A STUDY ON THE SUITABLE COMPACTION METHOD FOR PHYSICAL SLOPE MODEL

DARVINTHAREN A/L GOVINDASAMY

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A STUDY ON THE SUITABLE COMPACTION METHOD FOR PHYSICAL SLOPE MODEL

By

DARVINTHAREN A/L GOVINDASAMY

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Name of Student: Darvintharen A/L Govindasamy

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

____

Darvintharen A/L Govindasamy

Date : /06/2017

Approved by:

____

(Signature of Supervisor)

Name of Supervisor : Dr. Mastura Azmi

Date : /06/2017

Approved by:

____

(Signature of Examiner)

Name of Examiner : Professor Dr. Fauziah Ahmad

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ABSTRAK

Kegagalan cerun adalah suatu masalah yang dihadapi dalam pembinaan cerun. Proses pemadatan adalah antara kaedah untuk meningkatkan kekuatan tanah. Demi mencapai proses pemadatan tanah yang mencukupi, penentuan kandungan lembapan optimum, ketumpatan kering maksimum dan daya pemadatan serta kaedah pemadatan adalah penting. Model fizikal yang mengandungi jenis tanah berbutir telah digunakan untuk mengkaji masalah cerun. Saiz tanah yang sama telah digunakan untuk proses pemadatan. Kandungan lembapan optimum dan ketumpatan kering tanah ditentukan melalui ujian “Proctor Standard”. Faktor pemadatan tanah dikaji dengan membina model fizikal yang mempunyai ketinggian 0.25 m x 1 m panjang dan 1 m saiz lebar. Kemudian, 30° cerun dengan ketinggian 0.43 m dibina untuk mengenalpasti cara terbaik untuk membinanya dalam skala makmal. Blok kayu yang berberat 7.5 kg dengan pelantak “Standard Proctor” yang berberat sebanyak 2.5 kg digabungkan untuk menyiapkan pemadatan. Penggunaan jumlah tenaga iaitu kira-kira 600 kJ/m^3 dalam ujian “Proctor Standard” juga telah diaplikasikan dalam kajian pemadatan model fizikal. Pemadatan kering diutamakan. Tanah berlapis yang berbeza iaitu 3 dan 5 lapisan digunakan untuk mencapai ketinggian 0.25 m. Kaedah padat ke atas tanah berbutir harus dilakukan sepenuhnya dalam keadaan kering sehingga ketinggian yang diperlukan dan seterusnya memotong cerun yang diperlukan merupakan cara terbaik untuk membina cerun dalam skala besar. Tahap ketumpatan antara tanah yang berlapisan 3 dan 5 juga berlainan. Keseluruhan kawasan ditenggelami air dan diuji untuk mengenalpasti kegagalan cerun. Tiada sebarang kegagalan cerun diperhatikan. Pengisian air dalam model fizikal selepas proses pemadatan membantu menentukan pengagihan tenaga antara lapisan. Jika, terdapat garisan yang terbentuk antara lapisan tanah, kita boleh menyimpulkan bahawa jumlah daya usaha pemadatan tidak diagihkan dengan seragam.

ABSTRACT

Slope failure is a problem that encountered in construction of slope. One of the method to increase the strength of soil is by compaction. To ensure adequate soil compaction is achieved, the determination of optimum moisture content, maximum dry density, compaction effort, method of compaction is important. To study this problem in slope, a physical model is used with granular type of soil in it. For simplicity, the soil size was kept constant. The optimum moisture content and dry density were determined in the Standard Proctor Test. Height of 0.25 m x 1 m base and 1 m width size of soil layers are constructed in the physical model to study the compaction factors. Then, a 30° of slope with height of 0.43 m were constructed to determine the best method to build a slope in a laboratory scale. Wooden block weight of 7.5 kg with Standard Proctor rammer weight of 2.5 kg combined to complete the compaction part. The same amount of energy which is about 600 kJ used in Standard Proctor Test was applied in the study of compaction effort in the physical model. Dry compaction mainly applied in the physical model. For the height of 0.25 m, two different layers was used in the testing, which is 3 layers and 5 layers. The method of compact granular soil is kept entirely in dry condition until the necessary height is achieved then the slope should be cut because it is best to replicate the slope in a bigger scale. The density in between 3 layers and the 5 layers also varies. Thus, the fully constructed area was submerged and tested for the failure of the slope. However, no failure of slope was observed. Besides that, filling water in the physical model after compaction process also help to determine the energy distribution or compaction level between layers. If there is a line formed between soil layers, we can conclude that the amount of compaction effort not distributed uniformly.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

First of all, slope stability problems of landslides are among the most frequently encountered problems in geotechnical engineering. Due to the practical prominence of the subject, assessing the stability of a natural or man-made slope has received great responsiveness across the geotechnical community, for many decades. Slope failures triggered by rainfall cause substantial property damage with loss of life, every year throughout the globe (Egeli and Pulat, 2011). For instance, the landslide incident that happen at Cameron Highlands forces 25 people to evacuate homes this year (Landslide in Cameron Highlands force 25 people to evacuate homes, themalaymailonline, 2016). Furthermore, a number of laboratory, numerical and field studies have been conducted to understand interrelations between soil stability and rainfall. Moreover, A number of landslides in unsaturated soils usually occur during the wet period (Egeli and Pulat, 2011).

Therefore, compaction is the process of increasing the density of a soil by packing the particles nearer composed with a reduction in the volume of air there is no noteworthy change in the volume of water in the soil. Elsewhere, in the construction of fills and embankments, loose soil is placed in layers ranging between 75 mm and 450 mm in thickness, each layer being compacted to a specified standard by means of rollers, vibrators or rammers (Craig, 2013). As a result, compaction increase the strength characteristics of soils, which surge the bearing capacity of foundations constructed over them (Das, 2013).

