CHAPTER III

BASIC THEORY

3.1 Pavement Road

A highway pavement is part of a layer of material, consist of a mixture of aggregate and bonding material, which is selected and worked according to certain requirements and serves to spread the wheel load of the vehicle so that it can be held by the subgrade. Part of the pavement generally includes sub-grade, sub-base course, base course, and surface. The function of the pavement layer is to take the burden of traffic and spread it to the layers below it continue to the subgrade.

3.1.1 Flexible Pavement

Flexible pavement are confirm as the mixture of asphalt and aggregates placed on a bed of compacted granular material of proper quality in layers above the sub grade. Flexible pavement design is based on the concept which for a load of any magnitude, the intensity of a load diminishes when the load is transmitted downwards from the surface by virtue of spreading over an increasingly larger area, by carrying it deep enough into the ground through following layers of granular material. Typical cross section of a flexible pavement can be seen on Fig. 3.1 below.

Fig. 3.1 Flexible Pavement Cross-section
Source: www.theconstructor.org

Typical layers of flexible pavement includes:

a. Surface course : Surface layers are layers that come in direct contact with vehicle wheel loads. The forming materials is consist of crushed stone, gravel, and soil stabilization with cement or lime. The use of asphalt material is needed so that the coating can be waterproof and provide tensile stress assistance which means increasing the carrying capacity of the layer against the traffic wheel load.

b. Base course : The base layer is the pavement layer which is located between the subbase layer and the surface layer. Various materials can be used as foundation material. However, it must meet the minimum CBR value of 50% and must be higher than the CBR value in the lower foundation layer.

c. Subbase course : The sub-base course defined as the layer of material that lays below the base course and the main functions are to supply structural support, improve drainage, and bring down the intrusion of fines from the sub-grade in the pavement structure. According to Sulaksono (2001), pavement layers consists of 10% soil, and aggregate makes up 90-95% of the total weight.

d. Subgrade course : It is a layer of natural soil prepared to receive the stresses from the layers above. It is important that excess pressure is not experienced by the soil sub grade. It should be compacted to the desirable density, near the optimum moisture content.

3.1.2 Rigid Pavement

Rigid pavements possess sufficient flexural strength to transmit the wheel load stresses to a wider area below. Rigid pavements are placed directly on the prepared sub-grade, or on a single layer of granular or stabilized material. In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium. Rigid pavements are constructed from Portland cement concrete (PCC).

3.2 Ground Granulated Blast Furnace Slag (GGBFS)

According to Song (2000), Ground Granulated Blast Furnace Slag (GGBFS) is a glassy granular material formed when molten blast-furnace slag is rapidly cooled, usually by immersion in water, and then ground to improve its reactivity. The major components of blast furnace slag are SiO_2, CaO, MgO, and Al_2O_3, which are common components in commercial silicate glasses. The main hydration product of GGBFS is calcium silicate hydrate (C-S-H) with a low Ca/Si ratio regardless of the activator used.

The explanation that GGBFS react terribly slowly with the water outcome in less hydraulic activity. The GGBFS have a glassy texture that's why that locks the particle from reacting with water. The slag glass contains the same major oxides as does Portland cement, but with considerably different proportions of lime and silica. Like Portland cement, it has excellent hydraulic properties and, with a suitable activator (such as calcium hydroxide) will set in a similar matter.

Two main benefits of using GGBFS aggregate are resource conservation (reducing the usage of natural aggregate) and reduction or elimination of solid waste. Other than that there is also an economy benefit that can be taken as well, since the utilization of GGBFS aggregate reduces the need for natural aggregate and for landfill disposal of the GGBFS. Thus, the use GGBFS could help to fulfill sustainability needs in each of those three areas, and therefore potentially can contribute to the sustainability of pavement construction projects without compromising the overall pavement performance.

3.3 California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test is the test most commonly used in highway pavement design all over the world. California Bearing Ratio (CBR) is a parameter that measures the strength of road soils and used as an integral part of pavement design. This CBR test require sampling, transporting, preparing, compacting, soaking, and penetrating with a plunger of CBR machine to compute the soil resistance.

