CHAPTER III

BASIC THEORIES

3.1 Soil Classification

The soil classification system that used in this research as followed:

3.1.1 AASHTO Classification System

American Association of State Highway and Transportation Official (AASHTO) classification system (see Table 3.1) is based on the following criteria:

1. Grain size
    a. Gravel, which is the soil fraction passing the 75-mm sieve and retained on 2-mm sieve (No.10) U.S. sieve
    b. Sand, which is the soil fraction passing the 2-mm sieve (No.10) U.S sieve and retained on 0.075-mm sieve (No.200) U.S. sieve
    c. Silt and clay, which is the soil fraction passing the 0.075-mm sieve (No.200) U.S sieve
2. Plasticity

    If the fine fraction of the soil have a index of plasticity of 10 or less it is reffered to silty soil, and if the fine fraction of the soil have a index of plasticity of 11 or more it is reffered to clayey soil.
3. If the soil fraction larger than 75mm such as cobbles and boulder, they are excluded from the portion from the soil sample.

Table 3.1 Classification of Highway Subgrade Materials

General classification	Granular materials (35% or less of total sample passing No. 200)						
	A-1			A-2			
Group classification	*A-1-a*	*A-1-b*	*A-3*	*A-2-4*	*A-2-5*	*A-2-6*	*A-2-7*
Sieve analysis (percent passing)							
No. 10	50 max.						
No. 40	30 max.	50 max.	51 min.				
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.
Characteristics of fraction passing No. 40							
Liquid limit				40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand			
General subgrade rating	Excellent to good						

General classification	Silt-clay materials (more than 35% of total sample passing No. 200)			
Group classification	*A-4*	*A-5*	*A-6*	*A-7* *A-7-5** *A-7-6*†
Sieve analysis (percent passing)				
No. 10				
No. 40				
No. 200	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40				
Liquid limit	40 max.	41 min.	40 max.	41 min.
Plasticity index	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Silty soils		Clayey soils	
General subgrade rating	Fair to poor			

*For A-7-5, $PI \leq LL - 30$
†For A-7-6, $PI > LL - 30$

(Source: Das, Braja M., 2006, page 84)

3.1.2 Unified Soil Classifcation System (USCS)

On USCS, soil classified into two categories (see Table 3.2) :

1. Coarse-grained soil, which is sand and gravel where less than 50% of total weight of the soil sample that passing N0.200 sieve. The symbol of gravelly soil is S.G, gravel is G, and for sand is S.

2. Fine-grained soil, which is soil with 50% or more of the total weight of soil passing the No. 200 sieve. The symbol of silt is *M*, clay is *C*, organic silt and organic clay is *O*, and for peat, muck, and others is *PT*.

Table 3.2 Unified Soil Classification Systems

Criteria for assigning group symbols				Group symbo
Coarse-grained soils More than 50% of retained on No. 200 sieve	**Gravels** More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[a]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[c]	GW
			$C_u < 4$ and/or $1 > C_c > 3$[c]	GP
		Gravels with Fines More than 12% fines[a,d]	$PI < 4$ or plots below "*A*" line (Figure 5.3)	GM
			$PI > 7$ and plots on or above "*A*" line (Figure 5.3)	GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[b]	$C_u \geq 6$ and $1 \leq C_c \leq 3$[c]	SW
			$C_u < 6$ and/or $1 > C_c > 3$[c]	SP
		Sands with Fines More than 12% fines[b,d]	$PI < 4$ or plots below "*A*" line (Figure 5.3)	SM
			$PI > 7$ and plots on or above "*A*" line (Figure 5.3)	SC
Fine-grained soils 50% or more passes No. 200 sieve	**Silts and clays** Liquid limit less than 50	Inorganic	$PI > 7$ and plots on or above "*A*" line (Figure 5.3)[e]	CL
			$PI < 4$ or plots below "*A*" line (Figure 5.3)[e]	ML
		Organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$; see Figure 5.3; OL zone	OL
	Silts and clays Liquid limit 50 or more	Inorganic	*PI* plots on or above "*A*" line (Figure 5.3)	CH
			PI plots below "*A*" line (Figure 5.3)	MH
		Organic	$\frac{\text{Liquid limit — oven dried}}{\text{Liquid limit — not dried}} < 0.75$; see Figure 5.3; OH zone	OH
Highly Organic Soils	Primarily organic matter, dark in color, and organic odor			Pt

[a]Gravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.

[b]Sands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.

[c]$C_u = \frac{D_{60}}{D_{10}}$; $C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$

[d]If $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

[e]If $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol CL-ML.