On a previous model from researcher Tohari et al. (2007) four experimental soil slopes that were constructed by placing wet soils in a series of horizontal layers 50 mm thick to the full width of the tank. The wet soils were prepared by mixing up dry soils thoroughly with water to give the prescribed water content using a mixer. For the first three experiments, the river sand with a uniform water content of 5% was used to construct initially dry slope profiles. For following experiment, the residual granite soil was placed at its optimum water content of 11.8% to construct an initially wet model slope. Light compaction was applied to each soil layer using a wooden tamper to give slight apparent cohesion (Tohari et al., 2007).

Besides, every soil type acts differently with respect to maximum dry density and optimum moisture. Therefore, each soil type has its own unique requirements and controls both in the field and for testing purposes (Multiquip Inc, 2011). So, in general the overall experiment is to find out the best technique to compact granular material in a slope. As an overall picture, the relationship between the basic characteristics of mining sand with compaction parameters optimum moisture content and dry density can be made.

1.2 Study Area

The study basically done using mining sand which was taken from Kampong Trong mining site. This mining site is located at Taiping, Perak, Malaysia. Mining sand at this location receive lots of rainfall because Taiping is categorised as most humid area with high number of rainfall in Malaysia. The sample taken from the site and brought to the geotechnical laboratory in Universiti Sains Malaysia for further testing. Mainly, sieve analysis done to obtain 2 mm sample sand.

1.3 Problem Statement

In Malaysia, landslides occur mainly during heavy raining season. At Kuching, Sarawak, Malaysia on February 2016, it was reported four landslide incidents on the same day in Serian district, believed to be due to heavy rains throughout night (Serian hit by four landslides due to heavy rain, themalaymailonline, 2016). Due to voids in the soil water penetrate and disturbs the soil particle arrangement. When the soil particles lost its bond then landslide may have occurred. The intensity of the landslide depends on the movement of water through the soil layer and steepness of the slope. To simulate the problem in laboratory scale, a slope can be constructed as same as site condition. To do that, compaction plays important role to replicate the condition. In laboratory modelling it is difficult to achieve same parameter as in natural slope. Especially the compaction effort and method use to compact the soil. It is difficult to obtain optimum moisture content for a granular slope model. Improper compaction may bring slope failure. The correct and best method of compaction in slope will help to maintain the bonding of the soil material.

1.4 Objectives

The objectives of this study are:

1) To investigate basic soil characteristic for mining sand in particular to parameters in compaction.

2) To obtain the effective method to achieve optimum moisture content and dry density for 2 mm granular soil in Standard Proctor Test.

3) To determine method of compaction and construction of slope in a physical model.

1.5 Scope of Work

The scope of work is focusing on compaction method of slope by conducting several tests. This is to achieve the main objective which is to investigate basic soil characteristics for mining sand in particular to parameters in compaction. By conducting several tests, the compaction parameters are evaluated.

i) Size of sample: The sample undergo sieve process and only 2 mm size sample used for the experiment. The sample that passing sieve size 3.35 mm and retained on 2 mm sieve is used.

ii) Granular material: The sample comprises of granular material. The sample made of soil particles mainly granular particles.

iii) Size of the model: 1 m x 1m x 1m size of physical slope model used for this experiment.

1.6 Dissertation Outline

This dissertation includes of five main chapters where every chapter explain different parts of this study. Chapter one focus on explaining the background of the study, problem statement, location studied, objective and the scope of work so that it provides clear picture on what the study will be. Chapter two enlisted the literature review which include the slope stability, compaction, slope compaction in laboratory model and other relevant topics. Chapter three provide enlisted the stages in methodology and some of the laboratory tests performed including its procedure. Chapter four shows the results and discussion obtained from the laboratory test carried out including the tables, graph and figures. Chapter five is the conclusion and the recommendation for further improvement in the future.

1.7 Justification of Research

The proposed research is to obtain effective method to achieve optimum moisture content and dry density for laboratory scale model. This to bring the site condition to the laboratory. The potential benefit is with basic mining sand characteristics can be used in designing structures and building in mining area. Moreover, mining area slopes can be handled in a proper manner. Landslides can be prevented with better understanding about compaction of granular material. Mining areas can be used in future for development with better planning and design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

According to Egeli and Pulat (2011) slope stability problems of narrow landslides which is the impact of a wide range of ground movements in the form of mass wasting are among the most regularly encountered problems in geotechnical engineering. Due to the practical status of the subject, measuring the stability of a natural or man-made slope has received great responsiveness across the geotechnical community, for many eras. Slope failures prompted by rainfall cause substantial property destruction with loss of life, every year throughout the globe. A number of laboratory, numerical and field studies have been conducted to understand interrelations between soil stability and rainfall. At the meantime, soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant and roots. So, in this case, soil stability plays a significant role because shear strength of a soil is able to increase the bearing capacity which automatically enables the soil to support the pavement and foundation of the load. A number of landslides in unsaturated soils which is a state of soil where soils can be partially saturated with water and this phase usually occurs during the wet period.

2.2 Basic Characteristics of Soil

Budhu (2015) mentioned that common descriptive terms such as gravels, sands, silts, and clays are used to identify specific textures in soils. Moreover, texture refers to the appearance or feel of a soil. For an in-detail explanation, sands which is a naturally occurring granular material composed of finely divided rock and mineral particles and gravels which is also a loose aggregation of small water-worn or pounded stones that are grouped together as coarse-grained soils. Normally, coarse-grained soils feel gritty and hard because those are least affected by moisture-content changes. For instance, the coarseness of soils is determined from knowing the distribution of particle sizes, which is the primary means of classifying coarse-grained soils. Furthermore, if most particles are large and coarse the soil is called a sand. It looks and feels sandy. Therefore, a silt soil is conquered by medium-sized particles and feels like flour. Besides, small-sized soil particles primarily make up a clay soil which feels slippery or greasy when it is wet. Elsewhere, coarse-grained soils have good load-bearing capacities and good drainage qualities, and their strength and volume change characteristics are not significantly affected by change in moisture conditions because engineering properties are controlled by the grain size of the particles and their structural arrangement. They are practically incompressible when dense, but significant volume changes can occur when they are loose. In a general view, vibrations accentuate volume changes in loose coarse-grained soils by rearranging the soil fabric into a dense configuration.