This test was combines penetration testing experiments in the Laboratory or in the Field with an Empirical plan to determine the thickness of the pavement layer. This is used as a flexible pavement planning method for a road. The thickness of a pavement section is determined by the CBR value.

On pavement design, the thickness of the pavement is usually decided from the CBR value of compacted soil. CBR value which is used for design is called CBR design. CBR design value is obtained from laboratory experiment that calculates two factors, such as:

a. Soil water content and dry density during compaction.

b. Test on water content that might happen after the pavement is made.

The CBR is defined as:

$$\text{CBR} = \frac{(Unit\ load\ for\ 0.1\ piston\ penetration\ in\ test\ specimen)\ (lb/in.^2)}{(Unit\ load\ for\ 0.1\ piston\ penetration\ in\ standard\ crushed\ rock)\ (lb/in.^2)} \tag{3.1}$$

The unit load for 0.1 piston is standard crushed rock is usually taken as 1000 lb/in^2, that gives the CBR as:

$$\text{CBR} = \frac{(Unit\ load\ for\ 0.1\ piston\ penetration\ in\ test\ specimen)}{1000} \text{ x } 100 \tag{3.2}$$

The California Bearing Ratio (CBR) test is described on AASHTO-T193.

3.4 <u>Dynamic Cone Penetrometer (DCP)</u>

In addition to the CBR test there is also another penetration test called the Dynamic Cone Penetrometer (DCP). DCP is a tool used to measure the carrying capacity of land in place (in situ). The carrying capacity of the soil is calculated based on the processing of the results of the DCP test carried out by measuring how deep (mm) the tip of the conus enters the subgrade after receiving a hammer shear impact on the coupling.

The DCP is defined as:

$$\text{DCP} = \frac{Penetration\ depth}{blow\ counts\ corresponding\ to\ penetration\ depth} \tag{3.3}$$

The correlation between the number of blow and penetration at the conus tip of a DCP tools into the soil will give a picture of the strength of the subgrade at certain points. The deeper conus that comes in for each blow means that the softer the subgrade.

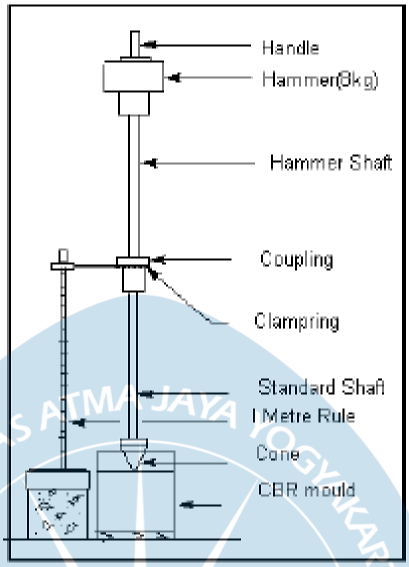

Fig. 3.2 Arrangement for Conducting DCP test on CBR
Source: Sahoo, 2009.

This test was worked by pressing the cone tip made of steel with a certain size and angle. The principle works is the penetration speed of the conus when pressed by standard strengths, proportional to the strength of the material measured. The changes in penetration values per punch indicate changes in soil strength, so that the thickness and strength of these layers can be known and identified.

3.5 <u>Relationships between DCP and CBR</u>

Civil engineers always encounter difficulties in obtaining representative CBR values for design of pavements. As it needs much time to have the end result and it cannot be easily determined in the field. While doing DCP test including its analysis and interpretation takes a very short time. DCP is also multi-advantageous equipment used to evaluate the in-situ strength of subgrade soil materials for road pavement works at shallow depths.

Farshad (2003), Ferede (2010), and Ehsan (2011) mentioned that most of the relationships developed between DCP and CBR are based on the best fit log-log equation having the form:

$$Log\ (CBR) = A + B\ log\ (DCP) \quad (3.4)$$

Where, CBR = California Bearing Ratio in percent

DCP = penetration value in units of mm per blow

A and B are regression constants for the relationships

Salgado (2003) has mentioned that the power model (or log-log equation) has been used by different authors for the relationship between the DCPI and CBR and Harison (1987) has concluded that the log-log equation produces reliable results.