25.08	18.24	49.75	31.51	31.3	1.352	Aceh Besar
19	8.3	12.9	15.63	18.13	25.2	14.28	41.15	26.87	26.9	1.31	Aceh Jaya
20	7.55	11.72	13.82	15.7	20.7	15.95	41.52	25.57	31.5	1.229	Aceh Jaya
21	1.3	2.25	2.98	3.68	10.77	28.13	61.37	33.24	27.9	1.452	Aceh Jaya
22	2.53	4.62	6.03	7.75	14.79	27.5	57.59	30.09	31.8	1.338	Aceh Jaya
23	5.31	8.48	24.2	28.54	51.33	23.62	47.14	23.52	18.8	1.771	Banda Aceh
24	2.55	7.27	16.54	30.51	54.36	19.28	34.79	15.51	19	1.455	Aceh Barat
25	0.27	1.6	3.98	7.32	14.48	20.31	40.38	20.07	17.1	1.748	Aceh Barat
26	0	0.47	0.98	1.98	13.167	19.23	39.13	19.9	20	1.575	Aceh Barat
27	0.17	1.33	2.73	4.27	18.27	11.06	32.96	21.9	22	1.562	Aceh Barat
28	1.58	3.18	6.45	15.88	43.02	17.52	40.26	22.74	23	1.508	Aceh Utara
29	0	16.67	33.33	50	100	9.77	51	41.23	20.8	1.577	Aceh Besar
30	0	0	0	0.48	11.45	21.61	43.46	21.85	20.7	1.351	Simeulue

Conclusions

Empirical studies demonstrated that the percentage of the coarse fraction of the soil is affecting the soil OMC and MDD. This phenomenon is used as a basis for testing of the Province of Aceh soils. The main aim of the present study is to determine the relationship between coarse-grained content and OMC and MDD of the Aceh's fill materials. Thirty (30) soil samples taken from various locations in Aceh Province were tested. Two correlations for investigating the effect of the coarse fraction content of Aceh's fill materials on their OMC and MDD characteristics are deduced. The first correlation shows that OMC value is decreased when the levels of coarse soil particles is increased. The later correlation shows the influence levels of coarse particles on the value of soil MDD. The relationship shows that the MDD is surge with the increasing of coarse particles content in the soil. In the practical aspect, these findings suggest that Aceh's fill material with highly variable of particles sizes is preferable for construction purposes than the less one.

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