Tohari et al. (2007) mentioned that he uses two different sandy soils, namely, river sand and residual granite soil were used to construct a number of homogeneous experimental slopes in his study. The effective particle size (D_{10}) and uniformity coefficient (D_{60}/D_{10}) of the river sand are 0.175 and 7.14 mm, respectively. The residual granite soil has an effective particle size and uniformity coefficient of 0.157 and 4.63 mm, respectively. Tests of specific gravity produced a value of 2.69 for both soils. The maximum dry density, from the standard Proctor test, is 1,800 kg/m^3 at an optimum water content of 14.5% for the river sand and 2,010 kg/m^3 at an optimum water content of 11.8% for residual granite soil. The saturated hydraulic conductivity, k obtained from constant head permeability tests using a rigid wall permeameter on the river sand was

6.4×10^{-2} cm/s at void ratio of 0.82 and on the residual granite soil was 7.2×10^{-3} cm/s at void ratio of 0.52. Shear strengths of both soils were obtained from conventional isotropically consolidated drained triaxial compression (ICD) tests. The tests show that the river sand and residual granite soil are cohesionless with an angle of internal friction of 50° and 37°, respectively.

2.3 Compaction

According to Kawai et al. (2016), compaction on site differs from lab compaction tests in respect to applied load, compaction volume, and other parameters. Dry density is assumed to provide an index of compaction, with a target dry density determined from lab compaction test results. However, compaction effects strongly depend on compaction conditions. He obtained the compaction curves of silty soil from one-dimensional static compaction simulations. The optimum water content to obtain maximum dry density under compaction loads of 800 kPa is 22% and that a larger dry density can be obtained at all water contents under compaction loads of 1600 kPa. The compaction induced dry density of specimens with 18% water content under loads of 1600 kPa corresponds to the maximum dry density of the 800 kPa compaction curve. In the following simulations, multi-layered compaction, which is used in the practice of constructing embankment, was conducted using the results. The material parameters were used for the multi-layered compaction simulations. The input material parameters provide the soil water retention characteristic curves used for the simulations. Though actual soil water retention characteristic curves depend on changes in void ratio. The multi layered compaction simulation was conducted using the following procedure. First, a certain thickness layer was defined, and a compaction load was applied under drained air and undrained water conditions. Two thicknesses, namely 0.6 m and 0.3 m, and two compaction loads, namely

800 kPa and 1600 kPa, were compared. When additional layers were overlain, the upper air and water boundaries from the previous layers were removed, and the compaction load was applied over the previous layer.

According to Das (2013) compaction escalate the strength characteristics of soils, which increase the bearing capacity of foundations constructed over them. Secondly, Craig (2013) state that compaction is the process of increasing the density of a soil by packing the particles nearer together with a reduction in the volume of air there is no noteworthy change in the volume of water in the soil. Generally, in basic engineering term soil compaction is the method of mechanically increasing the density of soil. Furthermore, in construction, this is a significant part of the building process. For this reason, if soil compaction performed inappropriately, settlement of the soil could occur and may lead to consequence of unnecessary maintenance costs or structure catastrophe. Moreover, in the construction of fills and embankments, loose soil is placed in layers ranging between 75 mm and 450 mm in thickness, each layer being compacted to a specified standard by means of rollers, vibrators or rammers. In general, the higher the degree of compaction, the higher will be the shear strength and the lower will be the compressibility of soil. Since the early work of Gidigasu (1976) any particular soil that compacted, the moisture content, degree of combination and type of compaction can be varied. At the same time, the most desirable combination if these placement variables depend on the particular soils and the particular set of properties needed as described by Wooltorton (1976).

Head (1992) mentioned that many civil engineering projects require the use of soils as fill material. Whenever soil is placed as an engineering fill, it is nearly always essential to compact it to a dense state to obtain suitable engineering properties that would not be achieved with loosely placed material. At the meantime, compaction on site is usually effected by mechanical means such as rolling, ramming or vibrating. This means that, control of the degree of compaction is necessary to achieve a satisfactory result at a sensible cost. Hence, laboratory compaction tests provide the basis for control procedures used on site. Compaction tests furnish the basic data for soils. Such as the relationship between dry density and moisture content for a given degree of compaction effort, the moisture content for the most efficient compaction at which the maximum dry density is attained under that compaction effort and the value of the maximum dry density so achieved.

2.3.1 Compaction Curve

Kurucuk et al. (2008) believed that typical compaction curve presents different densification stages when the soil is compacted with the same apparent energy input but different water contents. The water content at the peak of the curve is called the optimum water content and represents the water content at which dry density is at its maximum for a given compaction energy. The researcher showed that the assumption of constant coefficients of compressibility during compaction does not produce a proper shape of the compaction curve especially on the dry side of the optimum water content.

The researcher Arvelo (2004) mentioned that the compaction curve is the representation of the dry densities versus the moisture contents obtained from a compaction test. According to the situation given, the attained dry density depends on the water content during the compaction process. On top of that, when samples of the same material are compacted with the same energy but with diverse water contents, they present different densification stages, as shown on Figure 2.1.

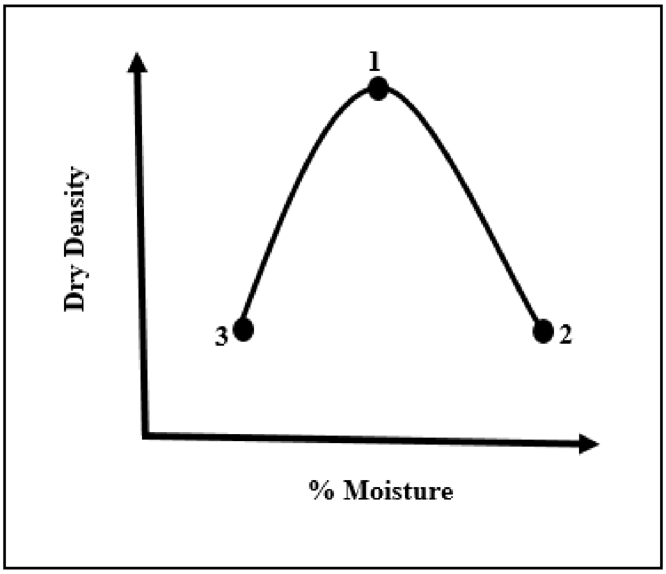

Figure 2.1: Typical Compaction Moisture or Density Curve (Arvelo, 2004)