(Source: Das, Braja M., 2006, page 103)

The other symbols are used for the Unified Soil Classification (USCS) are:

- *W* = well graded
- *P* = poorly graded
- *L* = low plasticity (*LL* < 50)
- *H* = high plasticity (*LL* > 50)

For the actual classification, the following are factors that must be considered:

1. The percentage of gravel fraction that passes the 76.2-mm sieve and retained on No.4 sieve
2. The percentage of sand fraction that passes No. 4 sieve and retained on No. 200 sieve
3. The percentage of silt and clay fraction that passes the No.200 sieve
4. The coefficient of uniformity *(Cu)* and the coefficient of gradation *(Cc)*
5. Liquid limit *(LL)* and plasticity index *(PI)* of the portion of soil that passes the No.40 sieve

Some symbols for coarse-grained gravelly soils are *GW*, *GP*, *GM*, *GC*,*GC-GM*, *GW-GC*, *GP-GM*, and *GP-GC* (see Figure 3.1). And for the classification of fine-grained soils are *CL*, *ML*, *OL*, *CH*, *MH*, *OH*, *CL-ML*, and *Pt*.

Figure 3.1 Flowchart Group Names for Gravelly and Sandy Soil

(Source: Das, Braja M., 2006, page 90)

3.2 Soil Stabilization

The most important thing on construction project is soil, because it will be used as base to support all construction of buildings or other civil engineering structures above it. Construction buildings and all structures that constructed above the weak soil is highly risky and susceptible to collapse because such soil has a differential settlements due to its poor shear strength and high compressibility. The effort to change the soil characteristics to increase its performance is known as soil stabilization. In soil stabilization, the soil properties that has alteration are mechanical properties, volume stability, permeability, and durabililty. Commonly there are two types of soil stabilization :

1. Traditional Stabilization

   Traditional stabilization methods usually require lengthly curing time and relatively needed large quantitives of additive for siqnificant strength improvement (Mamlouk and Zaniewski, 1999). Some traditional additives that are often used for this method are :

   1. Portland Cement
   2. Lime
   3. Fly-ash
   4. Fly-ash with Cement or Lime
   5. Cement Kiln Dust (CKD)
   6. Bitumen and Tar

2. Non – Traditional Stabilization

   Non-traditional stabilization methods becoming popular because they overcome some disadvantages of traditional methods, such as delayed hardening, low tensile strength, large drying shringkage, and low chemical resistance (Seyed and Masoud, 2010). Some non-traditional additives that are often used for this method are :

1. Polymers
2. Polyurethane
3. Biopolymer
4. Fyber Reinforcement
5. Calcium Chloride
6. Sodium Chloride

The main advantages of non-traditional method is that setting time and curing time can be controled, but this method is however generally more expensive than traditional method.

3.3 Sand

Sand are made of mostly quartz and feldspar, it is finer than gravel but coarser than silt. The composition of sand is silicon dioxide, but depending on the local rock sources. In tropical and subtropical beaches, sand generally formed by limestone.

Table 3.3 Type of Soil Based on Specific Gravity

S. No.	*Soil type*	*Grain specific gravity*
1.	Quartz sand	2.64 – 2.65
2.	Silt	2.68 – 2.72
3.	Silt with organic matter	2.40 – 2.50
4.	Clay	2.44 – 2.92
5.	Bentonite	2.34
6.	Loess	2.65 – 2.75
7.	Lime	2.70
8.	Peat	1.26 – 1.80
9.	Humus	1.37

(Source: Venkatramiah, C., 2006, page 32)

Altough sand has a good soil bearing capacity but the cohesion value of sand generally aproximately zero, than particle charateristic of sand is very loose so it can be easily blowed by wind and carried by water flow.

3.4 Polyurethane-Resin

Polyurethane are one of the most versatile plastic material. Polyurethane-Resin are formed by reaction between polyol and diisocyanate or polymetric isocyanate in the presence of suitable catalyst and additives. Polyurethane was first made by Otto Bayer and his co-worker at I.G Farben in Leverkusen, Germny in 1937. Since then, polyurethane has been used in different industrial application and recently in civil engineering and geotechnical applications (Avar, 2008).

This study focuses on the use of polyurethane-resin as binder material to enhance the strength of volacanic sand. Polyurethane-Resin that choosed for this study use automotive clear-coat materials.

3.5 Direct Shear Test

The direct shear test is purposed to determine the strength of the soil due to horizontal forces, as well as the soil stability, shear angle, and its cohesion. When a soil is loaded, its grains tend to be loose from each other. Before it happens, frictions will occur at the plane between grains. It will reach its maximum when grains start to be loose. It is known as soil strength.