Based on the situation given, this densification stages are symbolised in the compaction curve, which has a particular shape. There are countless theories have tried to explain the shape of this curve. For here are some of the principal theories are as follows:

Proctor (1933) believed that the humidity in soils relatively dry creates a capillarity effect that produces tension stress and grouping of the solid particles, that results in a high friction resistance that opposes the compaction stresses. In general, humidity is the amount of water vapour present in the air. Basically, water vapour is the gaseous state of water and is invisible to the human eye. Sow, from here we can infer that humidity in soil can cause tension in soil that opposes compaction pressures. For instance, it is very difficult the compaction of soils with low water content. For this reason, he obtained a better reorganisation of the soil particles by compacting it with higher water content, because of the increment of lubrication from the water. Therefore, by compacting the soil while the water content is increased, the lubrication effect will continue until a point where the water combined with the remaining air is enough to fill the voids. Thus, at this stage the soil is at its maximum dry density and optimum water content as represented in point 1 in Figure 2.1. So, we can see that for any rise in the water content after the "optimum water content", the volume of voids tends to increase, and the soil will obtain a lower density and resistance.

Hogentogler (1936) measured that the compaction curve shape reproduces four stages of the soil humidity: hydration, lubrication, expansion and saturation. These stages are represented in Figure 2.2.

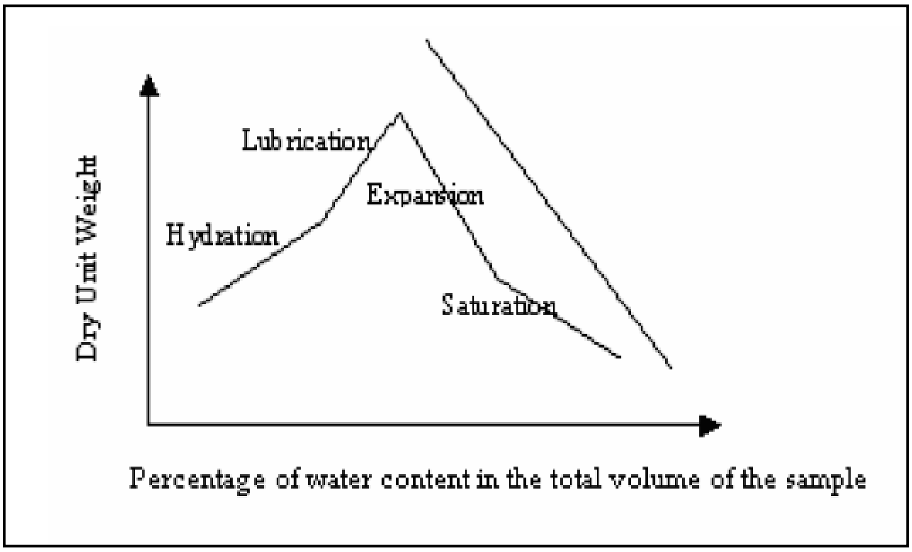

Figure 2.2: Compaction Curve (Hogentogler, 1936)

As shown in Figure 2.2, Hogentogler's moisture-density curve differs from Proctor's curve in the abscise axe. As a result, Hogentogler used for this axe percentage of water content in the total volume of the sample. Furthermore, Hogentogler believed that by using that chart the compaction curve becomes four straight lines that represent his humectation stages. "Hydration" is the stage where the water incorporation creates a surface coat in the solid particles providing viscosity.

Moreover, hydration also can be related to soil moisture sensors which measure the volumetric water content in soil. So, from here we can infer that hydration which also can be referred as soil moisture is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays a central role in the development of weather patterns and the production of rainfall that also contributes to the bearing capacity of soil indirectly. On top of that lubricant plays an important role in the process of compaction because lubricants act as a substance which is also similar to grease is capable of reducing friction, heat, and wear when introduced in between solid surfaces. In addition, “Lubrication” is the stage where the coat is increased by the addition of water acting as a lubricant, and making possible the rearrangement of the soil particles without filling all the air voids. The maximum water content in this stage matches to the maximum dry density obtained from the compaction. For instance, Hogentogler (1936) believed that more water after the lubrication stage will create the “expansion” of the soil mass without affecting the volume of the air voids, so the additional water in this stage acts in the displacement of the soil particles. At the same time, addition of more water to the soil produces its “saturation”, which is the stage where the air content is displaced. At the meantime, saturation also can be best explained when most soils have a water content less than porosity, which is the definition of unsaturated conditions as they are connected or interlinks to this process called compaction. Therefore, the capillary fringe of the water table is the dividing line between saturated and unsaturated conditions.

Hilf (1956) gave the first up-to-date type of compaction theory by using the concept of pore water pressures and pore air pressures. Therefore, he suggested that the compaction curve be presented in terms of void ratio where the ratio stands as volume of water to volume of solids. Furthermore, a curve similar to the conservative compaction curve results, with the optimum moisture content matching to a minimum void ratio. The main point is in his chart where the zero air voids curve is shown as a straight line and so are the saturation lines, all originating at zero void ratio and zero moisture content.

Elsewhere, points representing soil samples with equal air void ratios where volume of air is almost parallel to volume of solids in which the plot on the lines similar to the zero air voids or 100 % saturation line.

According to Hilf, dry soils are hard to compact because of high friction due to capillary pressure. Furthermore, air is expelled quickly because of the larger air voids. Thus, friction is a force repelling the comparative motion of solid surfaces where any types of materials or components sliding against each other. There are several types of friction. On top of that, dry friction resists relative lateral motion of two solid surfaces in contact. In addition, reducing friction by increasing the water content the tension in the pore water decreases, reducing friction and allowing better densification until a maximum density is reached. Besides, less-effective compaction beyond the optimum moisture content is attributed to the trapping of air and the increase of pore air which burdens and where the added water also taking space instead of the denser solid particles.

Lambe (1960) explained the compaction curve based on theories that used the soils' surface chemical characteristics. However, in lower water contents, the particles flocculation is caused by the high electrolytic concentration. Then, the flocculation causes lesser compaction densities, but when the water content is increased the electrolytic concentration is reduced.

Olson (1963) confirmed that the air permeability of a soil is affectedly reduced at or very close to the optimum moisture content. At this point, high pore air pressures and pore water pressures diminish effective stress allowing alterations of the relative position of the soil particles to produce a maximum density. Furthermore, when the water level content is below optimum point, Olson has also insisted that the attributes resistance to frequent compaction forces to the high negative residual pore pressures, where the relatively low shear-induced pore pressures, and the high residual lateral is in total stress.

Elsewhere, on the wet side of optimum, Olson also clarifies that the reduced densification is effected by pointing out that the rammer or foot penetration during compaction is larger than the drier soil, which may cause short-term negative pore pressure known to be related with large strains in over-consolidated soil, in addition the soil resists compaction by increasing bearing capacity due to the penetration outcome. As a result, the penetration process may go through temporary negative pore pressure that may increase the bearing capacity of the soil which will enable the soil to avoid the landslides problem which one the major issues in the geotechnical community around the globe.

Barden and Sides (1970) made experimental researches on the compaction of clays that were partially saturated, reporting the acquired microscopic observations of the modifications in the clay structure. In addition, the conclusions they obtained can be summarized as the theories based on the effective tensions used to control the curve shape are more dependable than the theories that used viscosity and lubrication. Next, it is logical to make an assumption that the soils with low humidity content remain conglomerated due to the effective tension caused by the capillarity. At the meantime, the dryer these soils are the bigger the tensions are. This means that, in the compaction process the soil remains conglomerated. Hence, by increasing the water content this tension are reduced, and the compaction is more effective. Besides that, the blockage of the air in the soil mass provides a sensible explanation of the effectiveness of a used compaction energy. Lastly, if by increasing the water content the blocked air is not expelled and the air pressure is increased, the soil will resist the compaction.

Lee and Suedkamp (1972) studied compaction curves of 35 soil samples. Furthermore, they observed that four types of compaction curves can be found. To get a clear picture of the compaction curve, these curves are shown in Figure 2.3. Secondly, type a compaction curve is a single peak. Normally, this type of curve is normally found for soils that have a liquid limit between 30 and 70. Then, curve type B is a one-and-one-half-peak curve while curve type C is a double-peak curve. At the meantime, compaction curves of type B and C can be found for soils that have a liquid limit less than about 30. Thus, compaction curve of type D does not have a fixed peak. Therefore, this is termed an "odd shape". So we can see that, soils with a liquid limit greater than 70 may exhibit compaction curves of type C or D, such soils are uncommon. (Das, 2013).

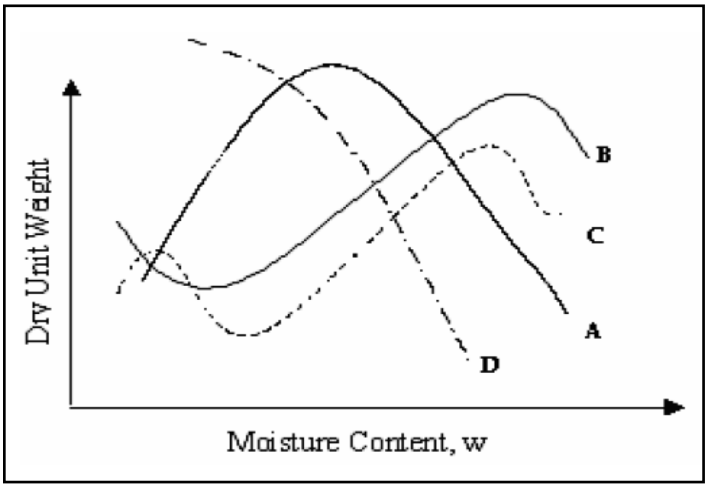

Figure 2.3: Types of Compaction Curve (Das, 2013)

According to Head (1992) the method of compaction curve for five typical materials is shown in Figure 2.4. The next point is, for ease of difference they have been related to a common zero air voids line by adjusting the curves to the same particle density. Then, these curves relate to BS or ASTM light compaction effort. In general, clay soils and well-graded sandy or silty soils show a clearly well-defined peak to the compaction curve. Next, we come to the uniformly graded free-draining soils, consisting of a slender range of particle sizes, give a flatter compaction curve from which the optimum condition which is not easy to define. Besides, a double peak is often attained from uniformly graded fine sands. As a result, for these types of materials which has moisture content for an optimum level and therefore the compaction process will be not easy to define. Hence, the results of laboratory tests can be meaningless or misleading, and provide a poor guide to field compaction behaviour. As an overall picture, a higher dry density can often be gained in the field, and a maximum density test might be more applicable.

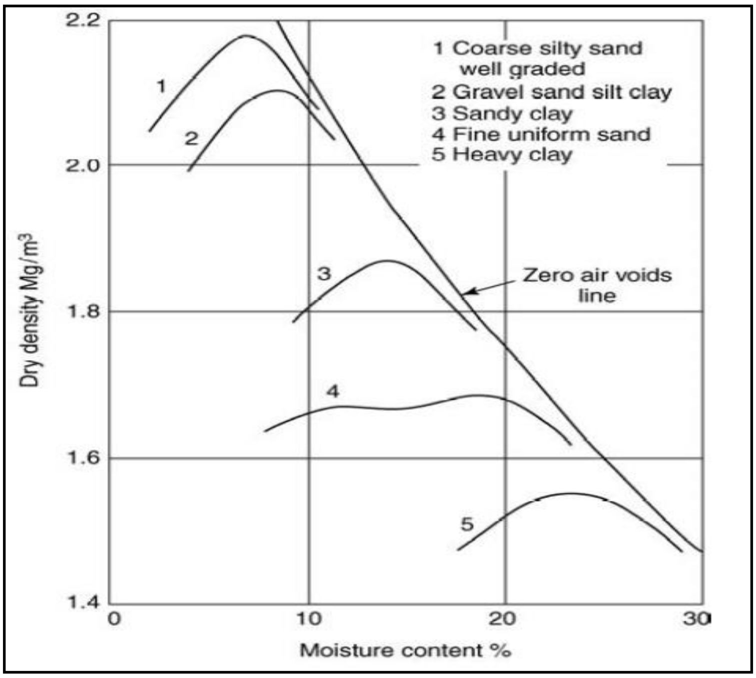

Figure 2.4: Compaction Curve for Some Typical Soils (Head, 1992)

The dry density ratio is the field whereby the dry density is divided by the maximum dry density which is completely determined or confirmed in the laboratory for the soil which are also can be expressed as a percentage when compacted at the optimum moisture content (Pipelines, 2017).

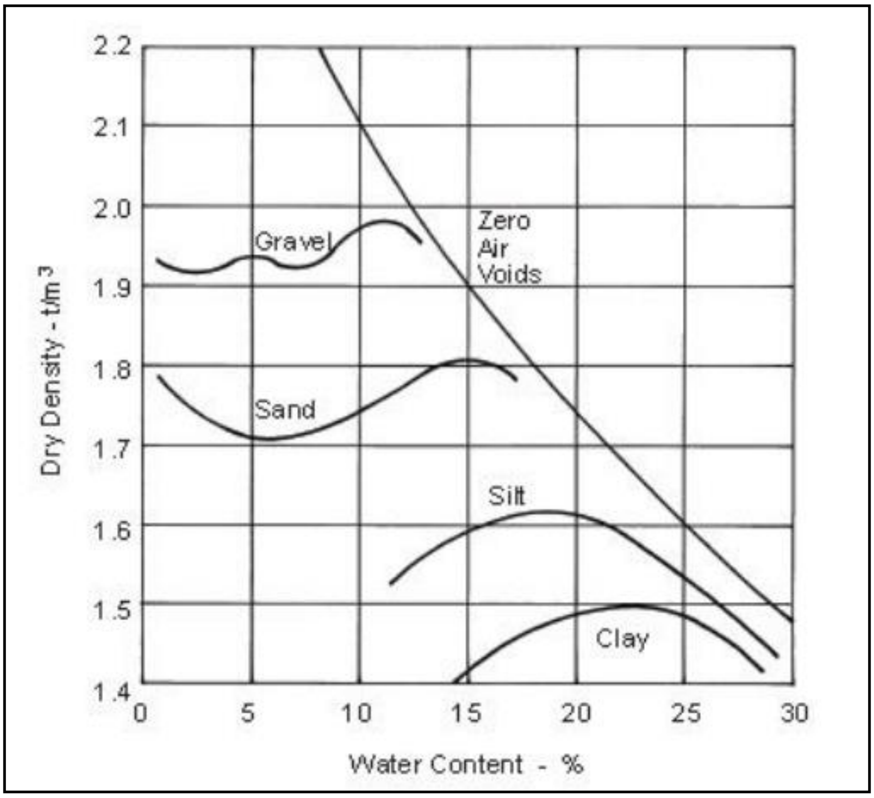

Figure 2.5: Typical Dry Densities for Different Soils (Pipelines, 2017)

Figure 2.5 shows the effect of compacting at dissimilar moisture contents on the dry densities of numerous soil types. Based on the situation given, it should be noted that the curve for gravel is relatively flat as water content has minimal effect on the achievable compaction. Therefore, these materials are preferred for embedment. According to the situation given, the curve shown for sand is concave over the intermediate range of moisture contents. Elsewhere, with some fine sands which are attached with these moisture contents, so the density can be more than 20% less than for the compaction achievable at higher moisture levels. Furthermore, because of some properties these “bulking sands” are highly inappropriate to be used as embedment material. Then, the convex curves for cohesive soils such as silt and clay are particularly sensitive with respect to moisture and are difficult to compact adequately in a pipe trench. The dry density may be determined in the laboratory or by either the ‘Standard’ method or neither by the ‘Modified’ test method where each giving significantly different types of outcomes. The compaction energy for the ‘Modified’ method is 4.5 times higher than for the ‘Standard’ method while the resultant maximum dry density ratio will be lower for a given field test sample. Therefore, for granular soils the difference is about 5% which can be considered as less for a uniformly graded sand and about 10% for cohesive soils.

2.3.2 Process of Compaction

Chen et al. (2016) says that the compaction process is closely correlated with the microstructural change in soils which is the reduction of voids. In recent years, experimental techniques based on nonlinear ultrasonic theory have been well developed for the characterization of microstructural features such as microcracks, inhomogeneity and voids of various materials including metals, composites, concrete and rocks. However, little research has been carried out to study the nonlinear ultrasonic behaviour of soils, which have actually been proven nonlinear media of the wave propagation. It thus becomes primary interest to initiate compaction process study to investigate the characteristics of soils, particularly from the perspective of porosity or void change during the compaction. The results indicate the nonlinear ultrasonic behaviours of soils are quite obvious and the defined nonlinear parameter is highly correlated with porosity change of materials. In terms of the engineering practice, his study also provides a possibility for the in-situ estimation of optimum moisture content.

Compaction of soil is the method by which the solid soil particles are arranged more closely together by mechanical means, thus increasing the dry density this statement mentioned by Shah and Shroff (2003). Head (1992) has also explain that dry density is achieved through the reduction of the air voids in the soil, with little or completely no reduction in the water content. Furthermore, this process must not be jumbled with consolidation, in which water is squeezed out under the action of a continuous static load. Besides, the air voids cannot be eradicated altogether by compaction, but with proper control they can be reduced to a minimum point. Hence, the effect of the amount of water present in a fine-grained soil on its compaction characteristics, when subjected to a given compaction effort, is discussed in below Figure 2.6.

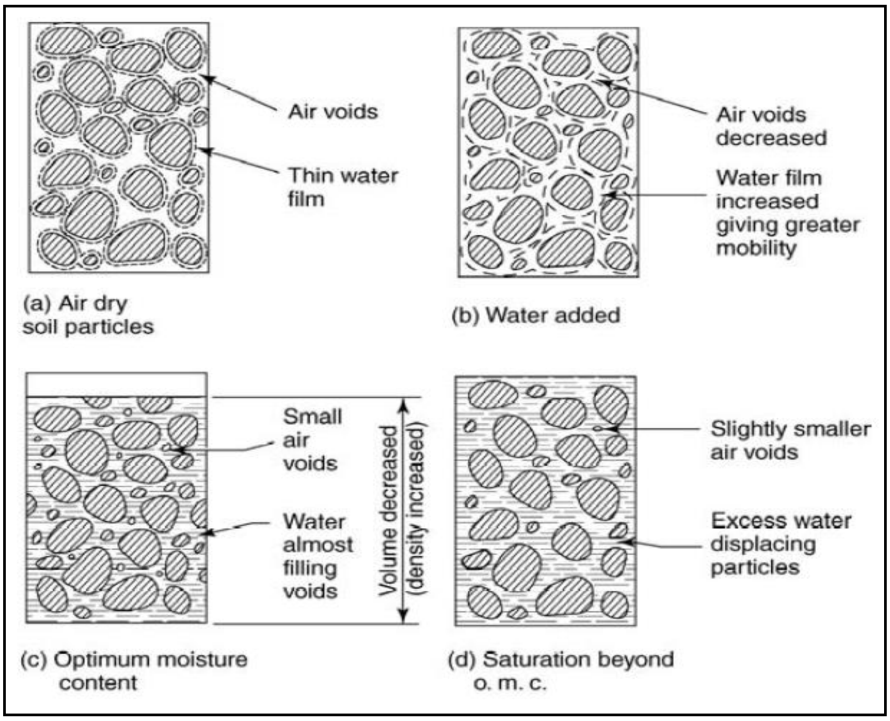

Figure 2.6: Representation of Compaction of Soil Grains (Head, 1992)

As for the starting, which is basically at low moisture content where the soil grains are surrounded by a thin film of water, which tends to keep the grains apart even when compacted as shown in Figure 2.6(a). Normally, the finer the soil grains, the more significant is this effect. Based on the situation given above, if the moisture content is increased, the additional water allows the grains to be more easily compacted together as shown in Figure 2.6(b). As an immediate reaction, some of the air is displaced and the dry density is increased rapidly. Therefore, the addition of more water, up to a certain level, enables more air to be expelled during compaction. So basically, at that point the soil grains become as closely packed together as they can be the dry density is at the maximum under the application of this compaction effort as shown in Figure 2.6(c). As the process continues, especially when the amount of water exceeds that required to achieve this condition and this is where the excess water begins to push the particles apart as shown in Figure 2.6(d), so that the dry density is reduced.

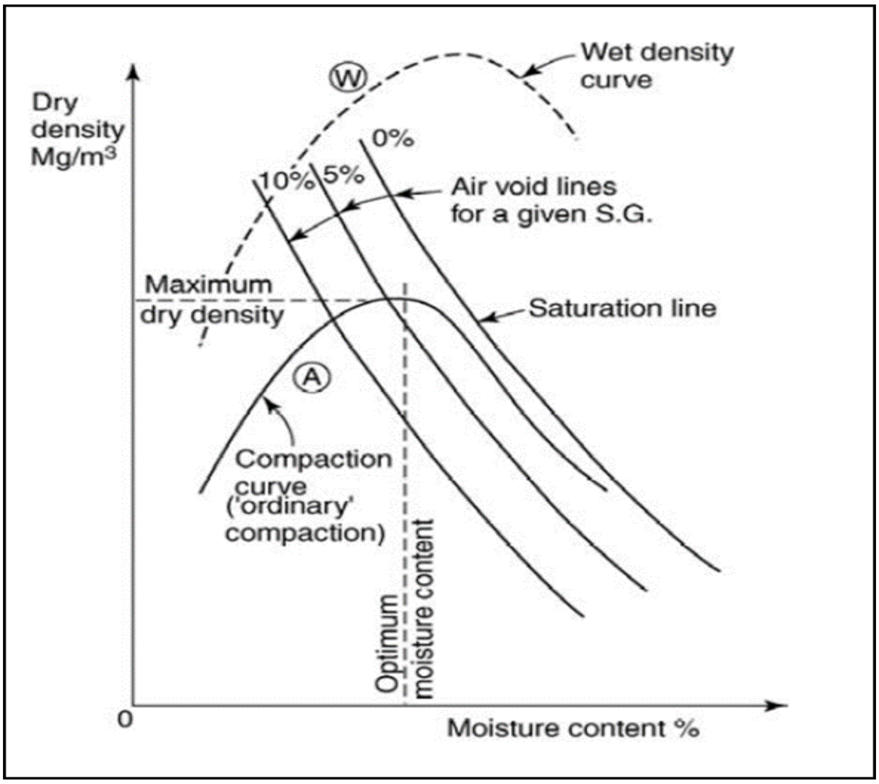

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Figure 2.7: Dry Density-Moisture Content Relationship for Soils (Head, 1992)

Firstly, at a higher moisture contents little or no more air is displaced by compaction, and the resulting dry density continues to decrease. Furthermore, if this phenomenon happens at each stage the compacted dry density is calculated and plotted against moisture content where we are able to find a graph which is similar to curve A in Figure 2.7 is obtained. Then, this graph will show the process or the relationship of moisture against density curve. Moreover, the moisture content at which the greatest value of dry density is reached at the given amount of compaction is the optimum moisture content (OMC), as the corresponding dry density is the maximum dry density. Elsewhere, at this moisture content the soil can be compacted most efficiently under the given compaction effort. The relationship between bulk (wet) density and moisture content is shown by the dotted curve (W) in Figure 2.7. As for now, this curve is not generally plotted, except perhaps as a guide during a compaction test before the moisture contents are measured.

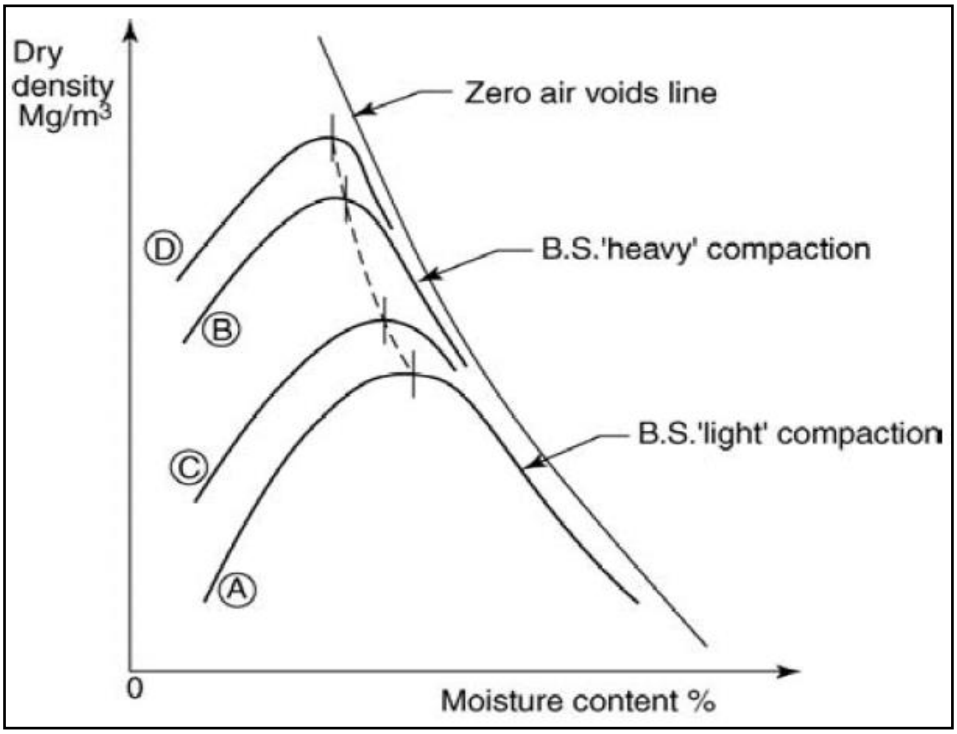

Figure 2.8: Dry Density-Moisture Curves for Various Compactive Efforts
(Head, 1992)

As we can see from the starting point that a typical compaction curve is obtained from the British Standard light compaction test is shown in Figure 2.8 as curve A. So, from here we can infer that if a heavier degree of compaction is corresponding to the BS where heavy compaction test is applied at each moisture content in which we can marginalised higher values of density. Furthermore, the resulting moisture-density relationship will sketch in a graph such as curve B in Figure 2.8. Thus, the maximum dry density is greater, but the optimum moisture content at which this occurs will be definitely lower than in the light test.

The situation states that, every different degree of compaction on a particular soil results in a different compaction curve because each curve has its own unique values of optimum moisture content and maximum dry density. For instance, a compaction test similar to the BS light test but using, say, 50 blows per layer instead of 27 would give a graph similar to that shown by curve C in Figure 2.8. At the meantime, a test similar to the heavy compaction test can be conducted but using a greater number of blows would give a graph similar to curve D. So, from this test, it can be seen that increasing the compaction effort increases the maximum dry density but decreases the optimum moisture content (Head, 1992).

2.4 Factors Influencing the Compaction Test

According to Arvelo (2004) the moisture content has a strong impact on the degree of compaction achieved by a given soil. Therefore, the moisture content, and other important aspects that affect the compaction of a soil are soil type and compaction effort which is energy per unit volume. These factors are described in the following section.

2.4.1 Effect of Soil Types

According to Arvelo (2004) the soil type in terms of the grain-size distribution, shape of the soil grains, precise gravity of soil solids, percentage of the fine content and the type of fine, offers a great impact on the maximum dry unit weight and optimum moisture content. Figure 2.9 shows the typical compaction curves obtained from four soils.

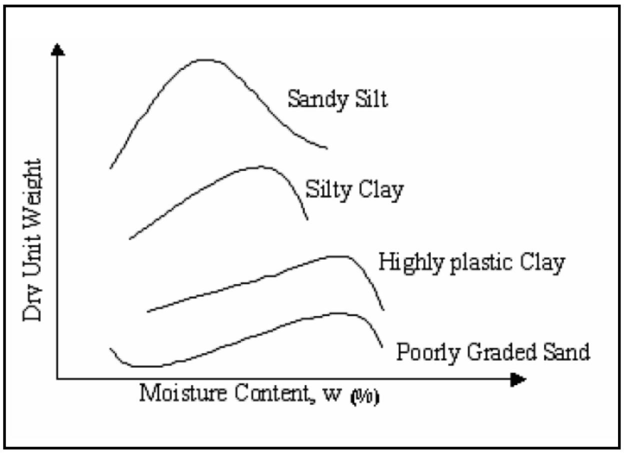

Figure 2.9: Typical Compaction Curves for Four Soils (Das, 2013)

This means that the bell-shaped compaction curves shown in Figure 2.9 are typically of most soils containing fines. Figure 2.9 also shows that for sands, the dry unit weight has a common tendency first to decrease as moisture content increases, and then to increase to a maximum value with further increase of moisture. However, the original decrease of dry unit weight with the increase of moisture content can be attributed to the capillary tension effect. This, at lower moisture contents, the capillary tension in the pore water inhibits the tendency of the soil particles to move around and be densely compacted which told by Das (2013).

2.4.2 Effect of the Compaction Energy

According to Arvelo (2004) the applied energy in a soil compaction is dignified by its specific energy value (E), which is the applied energy per unit volume. Therefore,